THE RELATIONSHIP OF BRACHIAL PULSE WAVE MEASUREMENTS TO THE PERFORMANCE OF CROSS COUNTRY RUNNERS

by

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B.P.E. University of British Columbia, 1962

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTER OF PHYSICAL EDUCATION

in the School

of

PHYSICAL EDUCATION

and

RECREATION

We accept this thesis as conforming to the required standard:

THE UNIVERSITY OF BRITISH COLUMBIA

April, 1963

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ABSTRACT

The cardiovascular condition of five members of the University of B.C. cross country team was checked weekly with the Cameron Heartometer. Heartograph measures taken twenty-four hours before competition were compared to the coach's subjective appraisal of the athlete's performance to see if fluctuations in any of the measures corresponded to fluctuations in performance. A record of the runners' training load was also kept.

Using case study methods the information above was observed and studied to see if the heartometer is a practical device for anticipating staleness, incipient infection or general inability to adapt to the training load. The autonomic nervous tone of the athlete is indirectly represented by the heartometer measures. The measures of the heartograph were also statistically interpreted to see which measures showed significant trends during the nine weeks of testing.

Each of the five athletes showed results that were different than those of his teammates. One athlete, with a long history of endurance training, significantly improved most of the aspects of his cardiovascular condition in the short nine-week season. This runner ran well throughout the season with no apparent staleness. Another athlete, who has had severe attacks of asthma, performed well until attempting a particularly heavy amount of work. After this work he ran a very poor race. The heartograph showed a rest-to-work ratio that had dipped sharply from previous readings, on a graph taken twenty-four hours before this race. A third subject had been training all year. From the beginning of testing this runner showed

strong pulse wave responses. However, his performance was not as would be expected from an athlete that was adapting well to his training. During the season the athlete had a slight nervous breakdown which indicates that he was not adapting to the stresses of his overall programme. With a reduction of training his running improved somewhat as did certain measures of his pulse wave. The fourth subject trained hard but did not perform as well as might be expected for an athlete undertaking this amount of training. The fifth man trained moderately throughout the season. This subject was basically a middle distance runner and participated in cross country in preparation for the track season. His heartograph measures showed gradual improvements and three - systolic blood pressure, pulse pressure and rest-to-work ratio - showed significant linear increase during the training period. This runner performed as expected in all races.

Four measures of the pulse wave showed parallel development with improving cardiovascular condition; these were the diastolic surge, rest-to-work ratio, systolic blood pressure and pulse pressure. The rest-to-work ratio showed variations that on observation best indicated staleness or inability to adapt to the training load.

ACKNOWLEDGEMENT

The writer would like to acknowledge the very considerable assistance given by Dr. S.R. Brown. Dr. Brown was always available for suggestions and recommendations; when discussing this thesis he always gave freely of his time and resource material whenever it was at all possible.

In addition, the writer would like to thank the five runners for their complete cooperation, despite heavy schedules of their own.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF GRAPHS

CHAPTER I

STATEMENT OF THE PROBLEM

The problem is to determine whether or not variations in autonomic nervous tone are related to variations in cross country running performance.

More specifically the problem is to determine by case study methods whether or not measurements of brachial sphygmographs taken one day before competition will be related to the quality of competitive performance.

Purpose of the Study

Coaches need to have some objective way to determine the effect of training stress on athletes.

It would be desirable to find some practical way to foresee staleness, incipient infection or general inability to adapt to the training load.

Delimitations

Five college students with an age range of 20-25 years were observed and tested. All five were members of the University of B.C. cross country team and all testing was done while the runners were in training.

Limitations

1. The operator of the machine was completely inexperienced before the study was undertaken. Although several practice graphs were taken, improvement of technique was apparent during the actual study.

2. Psychological apprehension of the subject is not controllable although it is an important factor in recording.

3. One instrument was used throughout; however, it is possible that variations in the performance of the instrument might have occurred over a period of time since no standardized procedure to control this was employed.

4. There is no way to get an objective measure of the runners' performance because of the nature of cross country running.

5. It is impossible to determine the psychological drive or motivation for each individual before each race.

6. The runners had a variety of body builds; the influence of this factor is not accounted for in the study.

7. Experience and learning that are a result of competition and training are also uncontrolled variables.

Assumptions

1. Cardiovascular condition is an important factor in the performance of an endurance activity.

2. The brachial sphygmograph as recorded by the Cameron Heartometer reflects cardiovascular condition.

3. The coach from his observation of the runners in training can make a reasonable estimate of how well the runner should perform in competition.

CHAPTER II

JUSTIFICATION OF THE PROBLEM

Some athletes fail to perform up to their previous standards even though vigorous training is being undertaken. Time trials and subjective questioning of the athlete are of little value in predicting these failures in performance.

There is a need for a simple objective measure which would indicate performance potential for an athlete performing in an endurance event such as cross country running. It was believed possible that the heartograph could provide such a method based on the premise that successful or unsuccessful adaptation to the training load would be reflected in measures of cardiovascular condition. If this is true, it will help coaches to scientifically design their training programs to obtain the best performance from individuals by following closely those factors which seem related to performance. The effects of specific training loads on the cardiovascular system can be observed in this manner[1].

Despite the many previous studies done with the Cameron Heartometer, much work remains to be done to show predictive values of the measurements and which of them best indicate impending fluctuations in athletic performance. A great number of the studies completed deal with swimmers. There was no previous study in which an athlete was followed through the competitive season with weekly measurements related to the actual performances which followed.

The full meaning of the pulse wave is not yet explained[2], but it is very clear that it has predictive value for endurance performance if properly administered. This study attempts to devise some reliable but simple methods to predict performance and, therefore, to assess also the effect of the training techniques employed. It is possible that at some point in the season rest may be of more benefit than vigorous training.

A case study of athletes in hard training may also reveal areas for further study. The heartometer, through further study, may prove to be a more valuable instrument in physical education and athletics than it has been to date.

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CHAPTER III

REVIEW OF THE LITERATURE

According to Carlile[1] one of the basic problems in training athletes is to know when the stressing load of exercise has reached a level to cause staleness.

Cureton[2] suggests the heartometer as a possible way to see physiological staleness.

> The heartograph measures a combination of blood vessel suppleness and energy of the blood stream eminating from the heart. The blood flow in terms of minute volume and also the stroke volume are quite proportional to certain measurements made on the heartograph by careful quantitative procedures, provided the graphs are properly taken....

Cureton[3] summarizes thirteen separate studies that aid in the interpretation of the pulse wave in normal young men: all studies were done at the Physical Fitness Research Laboratory, University of Illinois. He also states[4]: "The pulse wave has predictive value for endurance performance unless the muscles are unduly tensed during exercise".

Cureton[5] defines cardiovascular condition: "Both heart and blood vessels are muscular organs which are capable of contracting and relaxing in ways which move the blood continuously around the body. The efficiency with which this is done is called cardiovascular condition". Cureton also relates several conditions under which such circulation is poor.

In addition, Cureton[6] discusses Cardiovascular Component I - Autonomic Tone.

> Habitual autonomic tone in the quiet state or high versus low peripheral resistance. The component indicates the internal vascular tension we live with in our resting hours. The blood vessels and the heart are under the control of the autonomic nervous system to a very great extent. This nervous system has the power to "gear it up" (improve circulation) for quick action, thus producing a type of psychological warm-up even without exercise. It also has the power to depress it into lethargy quite unsuited for action in the muscular sense. When we are more or less ready for action, our circulation is ready and this is what we mean by sympathetic autonomic tone. Such states come and go with little conscious thinking and happen as conditional reflexes in spite of ourselves. We may be nervous without wanting to be nervous. We might also lapse into a drowsy state in spite of ourselves. One person may react almost as in a mild shock with less circulation (parasympathetic reaction), whereas, another may react in a fighting determined mood with more circulation (sympathetic reaction).

Good autonomic tone[7] is indicated by low pulse rates and high amplitude pulse waves with large area.

The autonomic tone is a very important aspect of fitness according to Cureton[8]:

> One can be apprehensive, tensed up internally and resistant to efficient physical action. In this state we have relatively high peripheral resistance (TPR) due to vasoconstriction of the small vessels in the lungs, muscles and heart itself. This vasoconstriction is brought about by an anxious nervous state, and it hurts circulation. On the other hand, there may be a persistently higher circulation in people in athletic training which is indicated by somewhat higher metabolic rate or higher core body heat; by larger volume of blood ejected per beat of the heart (stroke volume) or larger brachial pulse wave.

Carlile[9] conducted a study on Australian Olympic swimmers to observe if changes of a physiological nature could be demonstrated during a period of intense swimming training and if physiological changes could be detected which show an association with poor performance.

In this study Carlile[10] also states:

> It could possibly prove necessary for ultimate maximum performance to carry training to a point of strain not far from the point where the organism is on the verge of extensive breakdown. On the other hand, it may prove important to modify training considerably when a relatively small degree of strain is apparent. To throw light on this, we must first determine how to measure strain scientifically. Physiological measurements are the main objective means of assessing the degree of strain and controlling the training process.

An authority on circulation, Carl Wiggers[11], has pointed out that the pulse wave reflects important aspects of circulatory condition. Severe stress acts as a stimulus which will improve the organism eventually. However, there must obviously be a point where the training load should be eased before breakdown processes outstrip adjustment[12].

Hickham et al[13] stated that emotional disturbances may have a profound effect on circulation, causing changes in heart rate, cardiac output, blood pressure, tone of the peripheral vessels and electrocardiograph records. They cautioned that the interpretation of data relating anxiety to circulatory changes is handicapped by the absence of reliable objective means of measuring the degree of anxiety in individual subjects and they concluded that variability of the cardiac system is qualitative as well as quantitative.

Rushmer[14] states: "Cardio-acceleration occurs in anticipation of physical exertion before there is any significant increase in metabolism". He also mentions[15] that in man nor-epinephrine introduced into the blood stream is reported to have powerful vasoconstrictor effects on the peripheral vascular system but less effect on myocardial contraction.

Guyton[16] discusses peripheral resistance:

> If the peripheral resistance is greatly decreased, blood is allowed to flow from the arteries to the veins very rapidly, which increases the return of blood to the heart and thereby increases the pulse pressure. Obviously the opposite effect occurs when peripheral resistance increases rather than decreases.

He continues[17]:

> The velocity of transmission, of a pulse wave, is less the greater the distensibility. The pulse wave velocity normally averages thirty times the actual velocity of blood flow in the large arteries.

Wiggers[18] summarizes the variations in peripheral pulses. "The contour of the central pulse is altered in its transmission to peripheral arteries, such as the radial and femoral, by (a) damping of the basic transmitted pressure wave, and (b) by summation with a diphasic reflected wave. The former tends to reduce and the latter to raise systolic pressure over that in the aorta."

Rushmer[19] states:

> Waves of pressure are reflected by peripheral structures, these travel back toward the heart and become superimposed on the advancing pulse wave. This produces a higher peak

> of systolic pressure, a slurring of the incisura and a lower diastolic pressure in the femoral artery.... The systolic pressure in the femoral artery may exceed the systolic pressure in the brachial artery by 15 to 25 mm. Hg.

Remington and Wood[20] assert that in most cases reflected waves die out before the next systole.

A study showing the correlation between organic efficiency and actual performance in swimming 440 yards was done by McCurdy and Larson[21]. They also suggest[22]: "This work should be supplemented by case studies to determine the relationship by performance to changes in organic efficiency".

"While it is not the purpose here to go intensively into anatomy or physiology of the autonomic nervous system, it is important to give the concept that exercise, persistently taken, can affect the balance of the sympathetic versus parasympathetic dominance"[23].

Meeland[24] defines the heartometer and relates its uses: <u>heartometer</u> - a scientific precision instrument for graphing a permanent record of:

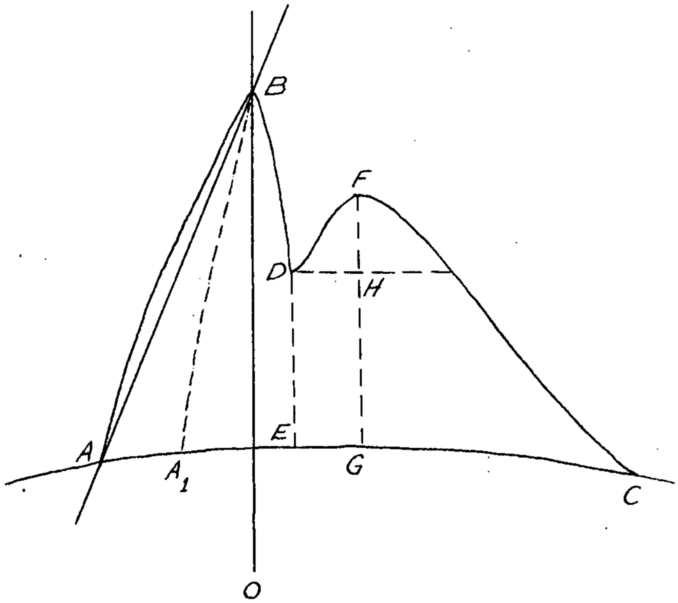
(a) Systolic and diastolic blood pressure.

(b) Pulse rate.

(c) Force and form of the heart impulses.

(d) The arterial changes throughout the extremities.

Measures of the Brachial Sphygmograph[25] (Cameron Heartometer)



(i) Area Under Curve (ABDFCA) (Abbr. A.U.C.)

This measurement reflects somewhat the blood pumped per stroke of the heart and also the tone of the wall in the brachial artery and its branches.

(ii) Systolic Pulse Wave Amplitude (A_1B) (Abbr. S.A.)

Indicates the magnitude of myocardial action due to the contraction of the ventricles. Psychological excitement due to apprehension or fear of a race, undoubtedly causes overaction of the vasoconstrictor system and the secretion of adrenalin in unusual amounts into the blood. The immediate response is a stronger systole and faster heart rate.

(iii) Dicrotic Notch Amplitude (ED) (Abbr. D.N.A.)

This measurement indicates the level of cardiovascular tone, i.e. it is proportional to the diastolic blood pressure which acts as back pressure to close the semilunar valves. If the elastic rebound of the aorta and other principal vessels is relatively strong, the pressure is transmitted mechanically through the blood to close the semilunar valves quickly. To close the valves this back pressure must be greater than the pressure in the heart ventricles. Fatigue of the Autonomic Nervous System and smooth musculature of the aortic arch seems a reasonable explanation as to why the dicrotic notch is lowered, but dilation of the arterioles and capillaries may be a greater causal factor.

(iv) Fatigue Ratio (ED/A_1B) (Abbr. F.R.)

This measurement is the ratio of the amplitude of the dicrotic notch to the amplitude of the systole. Good cardiovascular condition is normally associated with a relatively higher dicrotic notch compared to the systolic amplitude when the subjects are mentally and physically at rest.

(v) Angle of Obliquity (ABO) (Abbr. O.A.)

The significance of the angle of obliquity may be in the fact that a slow acting heart muscle, due to weakness or to sluggish heart tissue, gives a greater angle because more time is taken for the upward systolic stroke to the maximum point. In such a case it is inferred that the heart muscle has difficulty overcoming the resistance of the blood column above the semilunar valves or that there is internal resistance in the heart tissue itself.

(vi) Pulse Rate (Abbr. P.R.)

This is the regular rate of the heart beat taken in beats per minute from the heartograph.

(vii) Single Cycle Time

Alternate measure for rate.

(viii) Diastolic Pulse Wave Amplitude (GF) (Abbr. D.A.)

The part of the total heartograph in a single cycle which occurs after the semilunar valves close is represented by the diastolic pulse wave. In excitement, fear and during the laboring of the heart after effort, S.A. and D.A. increase greatly, with an accompanying lowering of the D.N.A.

(ix) Distolic Surge (HF) (Abbr. D.S.)

It seems to be caused by the reflected pressure wave from the semilunar valves and possibly by active contraction of the aorta after the semilunar valves close. Part of it is no doubt due to elasticity of the aorta, but the aorta contains smooth muscle which seems to develop an active function in athletic subjects. An important measure in endurance.

(x) Time of Diastole. (EC) (Abbr. D.T.)

It measures the time of diastole from the closing of the semilunar valves.

(xi) Time of Systole (AE) (Abbr. S.T.)

From the start of systole to the close of the semilunar valves.

(xii) Rest to Work Ratio (EC/AE) (Abbr. D.T./S.T.)

This measurement is the ratio of the systole contraction to the overall time of the diastole. A strong efficient cardiovascular system has a ratio of 4 to 1; an average cardiovascular system is 1.89 to 1; a poor cardiovascular system is lower than 1.21 to 1. Poor in this sense means untrained, probably with a low minute volume capacity.

(xiii) Diastolic Blood Pressure (Abbr. D.B.P.)

The low pressure value in the artery between heart beats.

(xiv) Systolic Blood Pressure (Abbr. S.B.P.)

The highest pressure exerted in the artery resulting from the contraction of the heart.

(xv) Pulse Pressure (Abbr. P.P.)

Systolic Blood Pressure minus Diastolic Blood Pressure.

"Low pulse pressure indicates vasodilation fatigue of the Autonomic Nervous System, possibly even fatigue of the heart muscle"[26].

Cureton[27] has prepared a paper that discusses the many ways the heartometer can be used:

(a) To rate the state of functional fitness.

(b) To show improvement of a subject.

(c) To follow the training of a subject.

(d) To measure "physiological warm-up".

(e) To measure "fright".

Further uses of the heartometer are outlined by Willet[28] in his study on predicting treadmill run time.

He also shows reliability values for test and re-test[29] for his own data obtained on two consecutive days and for Cureton's data obtained from two measurements at one sitting.

Measure	Willet	Cureton
D.P.W.A.	.818 (69 cases)	.768 (97 cases)
D.P.W.A.	.881 " "	.909 " "
O.A.	.757 " "	.788 " "
A.U.C.	.811 " "	.864 " "
D.S.	.783 " "	.878 " "
D.T./S.T.	.719 " "	.640 " "
P.P.	.818 " "	.794 (28 cases)
P.R.	.928 " "	.996 (97 cases)
S.B.P.	.808 " "	.765 (28 cases)
D.N.A.	.755 " "	.823 (97 cases)
D.B.P.	.764 " "	.794 (28 cases)

In addition, Willet[30] tested the validity of measurements by correlating them with the criterion of time of all-out treadmill run.

Measure	r	P.E. r
D.P.W.A.	.555	.060
S.P.W.A.	.528	.062
O.A.	-.513	.064
A.U.C.	.470	.067
D.S.	.405	.072
D.T./S.T.	.328	.077
P.P.	.263	.080
P.R.	-.256	.081
S.B.P.	.233	.082
D.N.A.	.165	.084
D.B.P.	-.101	.086
R.P.I.*	.333	.077

* Reciprocal of Ponderal Index $\left[\text{Height (in.)}/\sqrt[3]{\text{Weight (lb.)}}\right]$

The first six are significant in that their coefficients of correlation exceed four times the calculated P.E. (These are all measures of the actual wave.)

One of Willet's conclusions was[31]: "The six significant measures correlate more highly with an endurance criterion than any of the traditional Blood Pressure and Pulse Rate measures".

Carlile[32] showed in his study of 16 male Olympic swimmers that the average increase in diastolic surge was from .01 cm. to .19 cm. in eight weeks of hard training. In the same period rest-to-work ratio increased from 1.9 to 3.0. These same factors show increases in the women tested.

Precautions and procedure for heartometer operation are discussed by Meeland[33]. He also outlines techniques for wave selection and measurement[34].

Sterling[35] did a factor analysis of the five variables of cardiovascular condition, which included autonomic tone in the resting state. Brachial sphygmograph energy (S.A., D.A. and A.U.C.) had high loadings in autonomic tone.

Michael and Gallon[36] tested the Santa Barbara basketball team periodically during and after the 1957-58 season. During this period of time the blood pressure and pulse wave measures were studied to investigate the effects of basketball condition on these measurements.

Massey et al[37] divided a student sample into two groups; one with fast and one with slow times in an 880 yard run. They then tested statistically the difference between the two groups in the adjustment made in heartograph measures on changing position from sitting to standing. Measures such as Systolic Amplitude decreased but these differences were not significant at the 5% level of confidence[38].

Data collected by Cureton[39] shows the difference in the heartograph measures between trained and untrained young men.

	1948 Track and Field Champions	Normal Young Men, Freshman
N.	20	110
A.U.C.	.560	.298
O.A.	20.8	23.4
S.A.	1.63	1.16
D.A.	.82	.50
D.S.	.35	.08
P.R. (sitting)	50.8	79.2

The measurement which shows the greatest difference between the groups is the diastolic surge.

"This indicates that the variability in this item is greatest for the athletes and that this characteristic develops the most with training"[40].

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CHAPTER IV

METHODS AND PROCEDURES

Five regular members of the 1962 U.B.C. varsity cross country team were closely observed during the cross country season, which lasted from October 6, 1962 to November 17, 1962.

During this period a record was kept of their training regimen, irregularities in daily living and cardiovascular condition as measured by the Cameron Heartometer.

Three or four graphs were taken before the first race of the season to familiarize the subject with the experience of being graphed. In addition, these early recordings gave the writer a basis from which to judge later changes in the individuals' pulse waves. In addition, each subject was personally interviewed to determine his previous athletic experience and to discover any medical condition that exists or did exist that could possibly affect the results of the study.

All races took place on Saturday so a heartograph was taken each Friday approximately twenty-four hours before competition. An attempt was made to take all graphs at the same time of day, two hours after any eating or coffee.

The heartometer was operated essentially as described in <u>Physical Fitness Appraisal and Guidance</u>(1). There was one exception in the procedure: the systolic blood pressure was taken after diastolic blood pressure without first releasing the cuff pressure. The forearm was placed palm down in pronation - as this was found more conducive to relaxation - on a desk 31 inches high. The subject's graph was taken at a minimum of 80 mm. Hg or 15 mm. above diastolic blood pressure if this measure was above 65 mm. Hg.

After taking the sitting graph for 30 seconds, the subjects stood up and after one minute - to allow for circulatory adjustment - the diastolic blood pressure was checked in this new position and a standing pulse wave record was taken.

The measuring techniques used were as described in Physical Fitness Appraisal and Guidance[2] except that three sitting waves were measured and the averages recorded. Only one (the largest) standing wave was measured.

On one occasion during the season all subjects but one were tested approximately one hour before competition. This was done to observe what possible changes in the pulse wave recordings might occur on the day of the race compared with recordings made the day before.

Two runners' training were altered during the season, partially as a result of recordings. Subject "F" reduced training appreciably for the week of October 14th because of the apparent failure to adjust to his training load. Subject "M" decreased training due to medical advice received after the race of October 27th.

Analysis of Data

The method of analysis was the case study method[3][4]. This was used in the belief that it was the best method to extract maximum information from the study. The lack of standardization of cross country courses and the variability in weather conditions during the fall season make it impossible to obtain a reliable objective evaluation of an athlete's performance. In view of this, it was necessary to substitute an informed opinion as a subjective evaluation of performance. The coach made a subjective appraisal of actual race performance relative to expected performance. His estimate of expected performance was based on past performance and recent training load. This was the criterion used in interpreting variations and trends in the heartometer data. A subjective four point scale was used with scale values as follows: (1) better than expected, (2) as expected, (3) not well, (4) did not run.

Each individual's results were collated systematically on data sheets and variations and trends in each pulse wave measurement were compared with variations in running performance. Each case was considered separately to see which measurements showed concomitant variation with running performance.

Statistical Method

Although trends which occurred in pulse wave variables over the training period were shown graphically, the choice of scale dictated by such considerations as size of paper, could disguise relationships which statistical treatment might otherwise reveal. An additional method chosen for analysis of the data was the test for $\beta_{yx} = 0$, where x is the independent variable which, in this instance, is time in number of days reckoned from the initial test date and y is the dependent variable which, in this instance, is each of 14 variables measured from brachial pulse wave tracings. Thus the number of tests of whether βyx was significantly different from zero equalled 14 dependent variables times 5 subjects, i.e. 70 tests.

It was expected by this means to select those variables which showed progressive linear changes in runners who adjusted well to training and which did not show these changes in runners who failed to improve or whose cardiovascular condition deteriorated during training. The remaining variables would be those which could not be shown to differentiate between positive adjustments and indifferent or unstable adjustment to training.

The method of testing $\beta yx = 0$ was as described by Walker and Lev[5], using F ratios with $\alpha = .05$ arbitrarily chosen. When F was sufficiently large, βyx was significantly different from zero. This means that the pulse wave variable showed a linear relationship with days of training.

Regression coefficients, standard errors of estimate and correlation coefficients were all calculated by I.B.M. machine conputer at the University of British Columbia Computer Centre.

Results were presented in the form of (a) graphs, data sheets and case history reports for each subject, (b) a general analysis of pulse wave data obtained from all the subjects, and (c) statistical data sheets with each case study that included correlation coefficients, standard deviations, regression coefficients, standard errors of estimate and F ratios.

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CHAPTER V

RESULTS AND DISCUSSION

Case Studies

Case "J"

Subject "J" was twenty-four years old, five feet nine inches tall and weighed one hundred and forty pounds. He participated in cross country primarily as conditioning for the spring track season. His best event is the half-mile.

This runner did not begin competitive track until 1958. His first year of competition was in the 100 and 200 yard dashes. He participated in no activities of an endurance nature up to this time. In 1959 he increased his competitive distances to the 440 and 880. His best race that year was 800 meters in 1:58.1. That winter he participated in cross country for the first time. In 1960 subject "J" again participated in the 440 and 880 and had best times of :51.3 and 1:57 respectively. He competed in track and field all summer and continued with cross country in the fall. The 1961 track season was restricted to a few spring meets as his employment prevented summer competition and training. The athlete's best times for the 440 and 880 were :52 and 1:59. He participated in some cross country that fall. Again in 1962 there was no summer competition; best times in the 440 and 880 were :50 and 1:57.5. In the fall during cross country training he ran a 660 in 1:24.

Subject "J" has had no medical conditions that would be considered relevant to his conditioning programme.

A record was kept of this runner's training beginning September 24, 1962. His training was steady but moderate. At first it consisted of a four mile run on some days alternating with some timed track running of one or two miles done periodically. After a week, weight training, done about twice a week, was undertaken in addition to the running. Beginning the second week in October some repeat work was done on the track. Subject "J" did some twice-a-day training and trained daily with a day of rest before a cross country race.

The heartograph record of subject "J" at no time showed a wave that would indicate good cardiovascular condition as shown by Cureton[1] and described in Chapter III, page 17 of this study. Only the values for pulse rate and area under the curve could be considered better than the average values for normal young men. The latter was only slightly above the average.

Subject "J", who was fifth man on the cross country team of five, ran as expected (Appendix "A") in all four races in which he competed. He did not run on October 27th.

His cardiovascular condition as indicated by the heartometer did not improve appreciably over the season. The strongest pulse wave was recorded on October 19th. The subject trained a little harder than usual that week and said that he had been feeling tired all week when the heartograph was taken. However, the recording showed poor adjustment to standing on this occasion.

The poorest wave was recorded on November 16th. At this time the runner reported having had a slight cold for two days. Unfortunately, the coach was not present on the following day to make an appraisal of the race. This depressed wave was temporary and was back to normal the following week.

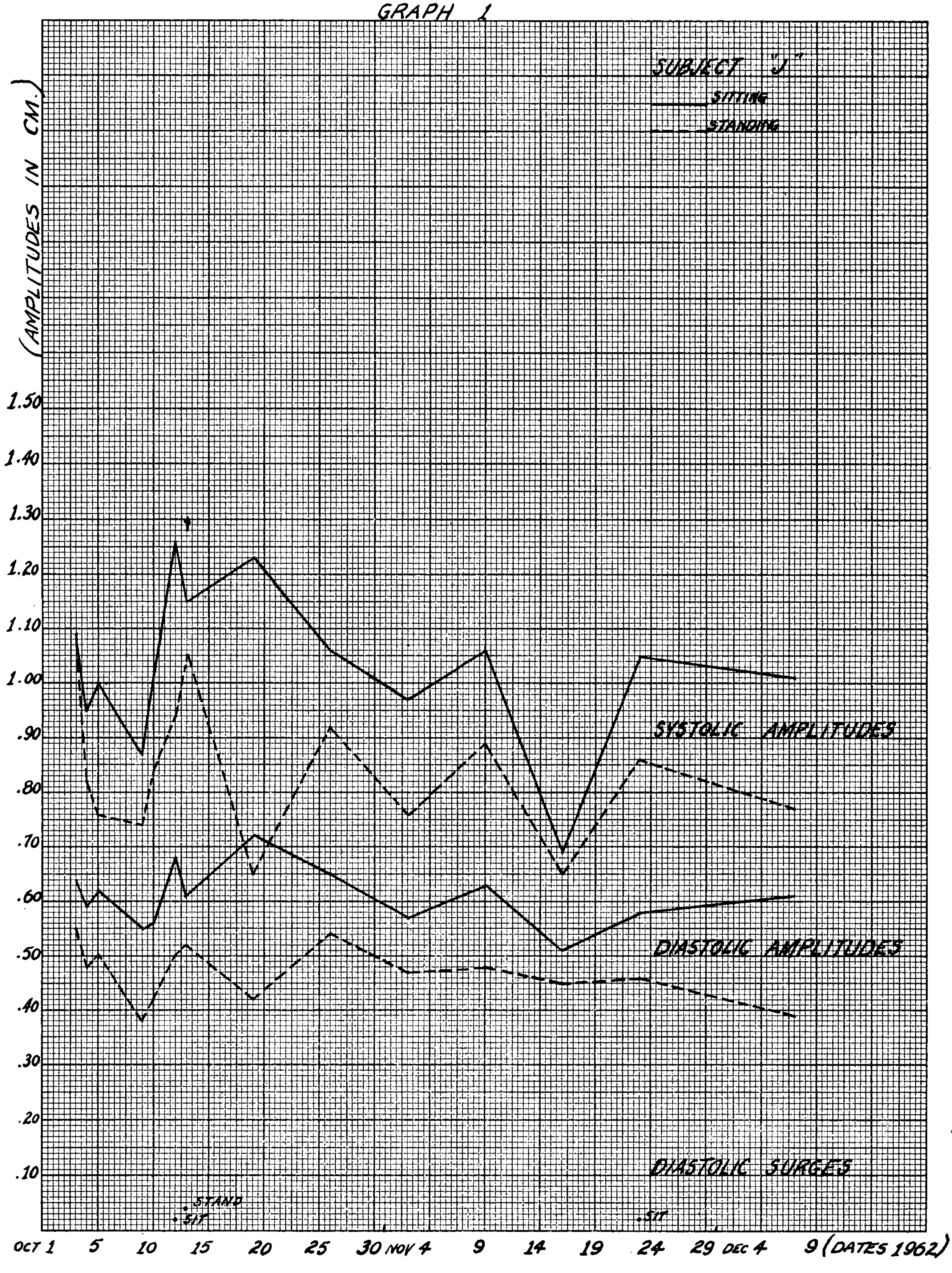
Subject "J's" rest-to-work ratio was very variable at the beginning of the season, but toward season's end it became stabilized at a fairly high value. According to Cureton, as reported in Chapter III, page 13, "A strong efficient cardiovascular system has a ratio of 4 to 1". This subject's ratio had a higher value than four from November 16th to the end of testing on December 7th.

No appreciable diastolic surge developed during the training period. Carlile(2) noted that diastolic surge appeared in 25 to 28 subjects after eight weeks of hard training. Possibly subject "J" was not training hard enough to show desirable gains in this aspect of the record. His actual training programme was not hard compared with those of modern champion trackmen.

Relatively low pulse rates are correlated with high endurance(3). This subject, however, did not show a decrease in pulse rate through training as often occurs, shown by Cureton(4). Of course, the pulse rate at the beginning of testing was relatively low.

Three aspects of subject "J's" cardiovascular condition showed trends significant at the .05 level for the nine weeks of testing. There were increases in rest-to-work ratio, systolic blood pressure and pulse pressure. All other aspects of the wave showed no definite trends. The training load at no time could be considered severe and the stress of training did not cause staleness. This type of training if continued over a longer period may lead to very good condition and performance. Subject "J's" 1:24 for the 660 during the cross country season indicated a fitness for that distance.

GRAPH 1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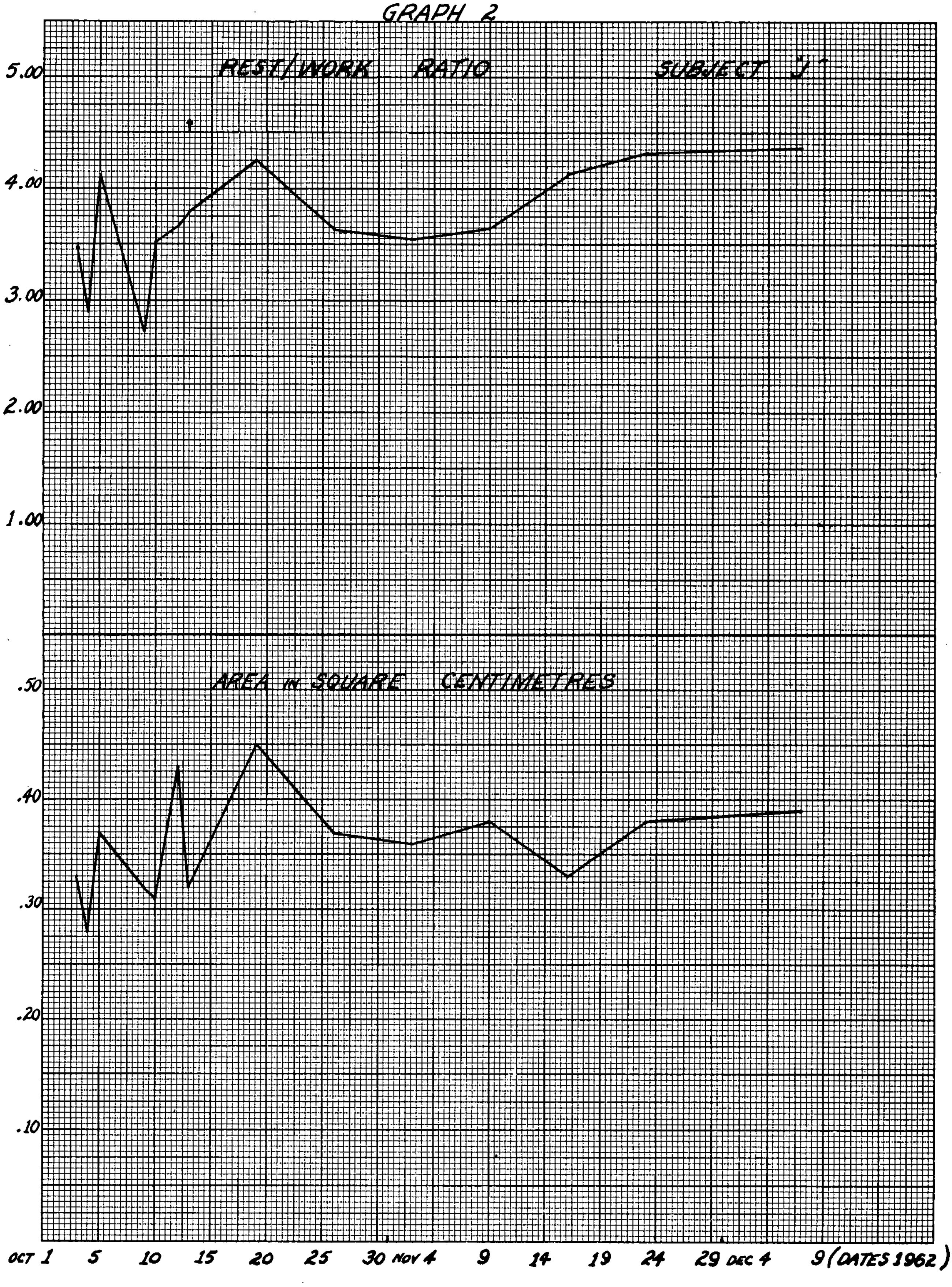
STANDING
(AMPLITUDES IN CM.)
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
SYSTOLIC AMPLITUDES
DIASTOLIC AMPLITUDES
DIASTOLIC SURGES
STAND
SIT
SIT
OCT 1
5
10
15
20
25
30 NOV 4
9
14
19
24
29 DEC 4
9 (DATES 1962)

GRAPH 2


REST/WORK RATIO
SUBJECT "J"
5.00
4.00
3.00
2.00
1.00
AREA IN SQUARE CENTIMETRES
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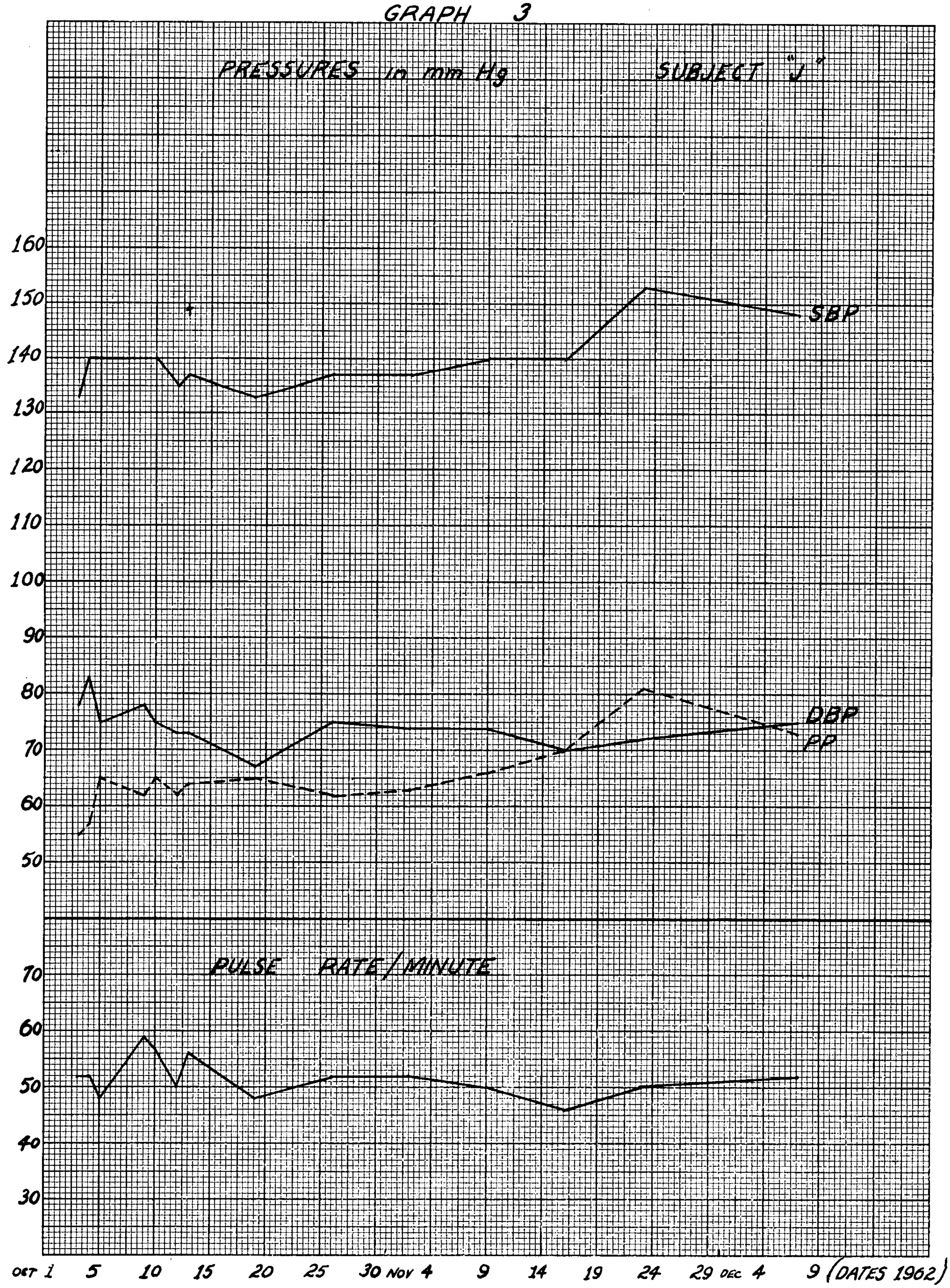
.40
.30
.20
.10
OCT 1 5 10 15 20 25 30 NOV 4 9 14 19 24 29 DEC 4 9 (DATES 1962)

GRAPH 3


PRESSURES in mm Hg
SUBJECT "J"
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150
140
130
120
110
100
90
80
70
60
50
SBP
DBP
PP
PULSE RATE/MINUTE
70
60
50
40
30
OCT 1
5
10
15
20
25
30 NOV 4
9
14
19
24
29 DEC 4
9 (DATES 1962)

TABLE I

SUBJECT "J"
Raw Scores

Date	Time	Record. Press.	S.A.	D.A.	O.A.	D.N.A.	D.S.	A.U.C.	D.T./S.T.	P.R.	S.B.P.	D.B.P.	P.P.	F.R.
3/10/62	12:35	90	1.08	.64	22½°	.64	0	.33	3.48	52	133	78	55	.59
	Stand	96	1.09	.55	24°	.55	0							
4/10/62	12:30	100	.95	.59	22½°	.59	0	.28	2.90	52	140	83	57	.62
	Stand	101	.82	.48	25°	.48	0							
5/10/62	12:25	92	1.00	.62	23½°	.62	0	.37	4.14	48	140	75	65	.62
	Stand	97	.76	.50	25°	.50	0							
9/10/62	12:30	88	.87	.55	24°	.55	0	.32	2.73	59	140	78	62	.63
	Stand	108	.74	.38	25°	.38	0							
10/10/62	12:30	90	1.01	.56	23°	.56	0	.31	3.51	57	140	75	65	.55
	Stand	105	.84	.42	25°	.42	0							
12/10/62	12:20	90	1.26	.68	22°	.66	.02	.43	3.66	50	135	73	62	.52
	Stand	92	.94	.50	22°	.50	0							
13/10/62	10:20	85	1.15	.61	21½°	.61	0	.32	3.78	56	137	73	64	.53
	Stand	90	1.05	.52	23°	.48	.04							
19/10/62	12:20	90	1.23	.72	22°	.72	0	.45	4.25	48	132	67	65	.59
	Stand	86	.65	.42	25°	.42	0							
26/10/62	11:55	93	1.06	.65	22½°	.65	0	.37	3.63	52	137	75	62	.61
	Stand	102	.92	.54	24½°	.54	0							
2/11/62	12:10	90	.97	.57	23°	.57	0	.36	3.55	52	137	74	63	.59
	Stand	101	.76	.47	25°	.47	0							
9/11/62	16:20	94	1.06	.63	22½°	.63	0	.38	3.65	50	140	74	66	.59
	Stand	97	.89	.48	23½°	.48	0							
16/11/62	12:30	86	.69	.51	24°	.51	0	.33	4.14	46	140	70	70	.74
	Stand	104	.65	.45	25°	.45	0							
23/11/62	12:00	88	1.05	.58	22°	.56	.02	.38	4.32	50	153	72	81	.53
	Stand	100	.86	.46	23½°	.46	0							
7/12/62	12:25	94	1.01	.61	23°	.61	0	.39	4.36	52	148	75	73	.60
	Stand	98	.77	.39	25½°	.39	0							

TABLE II

SUBJECT "J"
Statistical Data

	S.A.	D.A.	O.A.	D.N.A.	D.S.	A.U.C.	D.T./S.T.	P.R.	S.B.P.	D.B.P.	P.P.	F.R.
Coefficient of Correlation	-.243	-.230	.095	-.257	.172	.317	.608	-.331	.670	-.400	.805	.157
Regression Coefficient	-.167	-.061	.035	-.067	.006	.071	1.457	-.057	.177	-.072	.250	.042
Standard Errors of Estimate	.192	.074	.107	.072	.009	.062	.548	.047	.056	.048	.053	.076
F. Ratios	.759	.676	.110	.850	.366	1.342	7.050	1.478	9.781	2.289	22.103	.305

$F = 4.75$
$\alpha = .05$

Case "C"

Subject "C" was twenty-two years old, five feet nine and one-half inches tall and weighed one hundred and forty pounds. He is primarily an endurance runner with little speed for short track races.

This runner began competition in the fall of 1956. He competed in two, three mile cross country races but did not train that year. In 1957 subject "C" trained a little and competed in three cross country runs and two one mile races. In 1958 he did not run because of asthma (discussed later). In 1959 the athlete trained hard all year and competed for the full cross country season. In addition, he did some track running and ran a 4:37 mile. In 1960 he again did not run because of asthma. In 1961 subject "C" had severe asthma and was hospitalized in the spring; however, that fall he competed during the cross country season.

In 1962 subject "C" ran all year and had only slight attacks of asthma. He ran a two mile race in 10:13 and competed in the full cross country season.

Subject "C" has had asthma attacks for several years. He experiences the most trouble in the months of April, May and June. Fortunately the subject does not have attacks when he is in good running condition.

A record was kept of this runner's training, beginning September 24, 1962. His training alternated from moderate to heavy amounts of work. On some days he ran only four or five miles while on others he ran up to fifteen miles. Subject "C" took many more rest days in his training regimen than his teammates.

On October 6th, subject "C" ran as expected and his heartograph measures were fairly normal on the previous day. Pulse pressure and rest-to-work ratio were relatively low on this day. October 13th, the athlete ran better than expected. In the graphs taken that day and on the day before systolic amplitude showed a marked increase over the previous week as did also rest-to-work ratio and pulse pressure. This record also showed signs of a developing distolic surge. On the day of the race the pulse rate had accelerated from 65 to 72, the highest value recorded. Again on October 20th, subject "C" ran better than expected. On the previous day's graph systolic and diastolic amplitudes were especially high and a slight diastolic surge was still apparent. Area under the curve showed a definite increase, whereas rest-to-work ratio had dropped somewhat. The following week, October 27th, subject "C" repeated his better than expected performance. The previous day's graph showed a decrease in systolic amplitude but a continued rise in diastolic amplitude. The diastolic surge was no longer apparent. The rest-to-work ratio reached a value of 4.06, highest of the testing period. Two weeks later on November 10th the subject ran "not well". The subject had trained very hard the previous week-end, running twenty-seven miles altogether. Two measures showed a marked drop in size; the rest-to-work ratio dipped sharply to 2.30 and the fatigue ratio decreased to the lowest point reached during the season. Unfortunately the coach did not evaluate any further races. From this time on the subject reduced training and the rest-to-work ratio made an apparent recovery as did the fatigue ratio also.

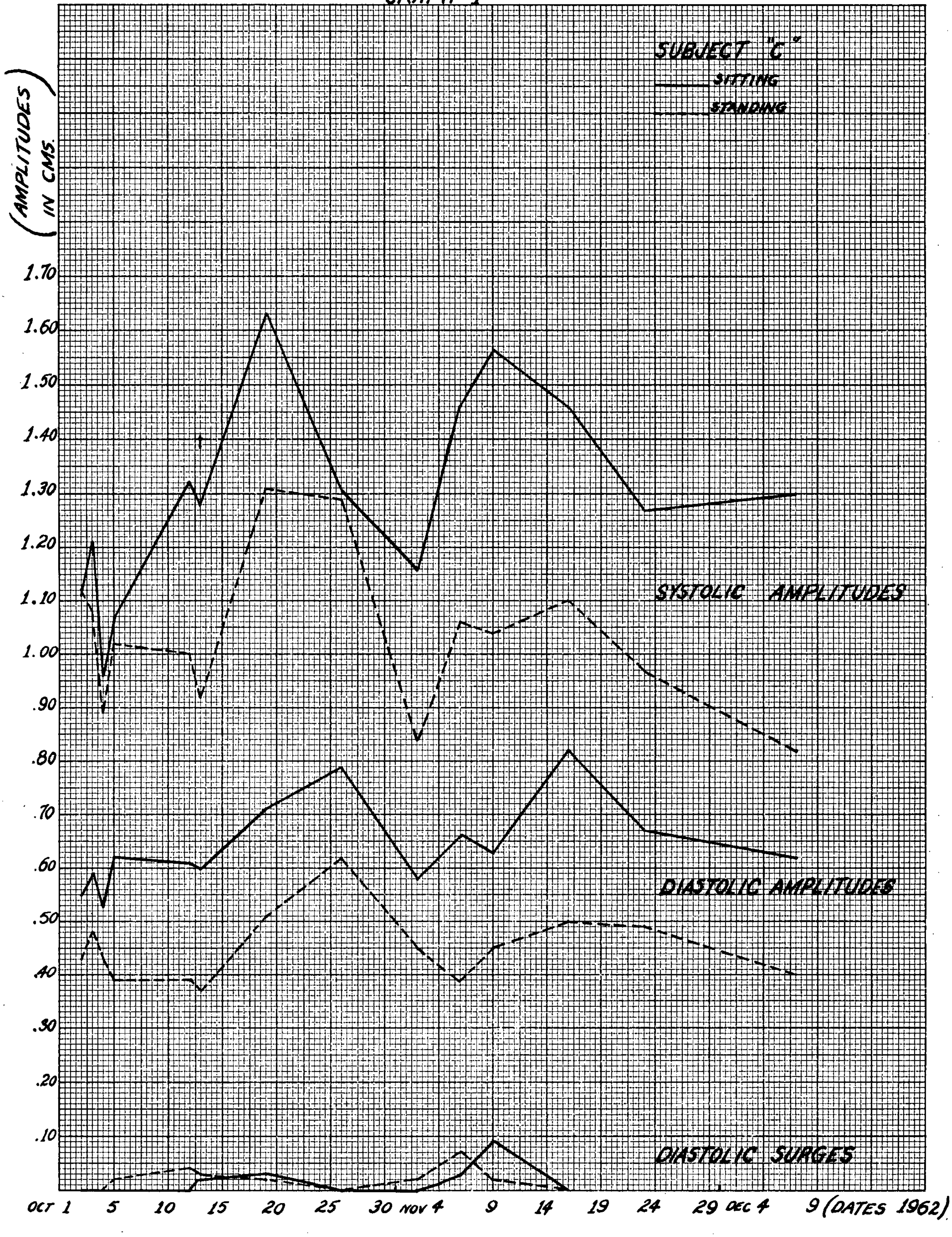
The pulse pressure of subject "C" was very high on the first record made and then dropped sharply; throughout the season this measurement showed a steady increase. The study by Carlile[5] of athletes in hard training showed a pulse pressure increase from 46 mm. to 65 mm. during training. Although the pulse pressure gives some indication of cardiovascular state[6] its interpretation is still controversial.

The hard training that subject "C" undertook gave some increases in cardiovascular condition as indicated by heartograph measures. Although there was a poor race on November 10th, one must be careful in stating that this is attributable to too much stress. Carlile[7] states: "Many athletes in hard training show deterioration of times and performance". However, in Carlile's study[8] with Olympic swimmers some, despite poor electrocardiographs and worsening performances, continued to train hard and later, with a week or so of light training, swam well.

Subject "C" was consistently one of the top performers on the cross country team. His failure to develop a diastolic surge seemed atypical for, as shown by Carlile[9], fifteen or sixteen swimmers developed diastolic surges while in hard training for eight weeks. In this subject a surge began to develop and then disappeared.

The statistical interpretation of subject "C's" data shows that only two aspects of his cardiovascular condition showed a significant trend over the nine weeks of testing. His systolic blood pressure and pulse pressure both increased. The rest-to-work ratio fluctuated throughout the season, as did performance, and showed no definite direction.

GRAPH 1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STANDING
(AMPLITUDES IN CMS.)
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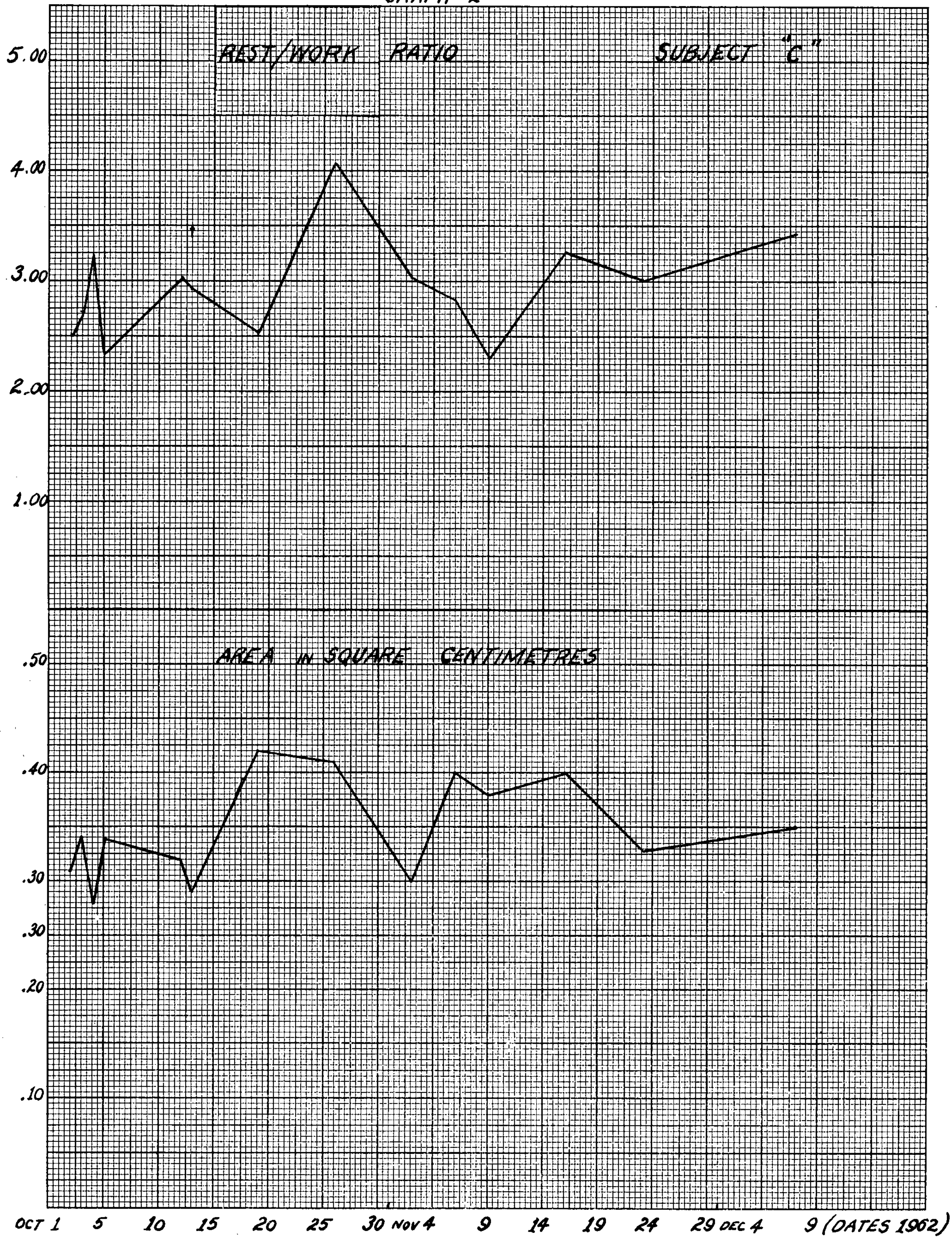
1.60
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
SYSTOLIC AMPLITUDES
DIASTOLIC AMPLITUDES
DIASTOLIC SURGES
OCT 1 5 10 15 20 25 30 NOV 4 9 14 19 24 29 DEC 4 9 (DATES 1962)

GRAPH 2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SUBJECT "C"
5.00
4.00
3.00
2.00
1.00
AREA IN SQUARE CENTIMETRES
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.40
.30
.30
.20
.10
OCT 1 5 10 15 20 25 30 NOV 4 9 14 19 24 29 DEC 4 9 (DATES 1962)

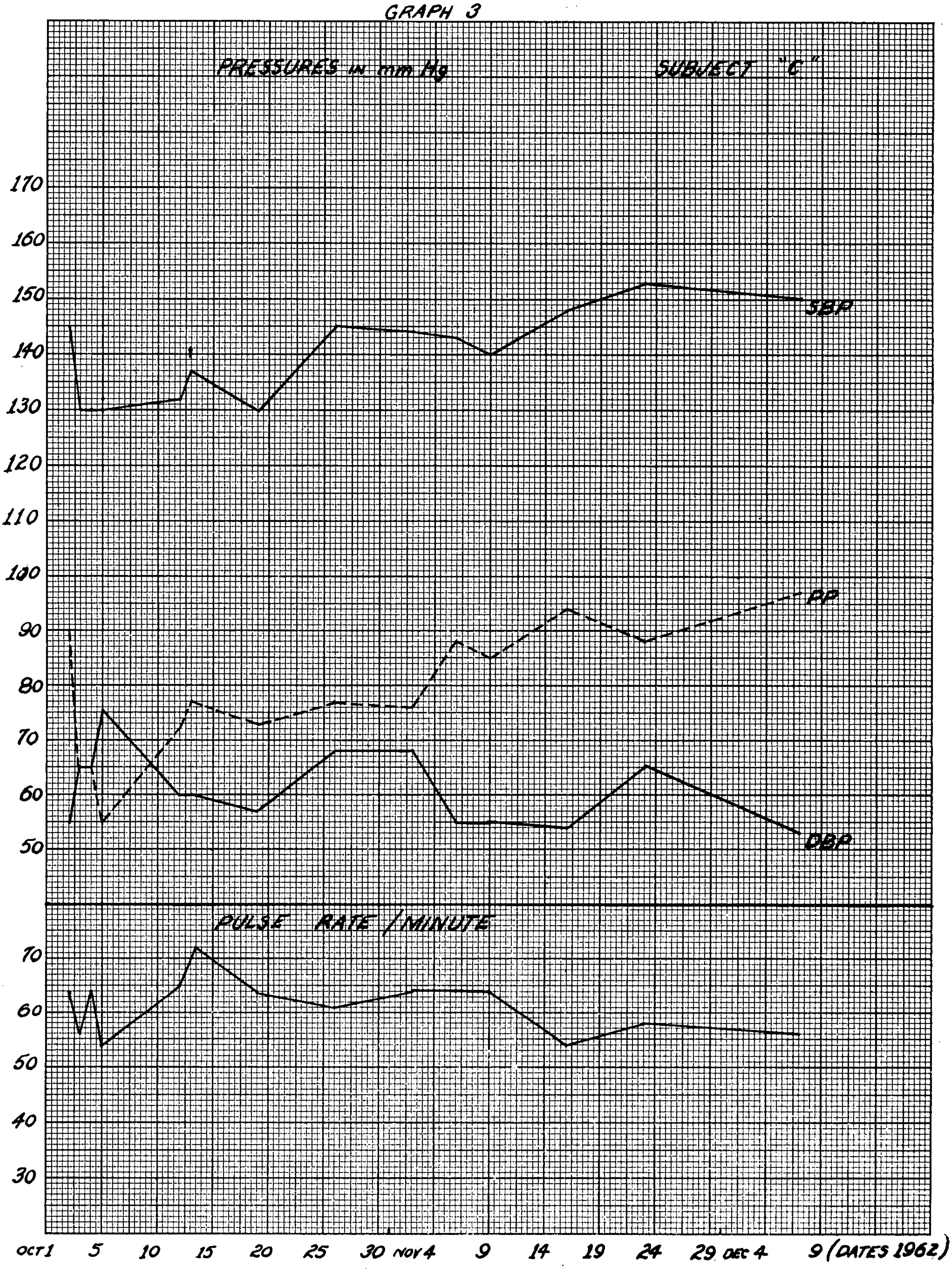

GRAPH 3
PRESSURES IN mm Hg
SUBJECT "C"
170
160
150
140
130
120
110
100
90
80
70
60
50
SBP
PP
DBP
PULSE RATE / MINUTE
70
60
50
40
30
OCT 1
5
10
15
20
25
30 NOV 4
9
14
19
24
29 DEC 4
9 (DATES 1962)

TABLE III

SUBJECT"C"
Raw Scores

Date	Time	Record. Press.	S.A.	D.A.	O.A.	D.N.A.	D.S.	A.U.C.	D.T./S.T.	P.R.	S.B.P.	D.B.P.	P.P.	F.R.
2/10/62	12:20	80	1.11	.55	21½°	.55	0	.31	2.50	64	145	55	90	.50
	Stand	80	1.12	.43	21°	.43	0							
3/10/62	12:45	80	1.21	.59	20°	.59	0	.34	2.69	56	130	65	65	.49
	Stand	92	1.08	.48	21°	.48	0							
4/10/62	12:05	80	.96	.53	22°	.53	0	.28	3.24	64	130	65	65	.55
	Stand	85	.89	.43	23°	.43	0							
5/10/62	11:15	90	1.07	.62	22°	.62	0	.34	2.34	54	130	75	55	.58
	Stand	85	1.02	.39	22½°	.37	.02							
12/10/62	11:15	80	1.32	.61	21°	.61	.0	.32	3.03	65	132	60	72	.46
	Stand	87	1.00	.39	21°	.35	.04							
13/10/62	10:15	82	1.28	.60	21°	.58	.02	.29	2.93	72	137	60	77	.45
	Stand	92	.92	.37	22½°	.34	.03							
19/10/62	11:20	80	1.63	.71	19°	.68	.03	.42	2.54	64	130	57	73	.42
	Stand	81	1.31	.51	22½°	.49	.02							
26/10/62	16:23	78	1.31	.79	22°	.79	0	.41	4.06	61	145	68	77	.60
	Stand	92	1.29	.62	22½°	.62	0							
2/11/62	16:00	87	1.16	.58	21°	.58	0	.30	3.04	64	144	68	76	.50
	Stand	85	.84	.45	23°	.43	.02							
6/11/62	10:30	80	1.46	.66	21°	.63	.03	.40	2.84	64	143	55	88	.43
	Stand	80	1.06	.39	22°	.32	.07							
9/11/62	16:30	82	1.56	.63	20½°	.54	.09	.38	2.30	64	140	55	85	.35
	Stand	82	1.04	.45	21½°	.43	.02							
16/11/62	16:20	81	1.46	.82	21°	.82	0	.40	3.26	54	148	54	94	.56
	Stand	80	1.10	.50	22°	.50	0							
23/11/62	16:30	82	1.27	.67	21½°	.67	0	.33	3.01	58	153	65	88	.53
	Stand	80	.97	.49	21°	.49	0							
7/12/62	11:55	77	1.30	.62	21½°	.62	0	.35	3.43	56	150	53	97	.48
	Stand	81	.82	.40	24°	.40	0							

TABLE IV

SUBJECT "C"
Statistical Data

	S.A.	D.A.	O.A.	D.N.A.	D.S.	A.U.C.	D.T./S.T.	P.R.	S.B.P.	D.B.P.	P.P.	F.R.
Coefficient of Correlation	.455	.437	.044	.374	.163	.370	.338	-.311	.785	-.406	.752	-.127
Regression Coefficient	.405	.173	.017	.153	.019	.082	.756	-.075	.305	-.128	.434	-.041
Standard Errors of Estimate	.229	.102	.113	.109	.033	.059	.608	.066	.069	.083	.109	.092
F. Ratios	3.138	2.843	.023	1.959	.330	1.909	1.548	1.287	19.274	2.381	15.631	.197

F = 4.75
α = .05

Case "E"

Subject "E" was twenty-five years old, five feet seven and one-half inches tall and weighed one hundred and forty-five pounds. He has participated in track since the age of twelve.

This athlete began competing in cross country events in England in September 1949. He trained twice a week, ran several races, and won most of them. In 1950 he competed in cross country from January to May and again from September to December. This cross country season was typical with those that followed until 1958. In the summer of 1952 subject "E" raced in four one-mile events; he had a best time of 4:48. In 1953 he did not compete in the summer. In addition to the cross country season in 1954, this runner again ran four one-mile races in the summer with a best time of 4:40. During these summer seasons he trained very little. In the summer of 1955 again this subject did not compete. In 1959 subject "E" trained very hard, that July he won the "All England Schools" one-mile race in a time of 4:20.8. In 1957 the athlete trained hard and ran for Oxford University. He competed in fifteen one-mile races in the summer track season with a best time of 4:10. He also ran some two and three mile races. In 1958 the pattern was very similar. In 1959 subject "E" ran a 4:05 mile placing third in the English Championships. That fall he did little cross country training. In 1960 the runner trained hard from February onward; his best race was 3:46 for 1500 meters in the Olympic trials. This is the year he came to Canada and he competed all year. In 1961 he did not train hard, ran a 4:13 mile in April and did some cross country. Finally, in 1962 subject "E" trained hard in the spring, ran a 4:11 mile in April, slowed training in the summer and picked it up again in the fall.

Subject "E" has had no medical history that would affect his running performance to any extent.

A record was kept of this runner's training, beginning September 24, 1962. The training load varied from light to moderate. Often throughout the season the runner would take two or three days rest. His running averaged between four and five miles on the days he trained. The type of training was mixed - some distance work and some track work. From September 26th to 30th the athlete had a cold and did not train. After November 10th subject "E" reduced his training appreciably, often running only once a week. This runner always rested for a day before and after each race.

On October 6th subject "E" ran as expected. The majority of measures of the pulse wave were in the range of those of normal young men, as described in Chapter III, page 17 of this study, on the day before this race. The pulse wave did not look like one of an athlete in good cardiovascular condition. However, this is partially explained by the cold mentioned earlier and the lack of training in the summer. Carlile[10] in his measurement of Olympic swimmers before training indicates that cardiovascular condition is lost quickly. A diastolic surge appeared for the first time the day before this race, whereas the area under the curve was very low at this time although it had been high on the previous day's recording. There is no good explanation for this apparent anomaly.

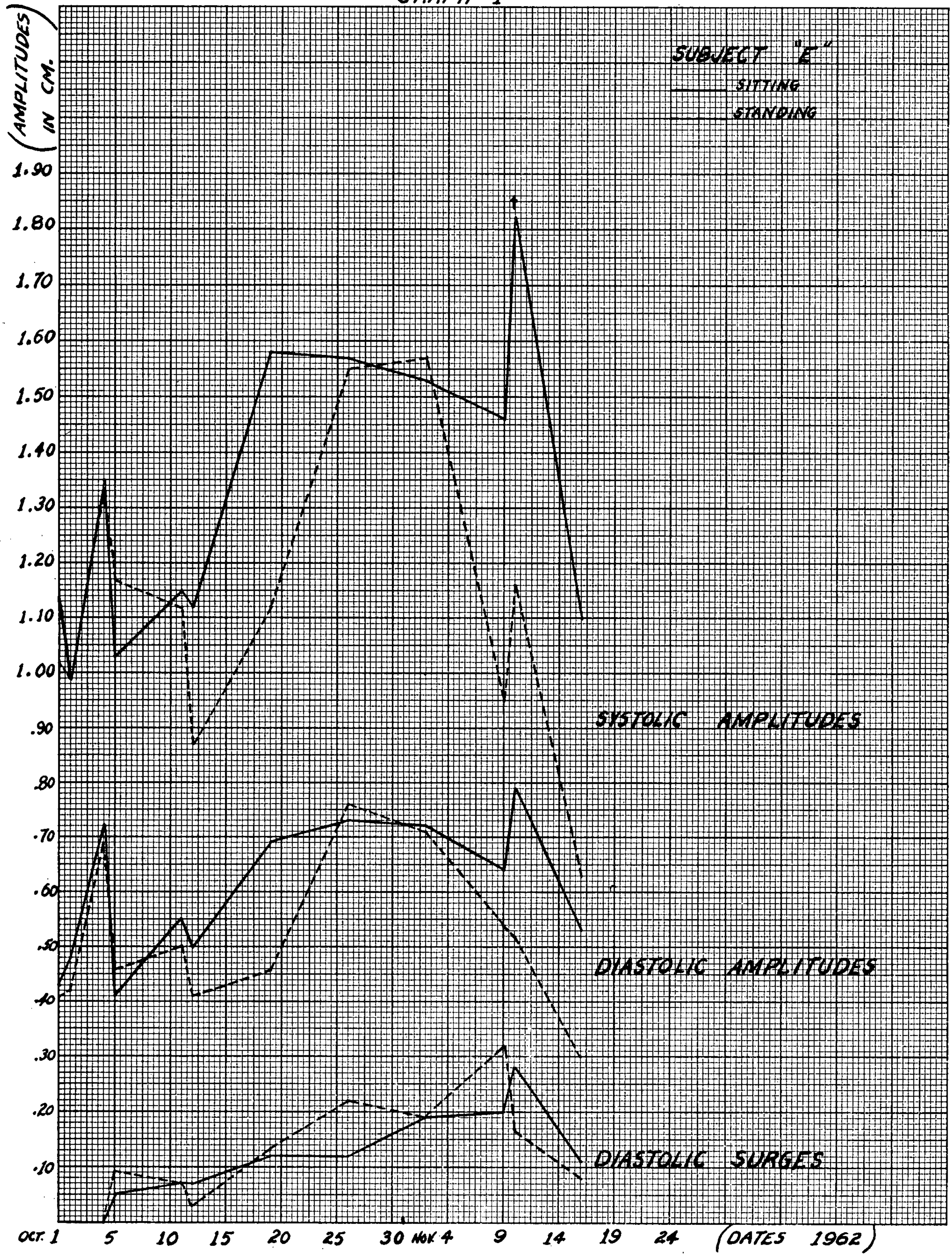
Subject "E" ran better than expected on October 13th. The overall pulse wave improved during this week with the rest-to-work ratio and the area under the curve making the largest advances. However, between October 11th and October 12th, these measures dipped slightly. On October 20th the athlete ran as expected. Systolic amplitude, diastolic amplitude and diastolic surge all showed increases. Rest-to-work ratio and area under the curve did not make marked changes. Subject "E" ran better than expected again on October 27th. The amplitude measures had leveled off although standing diastolic surge continued to climb. The adjustment to standing was very good the day before this race. The rest-to-work ratio and area made large increases. On November 10th this runner ran as expected. A heartograph was taken both on the day before the race and one hour before race time. The amplitudes all rose sharply between the times of these recordings, the pulse rate also increased somewhat. The systolic blood pressures during this period and for some time before were in the area of 160 mm. Hg which various authors imply is associated with unfitness[11]. However, Cureton[12] says: "The slightly built man trained for endurance running usually shows higher systolic pressure than would be expected". The rest-to-work ratio and area dipped slightly before this race. As mentioned earlier, training was decreased markedly after this time as this was the athlete's last competition of the season. Amplitudes dropped off very sharply after this point as did the area which is highly correlated with amplitude measures[13]. The rest-to-work ratio is the one measure that improved appreciably after the decrease in training.

This runner has had a long history of endurance training. Although subject "E" did not undertake a strenuous training programme for the 1962 season, his performance improved rapidly as did his cardiovascular condition as indicated by the heartometer. The runner's obliquity angle decreased to $19\frac{1}{2}°$ from $22°$ which, in addition to factors discussed earlier, indicates good cardiovascular condition[14].

Many of the aspects of pulse waves discussed above showed significant changes when tested statistically. There was a trend to increase in diastolic surge, rest-to-work ratio, systolic blood pressure and pulse pressure. Pulse rate and fatigue ratio decreased.

It would appear that the subject adapted very well to his training load; he ran well in all races. Although competing against individuals who trained more regularly, subject "E" consistently finished among the leaders. His background of training and experience is very likely an important factor here.

GRAPH 1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STANDING
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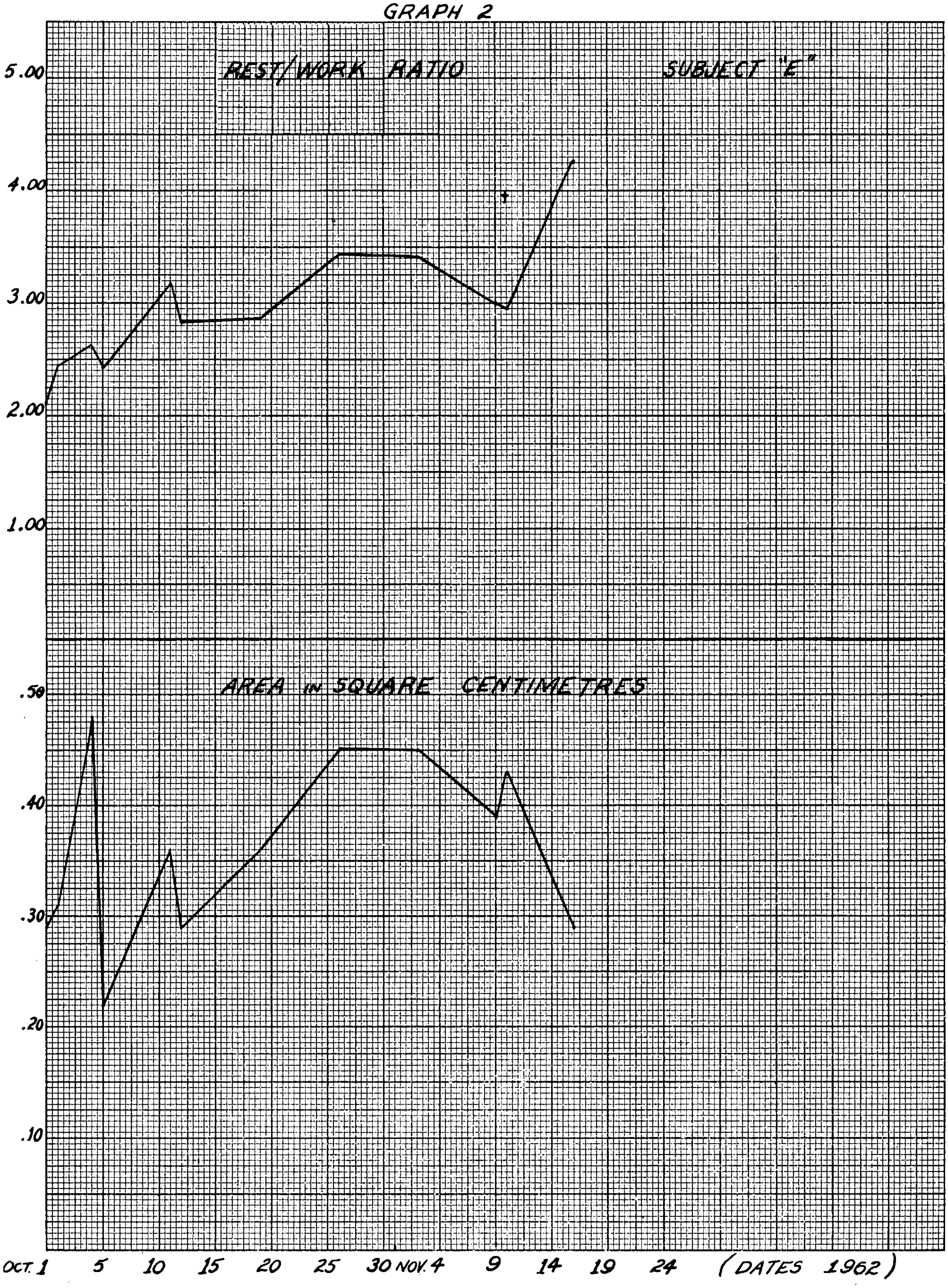
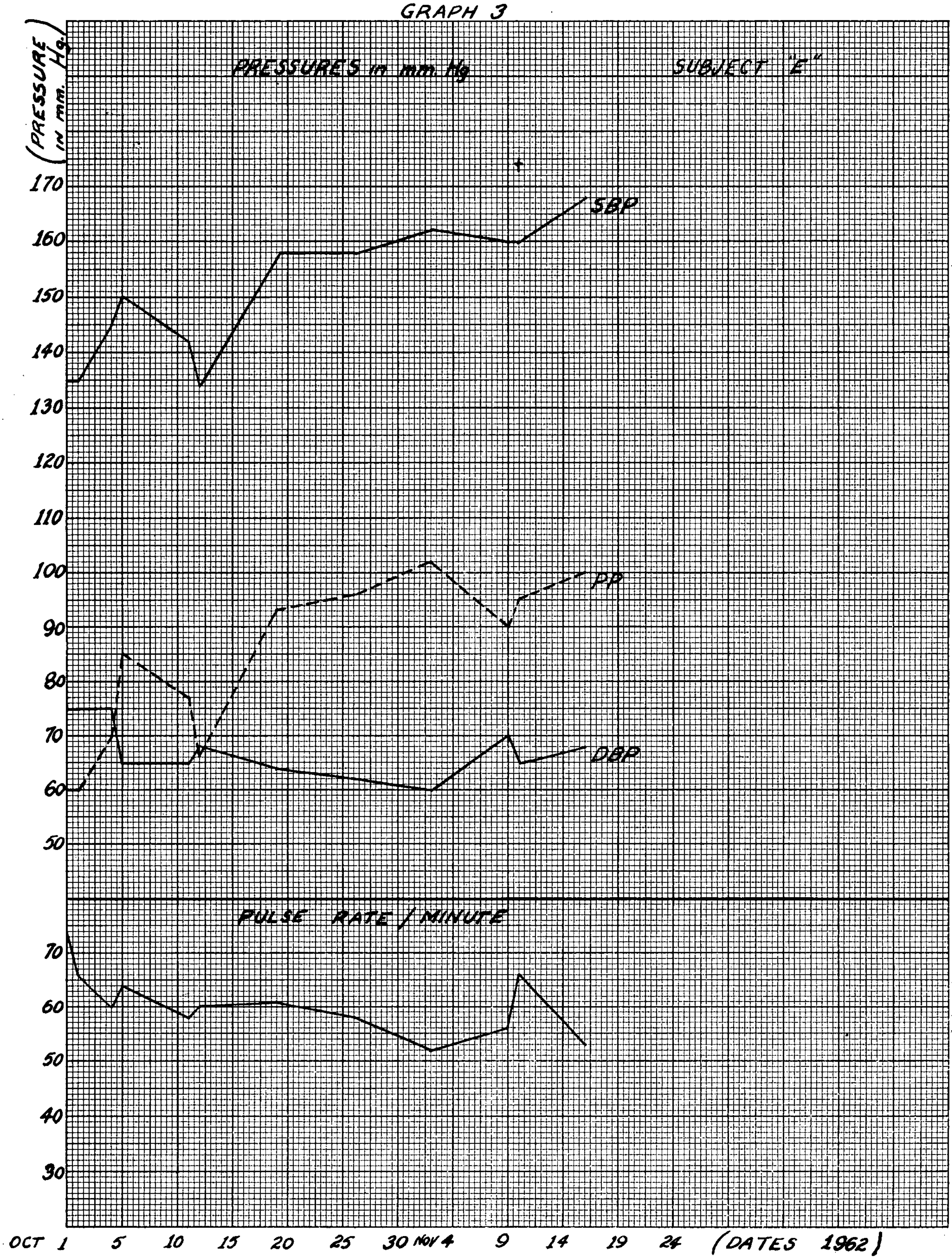
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
SYSTOLIC AMPLITUDES
DIASTOLIC AMPLITUDES
DIASTOLIC SURGES
OCT. 1
5
10
15
20
25
30
NOV 4
9
14
19
24
(DATES 1962)


GRAPH 2
REST/WORK RATIO
SUBJECT "E"
5.00
4.00
3.00
2.00
1.00
AREA IN SQUARE CENTIMETRES
.50
.40
.30
.20
.10
OCT. 1
5
10
15
20
25
30 NOV. 4
9
14
19
24
(DATES 1962)

GRAPH 3


(PRESSURE IN mm. Hg.)
PRESSURES in mm. Hg
SUBJECT "E"
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160
150
140
130
120
110
100
90
80
70
60
50
SBP
PP
DBP
PULSE RATE / MINUTE
70
60
50
40
30
OCT 1
5
10
15
20
25
30 NOV 4
9
14
19
24
(DATES 1962)

TABLE V

SUBJECT "E"
Raw Scores

Date	Time	Record. Press.	S.A.	D.A	O.A.	D.N.A.	D.S.	A.U.C.	D.T./S.T.	P.R.	S.B.P.	D.B.P.	P.P.	F.R.
1/10/62	20:45	90	1.14	.43	22°	.43	0	.29	2.12	74	135	75	60	.38
	Stand	100	1.02	.41	22½°	.41	0							
2/10/62	11:55	90	.99	.48	22°	.48	0	.31	2.44	66	135	75	60	.48
	Stand	99	.99	.42	23½°	.42	0							
4/10/62	12:20	90	1.35	.72	21½°	.72	0	.48	2.62	60	145	75	70	.53
	Stand	103	1.32	.69	22½°	.69	0							
5/10/62	11:25	80	1.03	.41	21½°	.36	.05	.22	2.42	64	150	65	85	.35
	Stand	87	1.17	.46	21°	.37	.09							
11/10/62	12:05	80	1.15	.55	21°	.48	.07	.36	3.17	58	142	65	77	.42
	Stand	90	1.10	.50	21°	.43	.07							
12/10/62	11:35	80	1.12	.50	22°	.43	.07	.29	2.83	60	134	68	66	.38
	Stand	86	.87	.41	22½°	.38	.03							
19/10/62	11:30	82	1.58	.69	19½°	.57	.12	.36	2.87	61	157	64	93	.36
	Stand	85	1.12	.46	21°	.33	.13							
26/10/62	16:15	80	1.57	.73	21°	.61	.12	.45	3.43	58	158	62	96	.39
	Stand	80	1.55	.76	20°	.54	.22							
2/11/62	12:35	80	1.53	.72	19½°	.53	.19	.45	3.42	52	162	60	102	.35
	Stand	90	1.57	.71	19°	.52	.19							
9/11/62	12:40	80	1.46	.64	20½°	.44	.20	.39	3.00	56	160	70	90	.30
	Stand	87	.95	.54	24°	.22	.32							
10/11/62	12:30	82	1.82	.79	19½°	.51	.28	.43	2.95	66	160	65	95	.28
	Stand	87	1.16	.52	22°	.35	.17							
16/11/62	12:35	80	1.10	.53	22°	.42	.11	.29	4.27	53	168	68	100	.38
	Stand	87	.63	.30	25½°	.22	.08							

TABLE VI

SUBJECT "E"
Statistical Data

	S.A.	D.A.	O.A.	D.N.A.	D.S.	A.U.C.	D.T./S.T.	P.R.	S.B.P.	D.B.P.	P.P.	F.R.
Coefficient of Correlation	.561	.527	-.493	-.063	.853	.323	.785	-.596	.874	-.481	.831	-.637
Regression Coefficient	.897	.412	-.301	-.037	.449	.157	2.684	-.219	.624	-.148	.772	-.263
Standard Errors of Estimate	.417	.209	.167	.185	.086	.145	.668	.093	.109	.085	.163	.100
F. Ratios	4.608	3.858	3.221	.040	26.794	1.167	16.133	5.527	32.575	3.018	22.346	6.831

$F = 4.96$
$\alpha = .05$

Case "M"

Subject "M" was twenty-three years old, five feet ten and one-half inches tall and weighed one hundred and fifty-six pounds. This athlete has participated in sports other than track to some extent.

This runner began training in 1957; his training was designed for the 880 and one-mile; however, he did not compete that year. In 1958 he trained all year and raced in the British Columbia inter-high track meet. His times for the 880 and one-mile were, 1:56 and 4:28 respectively. The number of competitive races were limited and no cross country was attempted. In 1959 subject "M" did not compete in races of any type but did continue light training. From 1957-1959 he played rugby regularly during season and also football at the high school level in 1957 and 1958. Subject "M" participated in cross country for the first time in 1960. He trained all year and competed in track meets in the spring and summer; he ran the 880 in 1:58 and the one-mile in 4:30. The pattern for 1961 was very similar; for the 880 and one-mile he had best times of 1:57 and 4:28. Again in 1962 subject "M" trained all year with the exceptions discussed later. His best track performances were 1:56 for the 880 and a 4:24 for the mile.

Up until 1962 subject "M" was not aware of any health problems that would directly or indirectly affect his performance. However, on October 29th he went to a doctor on the suggestion of his coach and was diagnosed as having had a slight nervous breakdown.

A record was kept of this runner's training, beginning September 24, 1962. His training load was moderate up until October 29th; he often ran six or seven miles in one session and some days did track workouts (for example, 15 x 440)instead. Subject "M" rested the day before and the day after races. His training load was cut back sharply after October 29th because of doctor's orders. After this the athlete trained only when he felt inclined and then only three or fours miles in any one session.

He had many intervals of rest up to three days duration. His study load and outside activities, which were quite heavy, were also cut back sharply. Subject "M" often reported, while being graphed, that he had trouble sleeping, especially before races. After the reduction in activities he had less trouble sleeping and appeared to be less nervous; a degree of nervousness was apparent before.

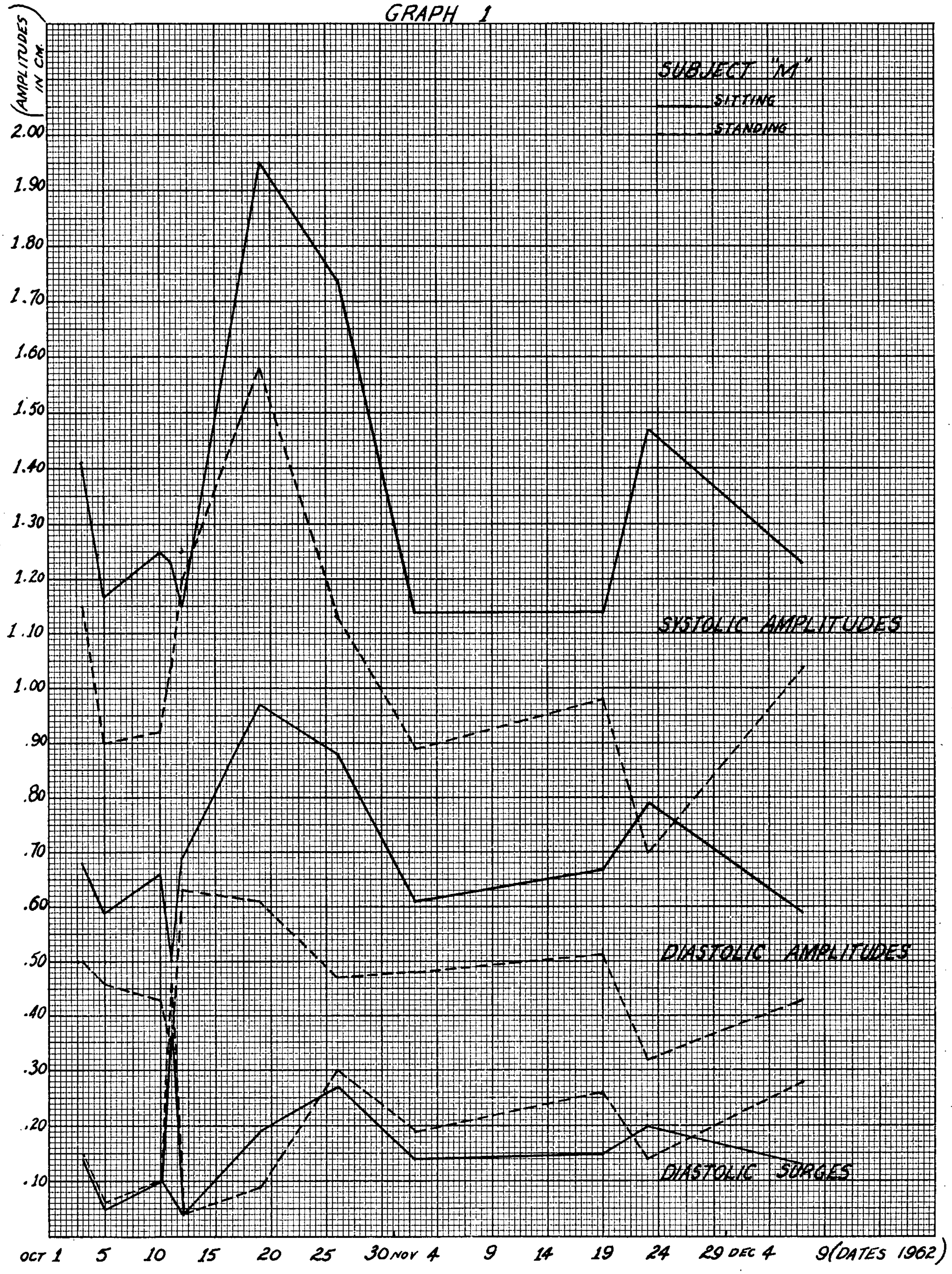
Subject "M" ran as expected October 6th. On the graph taken the day before the race all measurements were within normal limits (Chapter III, page 17). On October 13th this athlete again ran as expected; however there were some abrupt changes in his pulse wave. The graph of October 10th was very similar to that of the previous week, but the graph of October 11th differed sharply in some measures.

The dicrotic notch amplitude dropped from .56 to .14 in this twenty-four hour period. Fatigue of the Autonomic Nervous System and smooth musculature of the aortic arch seems a reasonable explanation as to why the dicrotic notch is lowered, but dilation of the arterioles and capillaries may be a greater causal factor, states Cureton[15]. The area under the curve, rest-to-work ratio and fatigue ratio were all greatly reduced; pulse rate increased. The increase in diastolic surge might be at the expense of the decreased dicrotic notch amplitude. The subject reported at the time of recording that he was feeling cold and had a headache. This could possibly be the cause or effect of the cardiovascular change. However, the runner made an apparent recovery on the graph taken one day later, October 12th, twenty-four hours before the race. The area under the curve made a particularly large gain.

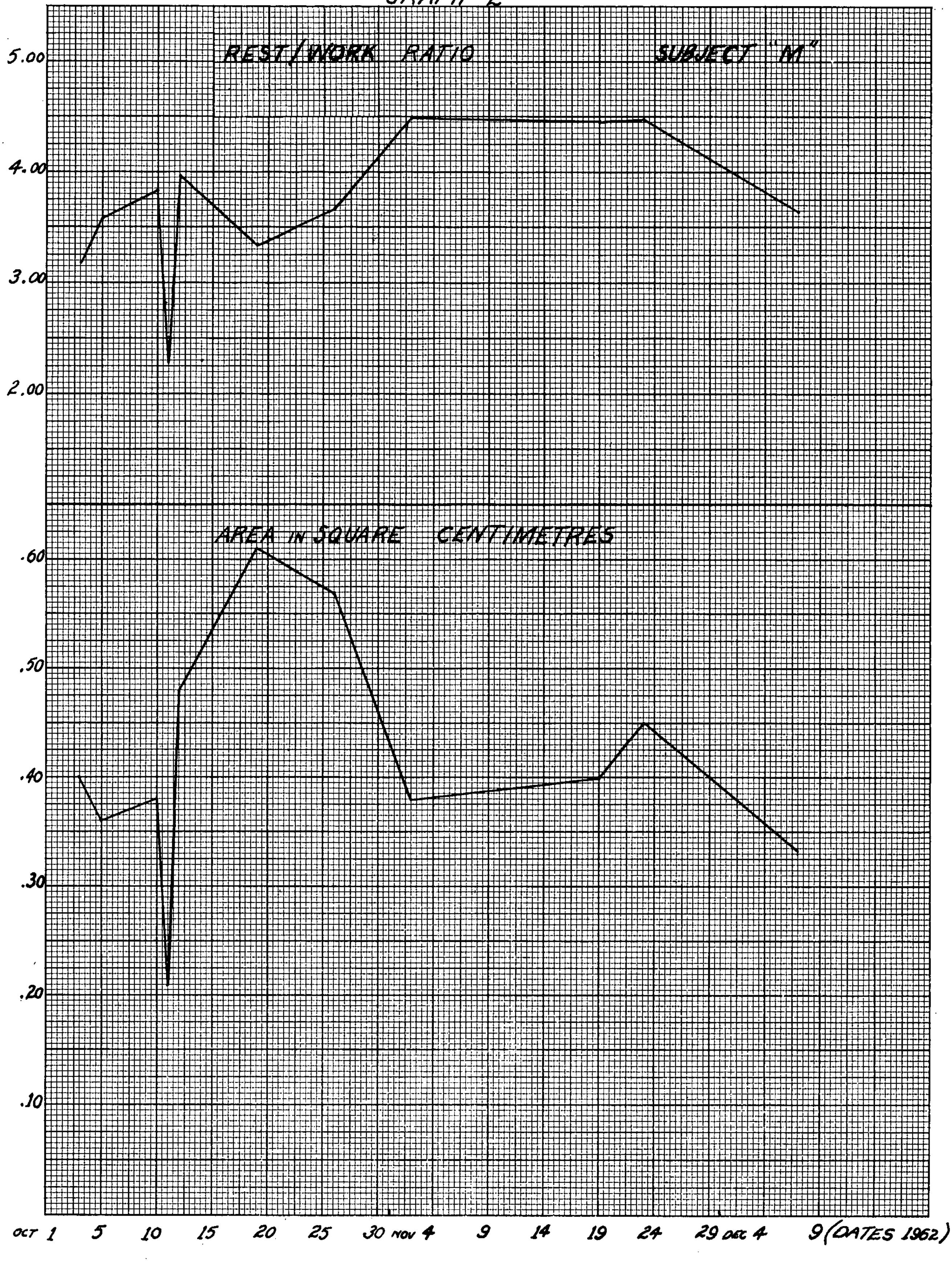
Subject "M" ran "not well" on October 20th. However, the wave at this time appeared especially strong, the amplitudes and area increased markedly. The rest to work ratio dropped a little. Again on October 27th the subject ran "not well". Twenty-four hours before this event the subject's pulse wave was strong. However, as a result of a talk with the coach the subject went to a medical doctor and was diagnosed as having had a nervous breakdown. A possible explanation is related by Cureton[16]: If sympathetic stimulation is overdone it can lead to staleness as a result of too much stimulation for too long a time. Athletes should learn to relax. Carlile[17] states: "...because of the effort involved in hard training there occurs something in the nature of "nervous depletion" so that, despite the improved circulatory response, performance may even deteriorate". Most of the factors of the pulse wave taken on October 26th would suggest that the athlete was in good cardiovascular condition. In excitement or fear Diastolic Amplitude rises[18]. This is one of the reactions that occurred during this period. On November 10th, after two weeks of light training, subject "M" ran as expected. The rest-to-work ratio increased in this period and the other measures returned to more normal values. According to Carlile[19] "... with the increased rest of the 'tapering-off' period, the nervous system 'regenerates' before the efficiency of the cardiovascular system has deteriorated".

Subject "M" had a very revealing cross country season. His cardiovascular system indicated good condition and rapid improvements although obviously his nervous system did not adapt to the combined stresses of training, competition and daily living. Therefore, he was not able to perform as one would expect from studying his cardiovascular condition as indicated by the heartometer. As discussed in Chapter III, page 7, "We may be nervous without wanting to be nervous". Hickham (ref. page 8 of the same chapter) discussed the absence of reliable objective means of measuring the degree of anxiety in individual subjects. Apprehension and its affect on competition is an area that needs much further study.

The statistical interpretation of subject "M's" data shows that two factors, systolic blood pressure and pulse pressure, indicate an increasing trend for the testing period. Subject "M" did not react favourably to his training load, especially before the enforced reduction in training. He did not perform as well as one might expect from observing the general pulse wave appearance (see Appendix B).


GRAPH 1
(AMPLITUDES IN CM.)
SUBJECT "M"
SITTING
STANDING
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
SYSTOLIC AMPLITUDES
DIASTOLIC AMPLITUDES
DIASTOLIC SURGES
OCT 1 5 10 15 20 25 30 NOV 4 9 14 19 24 29 DEC 4 9 (DATES 1962)

GRAPH 2


REST/WORK RATIO
SUBJECT "M"
5.00
4.00
3.00
2.00
AREA IN SQUARE CENTIMETRES
.60
.50
.40
.30
.20
.10
OCT 1 5 10 15 20 25 30 NOV 4 9 14 19 24 29 DEC 4 9 (DATES 1962)

GRAPH 3

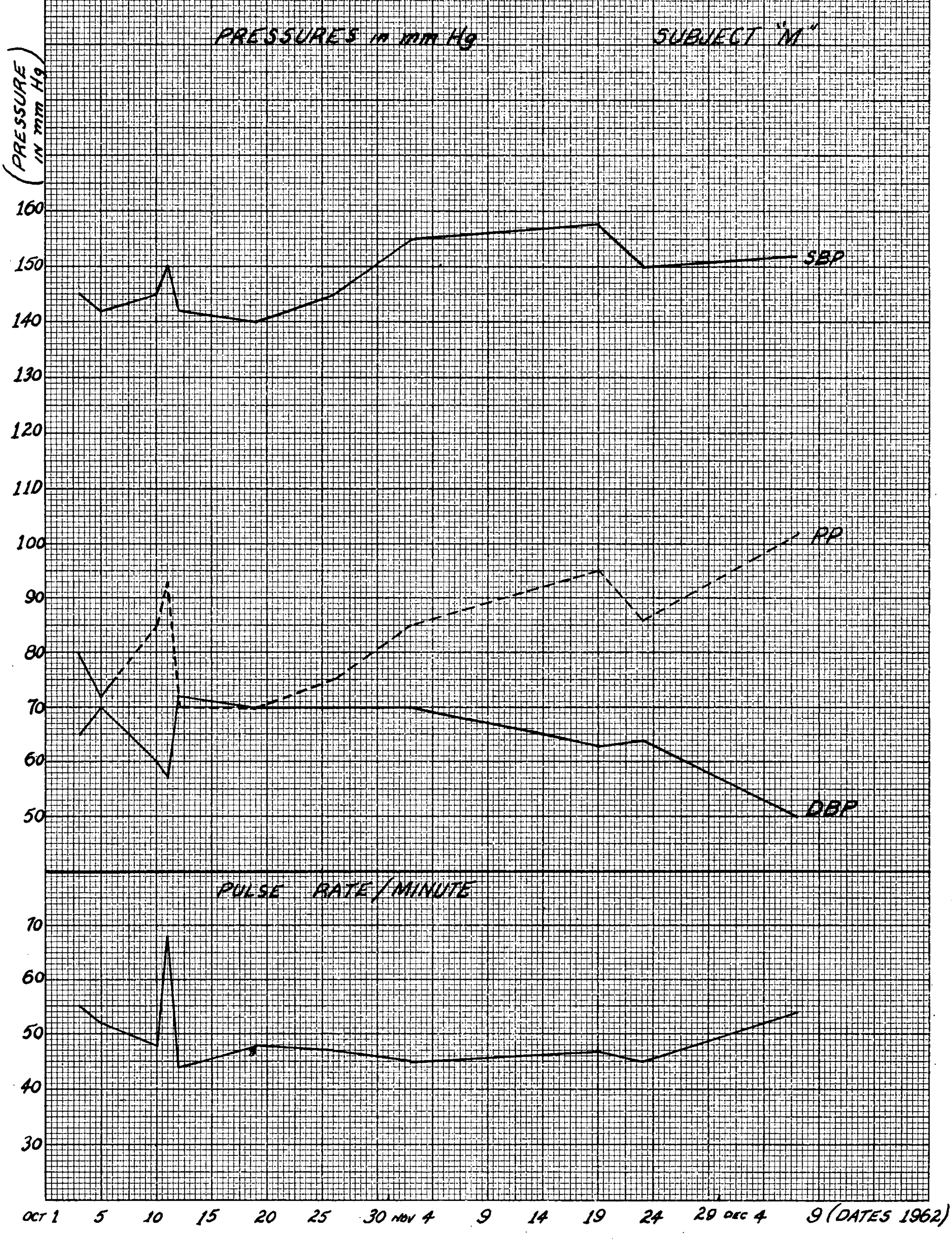

PRESSURES in mm Hg
SUBJECT "M"
(PRESSURE IN mm Hg)
160
150
140
130
120
110
100
90
80
70
60
50
SBP
PP
DBP
PULSE RATE/MINUTE
70
60
50
40
30
OCT 1
5
10
15
20
25
30 NOV 4
9
14
19
24
29 DEC 4
9 (DATES 1962)

TABLE VII

SUBJECT "M"
Raw Scores

Date	Time	Record. Press.	S.A.	D.A.	O.A.	D.N.A.	D.S.	A.U.C.	D.T./S.T.	P.R.	S.B.P.	D.B.P.	P.P.	F.R.
3/10/62	12:55	80	1.41	.68	20°	.54	.14	.40	3.19	55	145	65	80	.38
	Stand	95	1.15	.50	21°	.35								
5/10/62	12:45	85	1.17	.59	21°	.54	.05	.36	3.58	52	142	70	72	.46
	Stand	90	.90	.46	23½°	.40								
10/10/62	12:40	80	1.25	.66	21½°	.56	.10	.38	3.84	48	145	60	85	.45
	Stand	80	.92	.43	21°	.33								
11/10/62	12:30	80	1.23	.50	21°	.14	.36	.21	2.28	68	150	57	93	.11
	Stand	85	1.04	.34	21½°	-.12								
12/10/62	12:50	83	1.15	.69	21°	.65	.04	.48	3.97	44	142	72	70	.56
	Stand	100	1.20	.63	20°	.59								
19/10/62	15:40	85	1.95	.97	18½°	.78	.19	.62	3.33	48	140	70	70	.40
	Stand	96	1.58	.61	20°	.52								
26/10/62	12:45	85	1.74	.88	19½°	.61	.27	.57	3.67	47	145	70	75	.35
	Stand	82	1.13	.47	24°	.17								
2/11/62	12:50	85	1.14	.61	21½°	.47	.14	.38	4.49	45	155	70	85	.41
	Stand	85	.89	.48	24°	.29								
19/11/62	13:10	82	1.14	.67	22½°	.52	.15	.40	4.45	47	158	63	95	.46
	Stand	87	.98	.51	24°	.25								
23/11/62	13:00	85	1.47	.79	21½°	.59	.20	.45	4.48	45	150	64	86	.40
	Stand	87	.70	.32	26°	.18								
7/12/62	12:50	81	1.23	.59	21½°	.46	.13	.33	3.64	54	152	50	102	.37
	Stand	85	1.04	.43	23½°	.15								

TABLE VIII

SUBJECT "M"
Statistical Data

	S.A.	D.A.	O.A.	D.N.A.	D.S.	A.U.C.	D.T./S.T.	P.R.	S.B.P.	D.B.P.	P.P.	F.R.
Coefficient of Correlation	-.063	.041	.244	-.008	.081	-.016	.516	-.246	.680	-.469	.664	.031
Regression Coefficient	-.078	.025	.124	.005	.034	-.008	1.538	-.077	.178	-.145	.323	.016
Standard Errors of Estimate	.406	.207	.165	.237	.140	.170	.849	.101	.064	.091	.121	.167
F. Ratios	.036	.015	.570	.000	.060	.002	3.276	.584	7.745	2.542	7.120	.009

$F = 5.12$
$\alpha = .05$

Case "F"

Subject "F" was twenty years old, six feet four inches tall and weighed one hundred sixty pounds. His early athletic participation was in sports other than track.

In 1954 this athlete played rugby for his school team. During the period 1955-1958 he played touch football daily from September to May and played baseball daily from May to August. In addition, in 1957 he competed in the junior 880 in the British Columbia inter-high track meet, but he did very little specific training. In 1958 he again ran in the inter-high meet, this time he tried the 880 and one-mile, achieving times of 2:13 and 5:01.6 respectively. This, also, was with little training. That fall he competed in cross country for the first time, running in seven meets. During the cross country season he also ran a 4:48 mile.

Subject "F" started training twice to three times weekly in 1959. He ran 440 in 52.5; 880 in 2:10; and one-mile in 5:01.6. He competed in races of from 100 yards to three miles in length. In the fall this runner trained daily; the load was approximately three miles per session. He participated in a full cross country season. Subject "F" trained hard daily in the spring of 1960. His best times were: one-mile in 4:31; two-miles in 10:01; and three-miles in 15:35. He trained very hard during the cross country season running ten miles daily and often twenty miles a day on week-ends. In 1961 this athlete trained much more lighlty and competed only during the cross country season. Subject "F" ran very little in the spring of 1962 because of plantar warts. He resumed training in August with three sessions per week. He then competed in the whole 1962 cross country season.

The only medical involvement experienced by subject "F" was the plantar wart problem mentioned above. He had an operation in 1962 for their removal but they still bother him somewhat.

A record was kept of this runner's training, beginning September 24, 1962. For the first three weeks of the season subject "F" trained fairly hard, running seven and one-half miles daily. However, due to apparent lack of cardiovascular condition improvement, he reduced training for the week of October 15th. This step was taken after his coach studied his pulse waves with the writer and it was decided that possibly he was not adapting to his training load. The following week he trained twice a day, seven and one-half miles in the morning and some track work in the afternoon. He then returned, in the following week, to the seven and one-half mile run daily. Throughout the season subject "F" rested a day before and after each race.

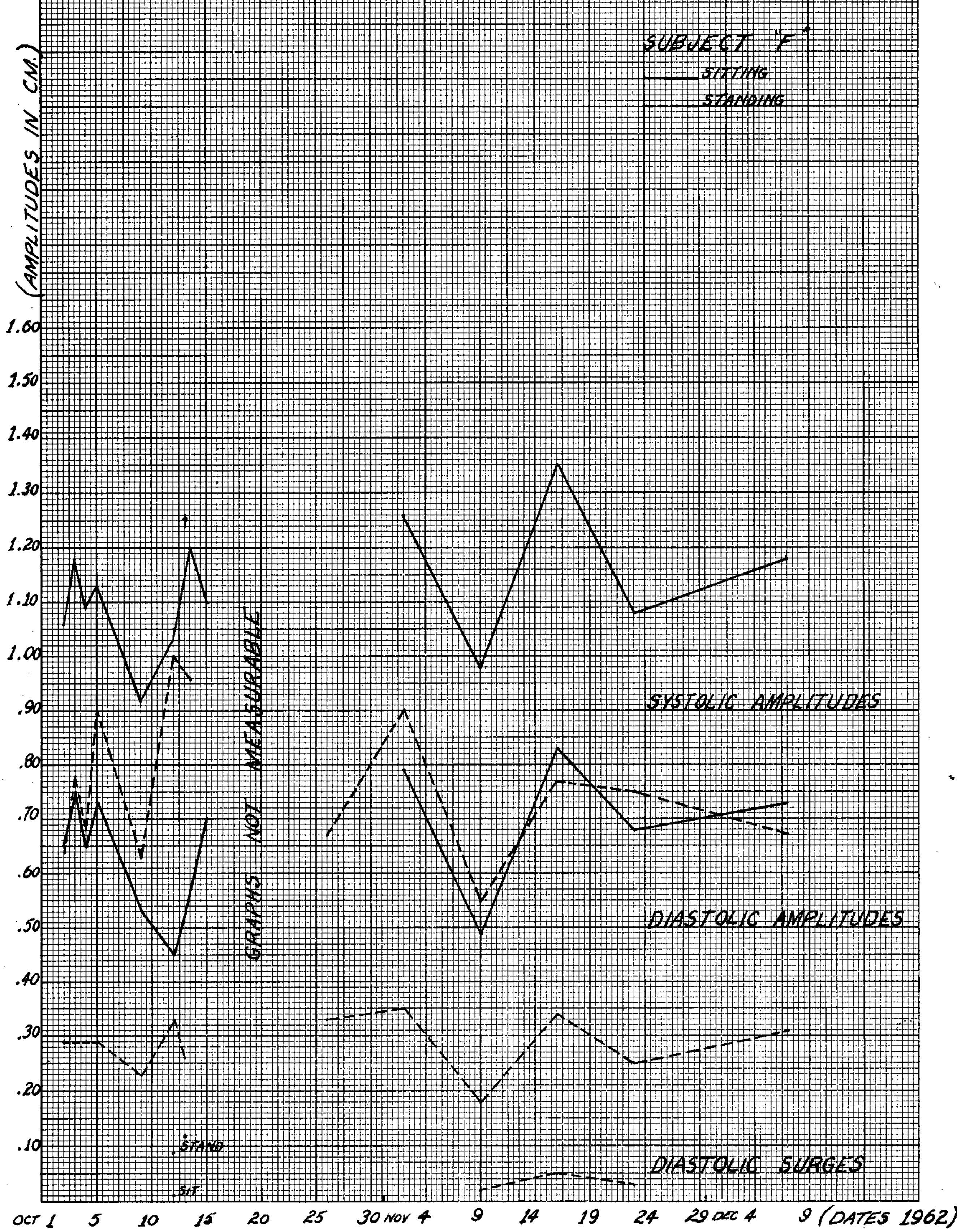
Subject "F" ran "not well" on October 6th. No aspects of the pulse wave were particularly deviant. However, the pulse wave was not typical of an athlete in condition for endurance running (see Appendix B). The systolic amplitude was slightly below that of normal young men and there was no diastolic surge apparent. This runner ran as expected on October 13th. The pulse rate was higher both on the day of the race and the day before, the amplitudes were low and the area under the curve was especially low the day before the race. A diastolic surge appeared for the first time on this week-end. It was mostly evident on the pulse waves taken standing. The rest-to-work ratio dipped somewhat twenty-four hours before the competition, but recovered by race time.

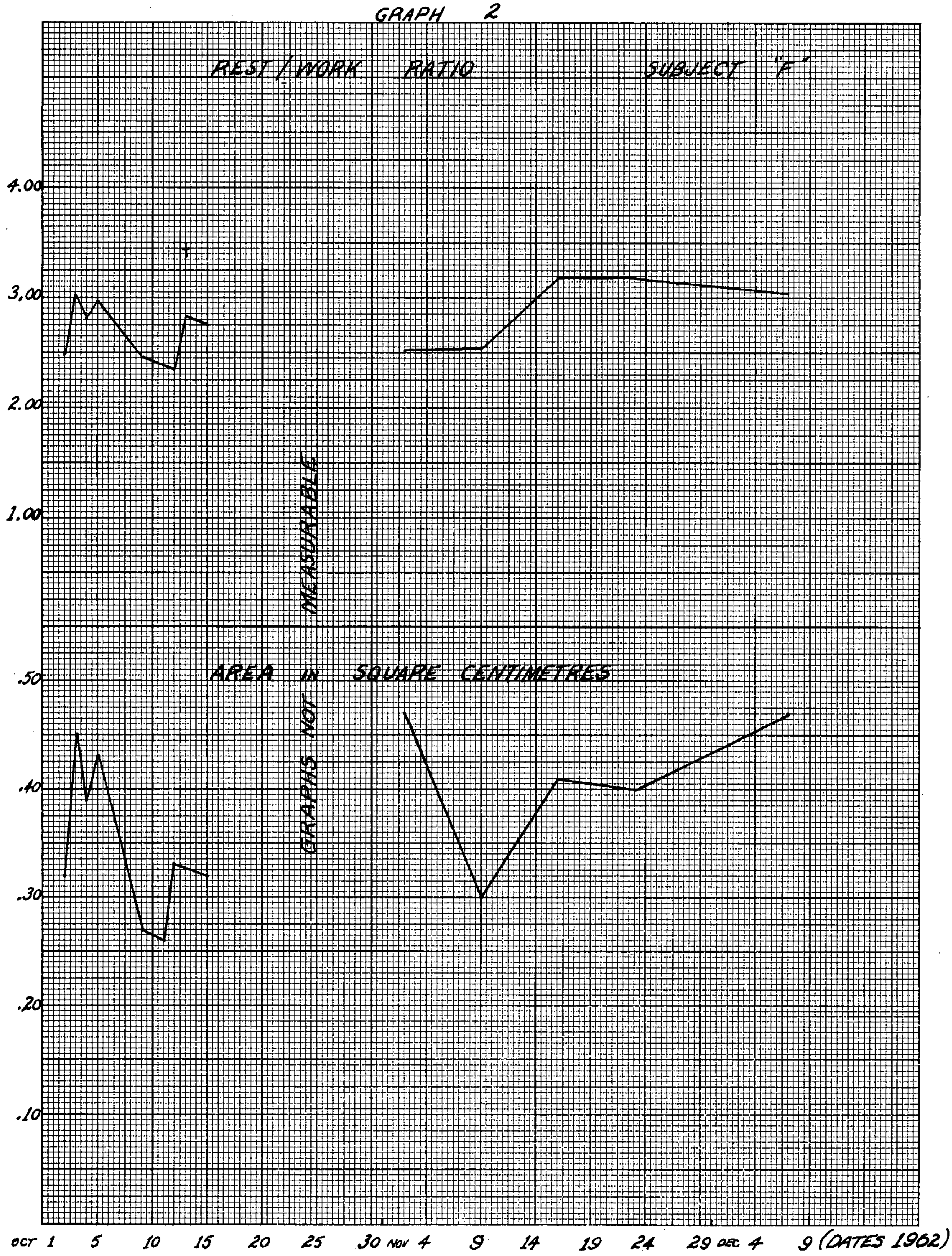
Subject "F" ran not well again on October 20th; the wave of the preceding day was so poor that it was unmeasurable. It was at the beginning of this week that the runner's training load was reduced. This decision was reached because of the better times achieved by John Devitt and Alva Colquhoun after easy workouts, as discussed in Carlile's study[20]. This change in regimen did not have an immediate effect on performance. The following week subject "F's" training load was stepped up to a higher level than before. He ran as expected on October 27th; however his sitting pulse wave was still unmeasurable. It was, however, possible to make measurements on the pulse wave taken on the subject while standing. The heartograph taken on November 2nd showed a wave of greater amplitude and area than any preceding wave. Unfortunately there was no race that week. Possibly anticipation of races depressed the waves of subject "F". This possible action on the cardiovascular system is mentioned by Cureton[21]. Cureton[22] shows that better endurance is associated with low diastolic blood pressure, low pulse rate and a small obliquity angle. Subject "F" showed the former two throughout the season. However, at no time during the season did his obliquity angle decrease appreciably. In fact, sometimes throughout the season this aspect of the wave showed increases. This unexplained inability of the heart to contract rapidly may have been a causative factor in subject "F" not performing as well in cross country running as might be expected considering his training load. On November 10th the subject ran as expected. The amplitudes and area of the wave were down markedly in size, the angle of obliquity was high and the rest-to-work ratio was low. The athlete performed adequately and it would appear, from the heartograph record, that he did so in spite of relatively poor cardiovascular condition. The pulse wave record was the best for the season in many respects on November 16th. The rest-to-work ratio read its highest value of the season. Unfortunately the coach was not present to judge the athlete's performance on the following day. This was a race in which annually the subject performed very well and he may have felt more confident than usual about the race to come. Also, because of an injury, subject "F" was able to train only on Tuesday of that week. This enforced rest may have been the principal reason for the improvement in the heartograph measures or a reduction of pre-race apprehension in association with rest may have exercised a combined effect.

There were no significant Regression Coefficients for any of the aspects of subject "F's" pulse wave measurements. This shows that no consistent changes resulted due to the training undertaken.

Although subject "F" trained fairly hard, his performance was never really good. His pulsewave at its best (see Appendix B) was not indicative of someone doing systematic and progressive endurance training.

GRAPH 1


SUBJECT "F"
SITTING
STANDING
(AMPLITUDES IN CM.)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
GRAPHS NOT MEASURABLE
SYSTOLIC AMPLITUDES
DIASTOLIC AMPLITUDES
DIASTOLIC SURGES
STAND
SIT
OCT 1 5 10 15 20 25 30 NOV 4 9 14 19 24 29 DEC 4 9 (DATES 1962)


GRAPH 2
REST / WORK RATIO
SUBJECT "F"
4.00
3.00
2.00
1.00
.50
.40
.30
.20
.10
GRAPHS NOT MEASURABLE
AREA IN SQUARE CENTIMETRES
OCT 1
5
10
15
20
25
30 NOV 4
9
14
19
24
29 DEC 4
9 (DATES 1962)

GRAPH 3

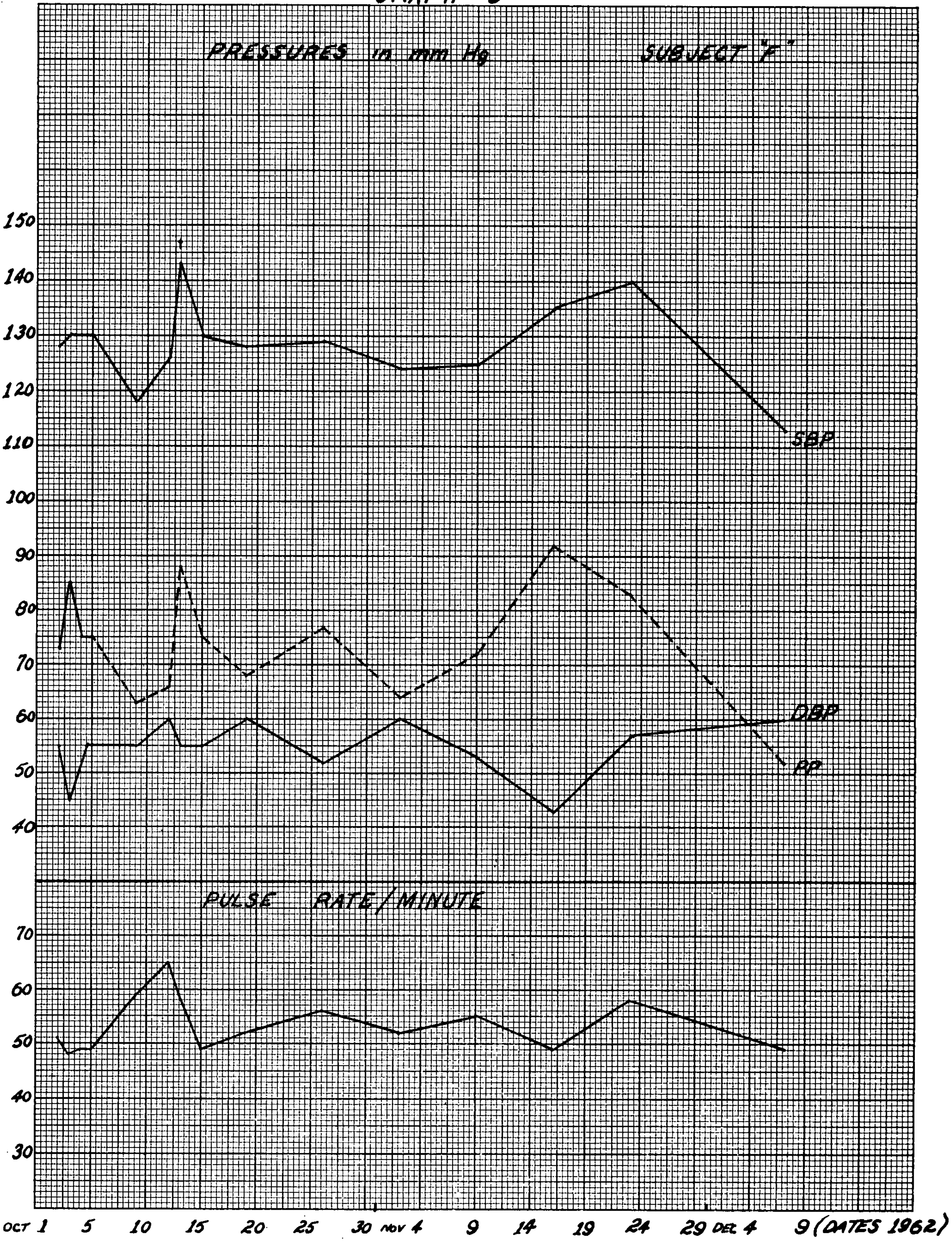

PRESSURES in mm Hg
SUBJECT "F"
150
140
130
120
110
100
90
80
70
60
50
40
SBP
DBP
PP
PULSE RATE/MINUTE
70
60
50
40
30
OCT 1 5 10 15 20 25 30 NOV 4 9 14 19 24 29 DEC 4 9 (DATES 1962)

TABLE IX

SUBJECT "F"
Raw Scores

Date	Time	Record. Press.	S.A.	D.A.	O.A.	D.N.A.	D.S.	A.U.C.	D.T./S.T.	P.R.	S.B.P.	D.B.P.	P.P.	F.R.
2/10/62	11:45	80	1.06	.65	22°	.65	0	.32	2.49	51	128	55	73	.61
	Stand	92	.64	.29	27°	.29	0							
3/10/62	11:45	80	1.18	.75	21½°	.75	0	.45	3.04	48	130	45	85	.64
	Stand	82	.78	.29	26°	.29	0							
4/10/62	11:40	80	1.09	.65	22°	.65	0	.39	2.82	49	130	55	75	.60
	Stand	82	.68	.29	24½°	.29	0							
5/10/62	11:30	80	1.13	.73	21½°	.73	0	.43	2.97	49	130	55	75	.65
	Stand	80	.90	.29	22½°	.29	0							
9/10/62	12:00	80	.92	.53	23½°	.53	0	.27	2.47	59	118	55	63	.58
	Stand	80	.63	.23	26°	.23	0							
12/10/62	11:20	80	1.03	.45	22°	.44	.01	.26	2.35	65	126	60	66	.43
	Stand	80	1.00	.33	21½°	.24	.09							
13/10/62	10:30	80	1.20	.53	21°	.53	0	.33	2.84	59	143	55	88	.44
	Stand	78	.96	.26	22½°	.14	.12							
15/10/62	11:55	87	1.10	.70	23°	.70	0	.32	2.75	49	130	55	75	.64
		Waves very irregular ∴ no standing wave taken												
19/10/62	11:35	No regular waves ∴ none measured								52	128	60	68	
26/10/62	15:10	No good sitting waves								56	129	52	77	
	Stand	85	.67	.33	26½°	.33	0							
2/11/62	12:00	82	1.26	.79	23½°	.79	0	.47	2.51	52	124	60	64	.62
	Stand	85	.90	.35	25°	.35	0							
9/11/62	12:50	80	.98	.49	24°	.49	0	.30	2.54	55	125	53	72	.50
	Stand	80	.55	.18	27°	.16	.02							
16/11/62	12:10	80	1.35	.83	22°	.83	0	.41	3.20	49	135	43	92	.61
	Stand	78	.77	.34	25°	.29	.05							
23/11/62	12:10	72	1.08	.68	23°	.68	0	.40	3.19	58	140	57	83	.63
	Stand	80	.75	.25	24½°	.22	.03							
7/12/62	12:10	75	1.18	.73	22°	.73	0	.47	3.04	49	112	60	52	.62
	Stand	77	.67	.31	25°	.31	0							

TABLE X

SUBJECT "F"
Statistical Data

	S.A.	D.A.	O.A.	D.N.A.	D.S.	A.U.C.	D.T./S.T.	P.R.	S.B.P.	D.B.P.	P.P.	F.R.
Coefficient of Correlation	.309	.272	.318	.273	-.154	.381	.425	-.036	-.178	.117	-.185	.103
Regression Coefficient	.158	.146	.130	.148	-.001	.127	.555	-.008	-.065	.027	-.093	.035
Standard Errors of Estimate	.146	.156	.117	.157	.003	.093	.356	.073	.109	.069	.148	.102
F. Ratios	1.167	.885	1.230	.887	.269	1.875	2.428	.014	.359	.154	.393	.119

$F = 4.84$
$\alpha = .05$

General Discussion

The pulse wave measurements of the subjects in this study varied somewhat from week to week. Rest-to-work ratio and diastolic surge seemed to be the most important and consistent variables in reflecting the effects of the endurance training that was done. The main purpose in analyzing the data by case study method was to see, if possible, how the individual adapted to his training load. This was an attempt to determine how practical the heartometer is as an adjunct to usual methods of assessing an athlete's training (i.e. time trials, performance and subjectively described feelings of the athlete).

Increases in diastolic surge as an indication of improving condition has been discussed by Carlile[23,24], Cureton[25,26,27,28] and Michael and Gallon[29]. Diastolic surges of any consequence appeared in only three of the five subjects studied. This would seem unusual as Carlile[30] observed diastolic surge development in fifteen of sixteen male swimmers tested in hard training. Subject "J" showed signs of a diastolic surge only on two occasions; these were very small. A slight diastolic surge was developed by subject "C" but this disappeared before testing had concluded. This subject performed well without developing a surge and ran his poorest race after recording his largest surge of the season. However, this surge possibly developed at the expense of a slower closing of the semi-lunar valves as the fatigue ratio was at its low point on this day also. Subject "E", who had not been training over the summer and had a cold for four days before the first graph, developed a good diastolic surge through the training season. He consistently performed well. His diastolic surge decreased rapidly after the training was reduced on November 10th. This runner had a thirteen year background of endurance training. In some of these years the training was very hard which may partially explain the rapid development of a diastolic surge during this study. A diastolic surge was present in the record of subject "M" at the beginning of testing. This runner had been training all year. As in the case of subject "C", subject "M's" largest surges seemed to develop at the expense of a lowered dicrotic notch amplitude and hence an unfavourable fatigue ratio. Dicrotic notch lowering can be caused when an athlete suffers apprehension before a race[31]. This runner did not run well on November 27th after recording a large diastolic surge of this type on the preceding day. Subject "F" developed a diastolic surge in the standing waves only, and these were not regular or well developed. This subject had not been training regularly up to the beginning of the cross country season due to the plantar warts discussed earlier.

Rest-to-work ratio is another aspect of the pulse wave that showed changes which paralleled the individuals' ability to perform. Carlile[32] observed outstanding changes in the heart's rest-to-work ratio; 27 of 28 swimmers showed an average increase of 69% at the end of eight weeks hard training. As discussed in Chapter III, page 13, a strong efficient cardiovascular system has a rest-to-work ratio of four to one. Subject "J's" ratio reached four by November 16th and stayed above this figure until the end of the testing. When subject "C" ran his poorest race on November 10th, his rest-to-work ratio was 2.30 the day before. This was his lowest of the season. Two weeks earlier, when he ran better than expected, his ratio was 4.06. It would appear that sudden decreases in the size of this ratio after it has reached a high level indicates failure to adapt to the stress load. The experience of subject "E" showed a direct relationship between the rest-to-work ratio and performance. He had no poor races and his condition generally improved throughout the season; the rest-to-work ratio showed a steady trend upwards (significant at .05 level) with no sharp reductions and a sharp rise when training was reduced. This trend to increase was apparent in all five cases, although not always statistically significant. Large gains were indicated by all subjects after reductions in their training loads during or after the season. This measurement appears to increase in size when the body is given time to adapt to training. Too long a rest or reduction in training causes the ratio to drop. This was apparent in the case of subject "M" who, because of his nervous condition, was on a prolonged reduction in training. Through further study it may be possible to see if these indications bear out the observations of the writer who believes that fluctuations in the rest-to-work ratio may be measured to aid in scientific design of an athlete's training. That is, when sudden decreases in the rest-to-work ratio appear a change in training load may be in order. For some athletes this may be a reduction in the total amount of work done; for others it may indicate a change in type of training needed; for others some outside stress (e.g. incipient infection or emotional problem) may be effecting the adaptation to the training load. If the coach has some objective measure to indicate that the athlete is failing to adapt to the stresses encountered, he is in a position to look for the problem with conviction that one exists.

Four of the five runners showed a significant increase in systolic blood pressures and pulse pressures as a result of the season's training. Subject "F" was the exception. Although high blood pressure is often thought of as a pathological condition, it would appear that for an athlete undertaking endurance training this could indicate a physiological improvement. Two of the runners who showed this increase performed very well. With the small decreases in diastolic blood pressure that occurred in these four cases, a definite trend toward pulse pressure increase accrued, significant at the .05 level.

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(4) Cureton, Physical Fitness of Champion Athletes, op. cit., 236.

(5) Carlile, op. cit., 21.

(6) R.F. Rushmer, Cardiovascular Dynamics, Philadelphia, Saunders, 1961, 89-90.

(7) Ibid., 27.

(8) Ibid., 29.

(9) Ibid., 11.

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(19) Carlile, Loc. cit.

(20) Ibid., 27.

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(22) Cureton, Physical Fitness of Champion Athletes, op. cit., 251.

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(24) Ibid., 12.

(25) Cureton, op. cit., 238.

(26) Ibid., 251.

(27) Ibid., 253.

(28) Cureton, Physical Fitness Appraisal and Guidance, op. cit., 247.

(29) E.D. Michael and A.J. Gallon, "Pulse Wave and Blood Pressure Changes Occurring During a Physical Training Program", Research Quarterly, 31 (March, 1960), 51-52.

(30) Carlile, op. cit., 11.

(31) Cureton, op. cit., 240.

(32) Carlile, op. cit., 12.

(33) R.F. Rushmer, Cardiovascular Dynamics, Philadelphia and London, Saunders, 1961, 137.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Five members of the University of B.C. cross country team were observed throughout their 1962 cross country season. Records were kept of their weekly cardiovascular condition as measured by the Cameron Heartometer, training regimen, and the coach's subjective appraisal of their competitive performances.

Using case study methods, each individual was observed to see if he was adapting to his training load. Fluctuations in performance were compared with heartometer measures to see if these measures which reflect changes in autonomic tone would also reflect improvement or lack of improvement in running performance.

Each of the athletes had a different experience from his fellows during the course of the study. One athlete, with a long history of endurance training, improved his condition markedly in the short nine week season. Another athlete, who has had severe attacks of asthma, performed well until attempting a particularly heavy amount of work. After this work he ran a very poor race. A third subject failed to adapt to the stresses of his overall programme and suffered a slight nervous breakdown during the season. Another athlete did not run as well as might be expected considering the amount of training done. The fifth improved slowly but steadily under a moderate conditioning programme.

Four measures of the pulse wave showed parallel development with improving cardiovascular condition; these were diastolic surge, rest-to-work ratio, systolic blood pressure and pulse pressure. Diastolic surges developed in only three of the five subjects. Systolic blood pressure and pulse pressure increased significantly in four of the five runners tested. These four included the subject who experienced the nervous breakdown. The one runner whose systolic blood pressure and pulse pressure did not improve significantly did not show any improvements in condition or performance that might be expected from an athlete undertaking a programme as hard as his. The rest-to-work ratio seemed to show best how well the individual was adapting to his training. Fluctuations in this measure paralleled good and bad performances; these were apparent on examination of the graphs. The other aspects of the pulse wave showed no consistent trends.

Conclusions

1. Diastolic surge is an indication of improving cardiovascular condition if it is not developed at the expense of a large decrease in dicrotic notch amplitude. It takes a longer period than eight or nine weeks of moderate training to develop a diastolic surge unless the athlete has a long history of endurance training.

2. Rest-to-work ratio, at rest, gives a good indication of the athlete's ability to adapt to a given training load. A sharp drop in rest-to-work ratio at any stage of the training period is a sign that a reduction in stresses should be sought. Since time of diastole bears a relationship to pulse rate it is important to insure that all heartographs are obtained under standardized resting conditions.

3. Systolic blood pressure and pulse pressure increase when an athlete undertakes a running programme designed to improve endurance performance, if he is adapting to the training load.

Recommendations

1. It is suggested that studies be undertaken following athletes for a much longer training period so that more definite trends can be established.

2. With the use of heartometer measures a study could be undertaken to show the types and amounts of training that would result in the greatest improvements in cardiovascular condition.

3. The regimen of an athlete in hard training may be modified with reference to the improvement or lack of improvement in the rest-to-work ratio. Such a programme may achieve optimum condition for the athlete considering the training period available.

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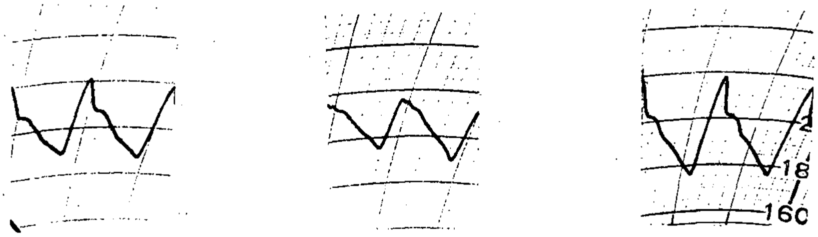
APPENDIX A

SUMMARY OF PERFORMANCE

	Oct. 6, 1962	Oct. 13, 1962	Oct. 20, 1962	Oct. 27, 1962	Nov. 10, 1962
Subject "J"	AE	AE	AE	DNR	AE
Subject "C"	AE	AE	BTE	BTE	NW
Subject "E"	AE	BTE	AE	BTE	AE
Subject "M"	AE	AE	NW	NW	AE
Subject "F"	NW	AE	NW	AE	AE

Abbreviations

BTE - Better than expected
AE - As expected
NW - Not well
DNR - Did not run



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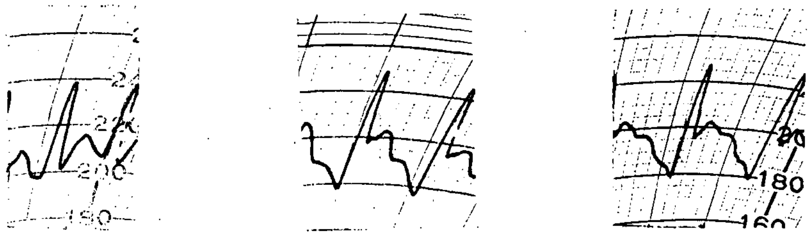

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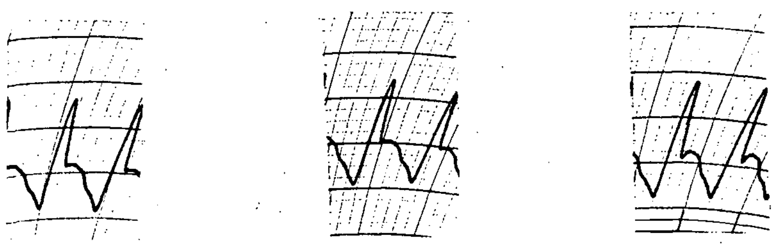

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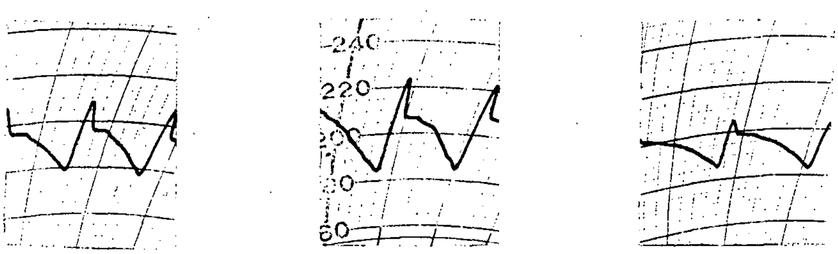

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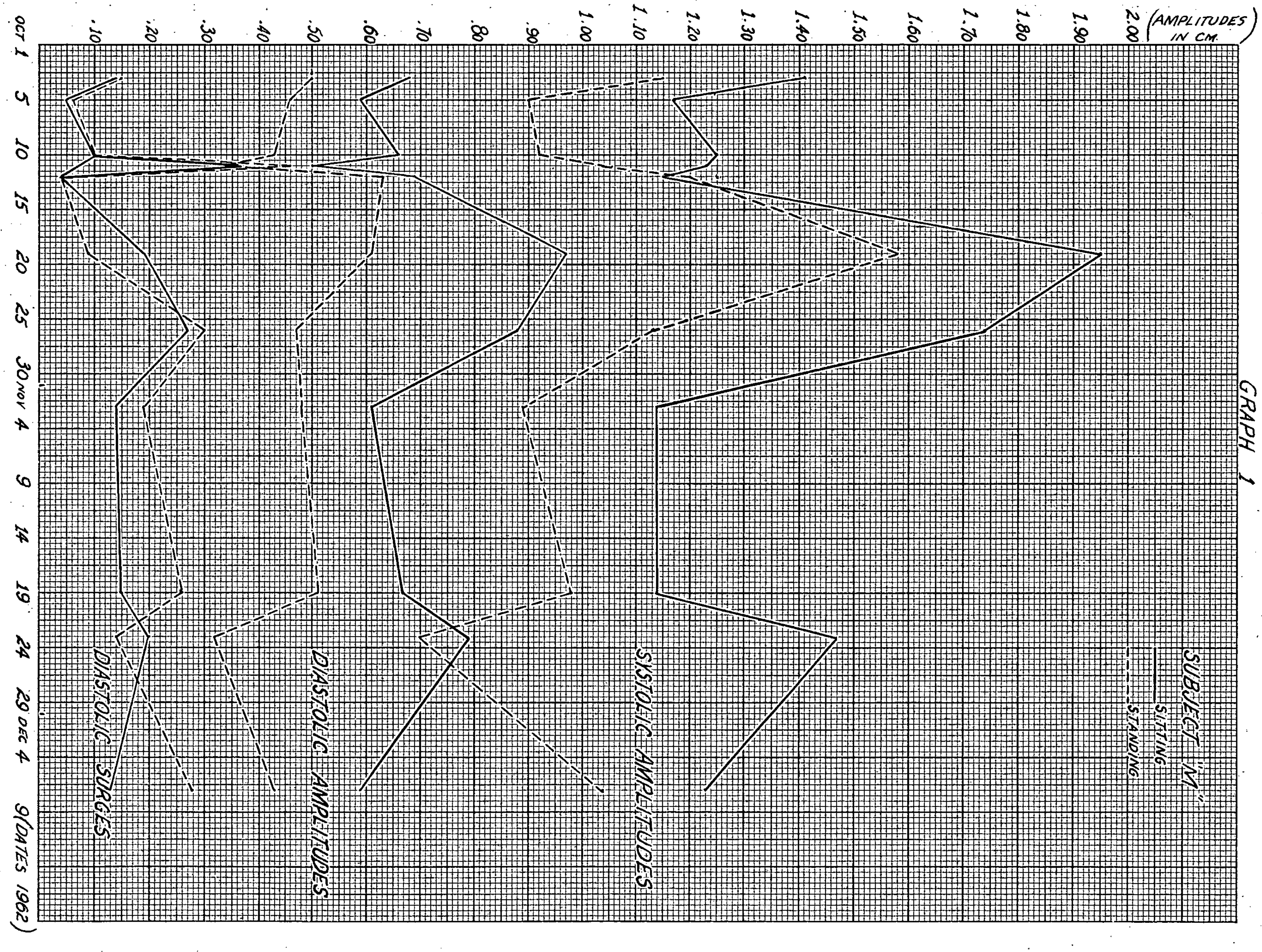
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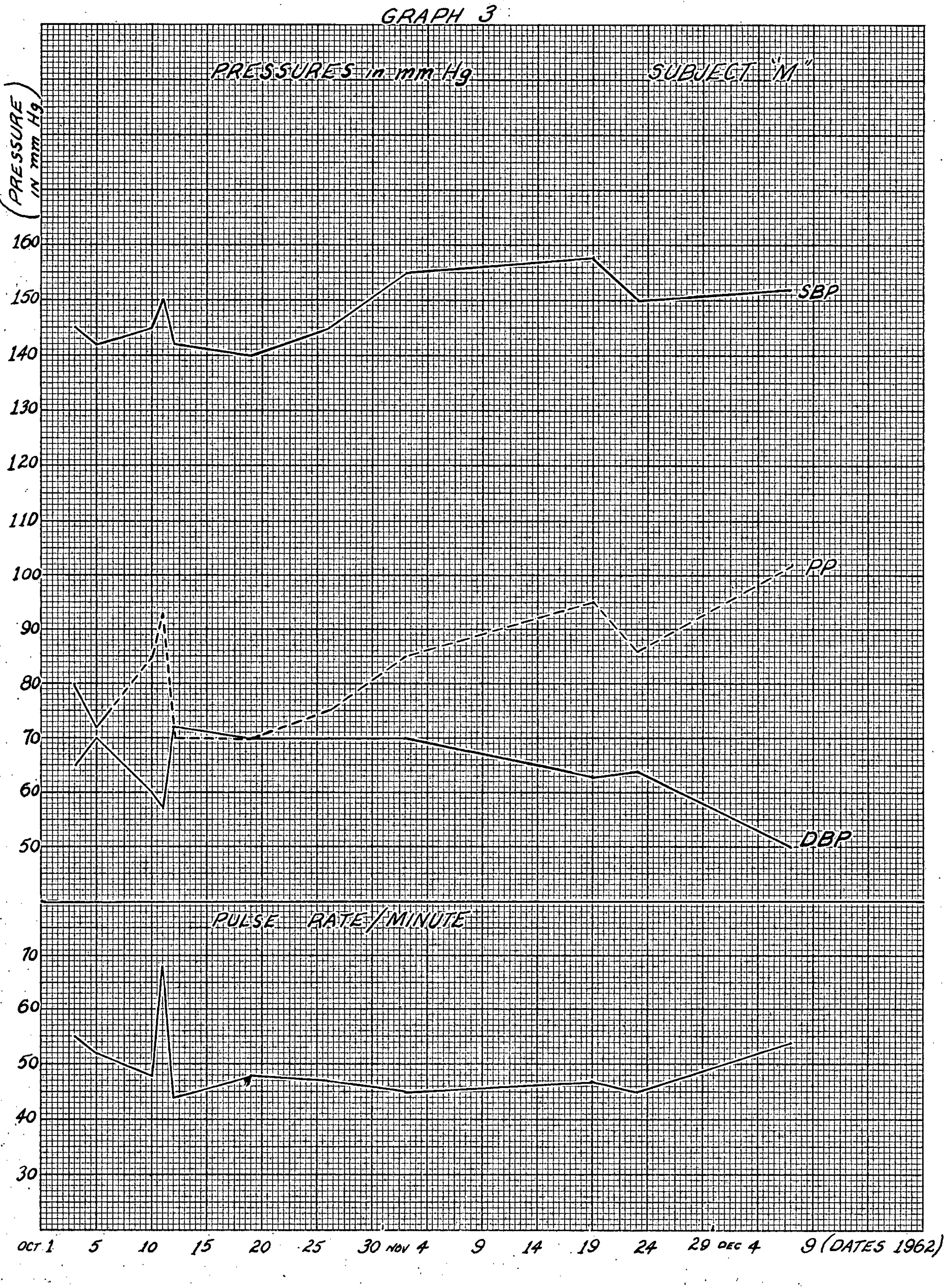
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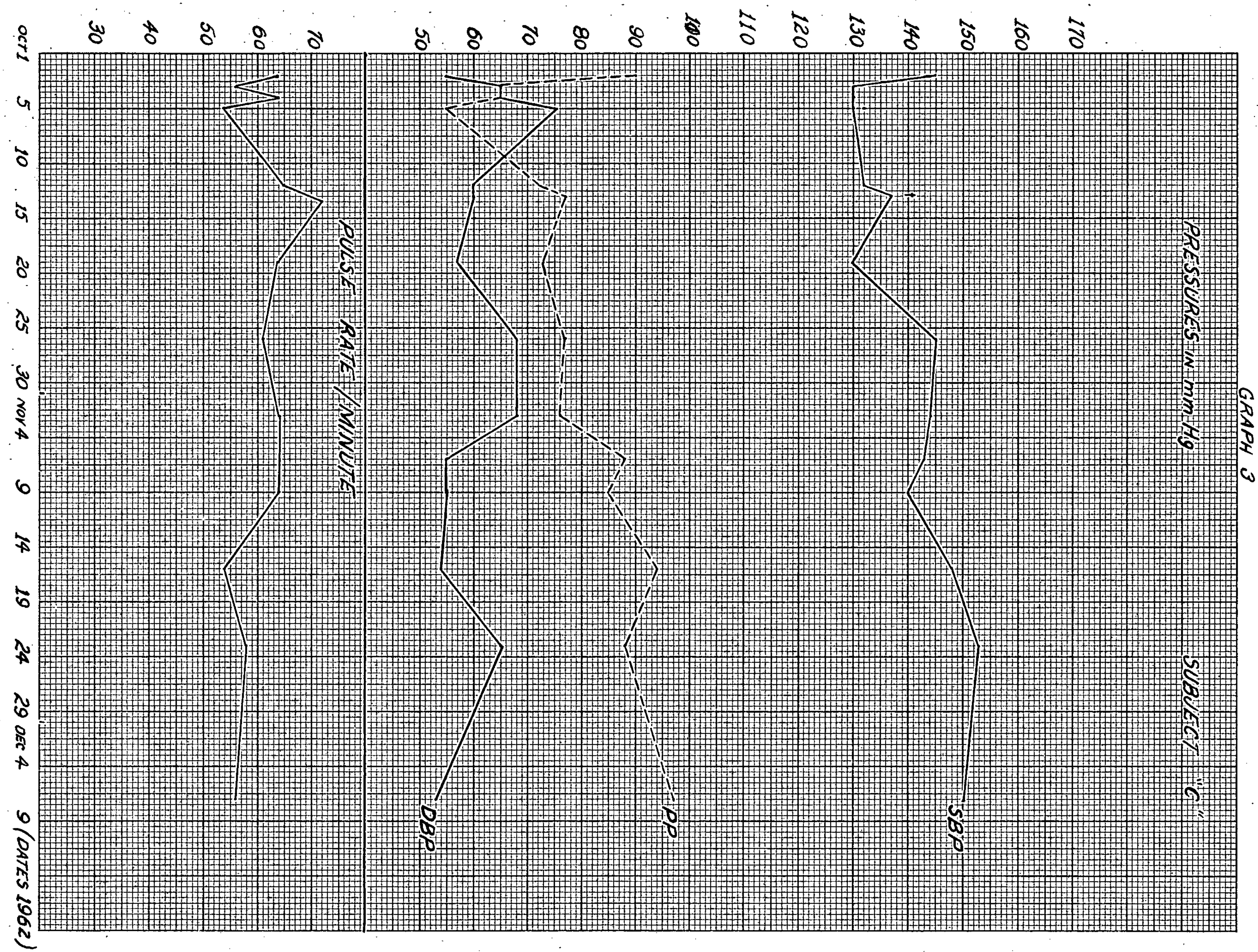
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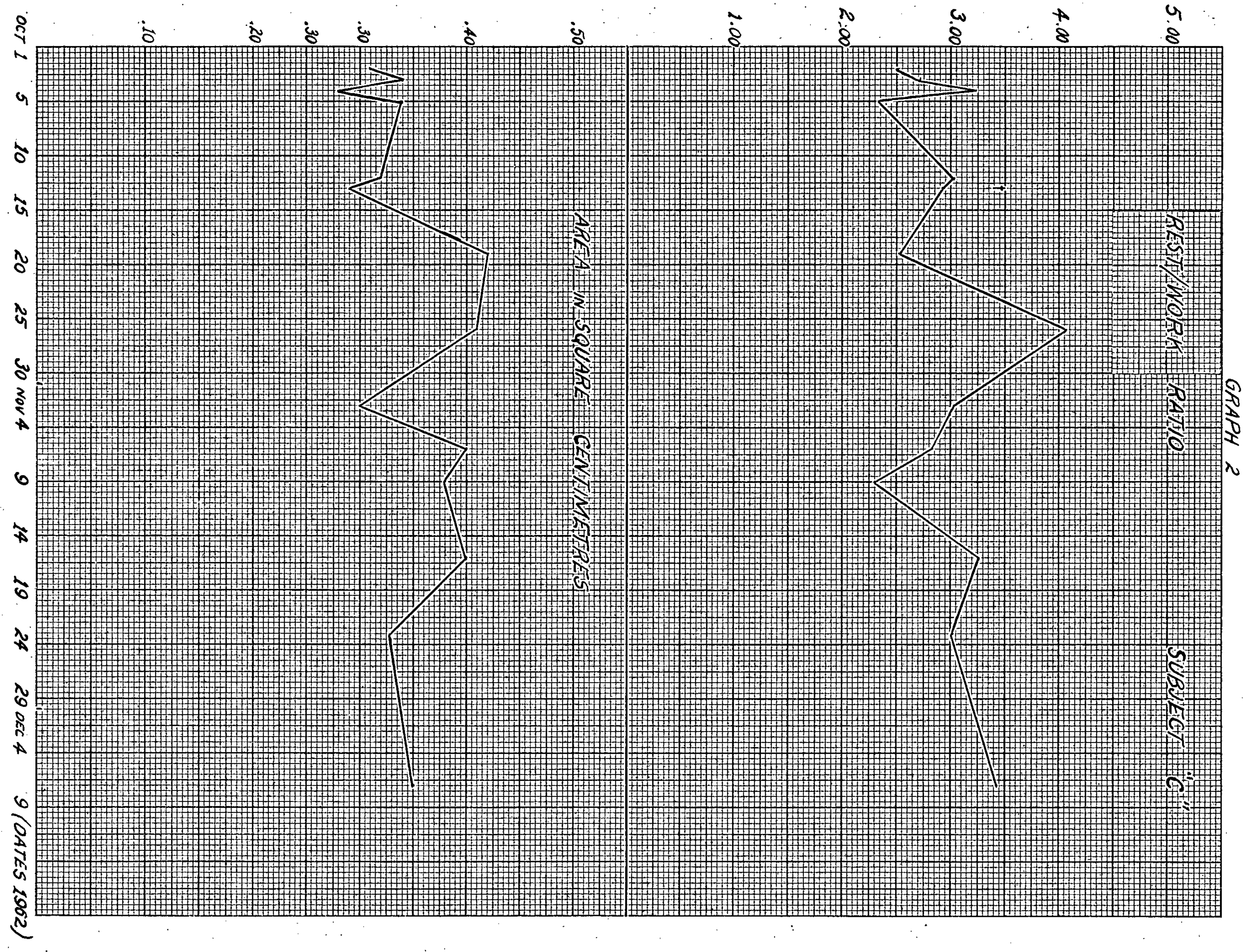
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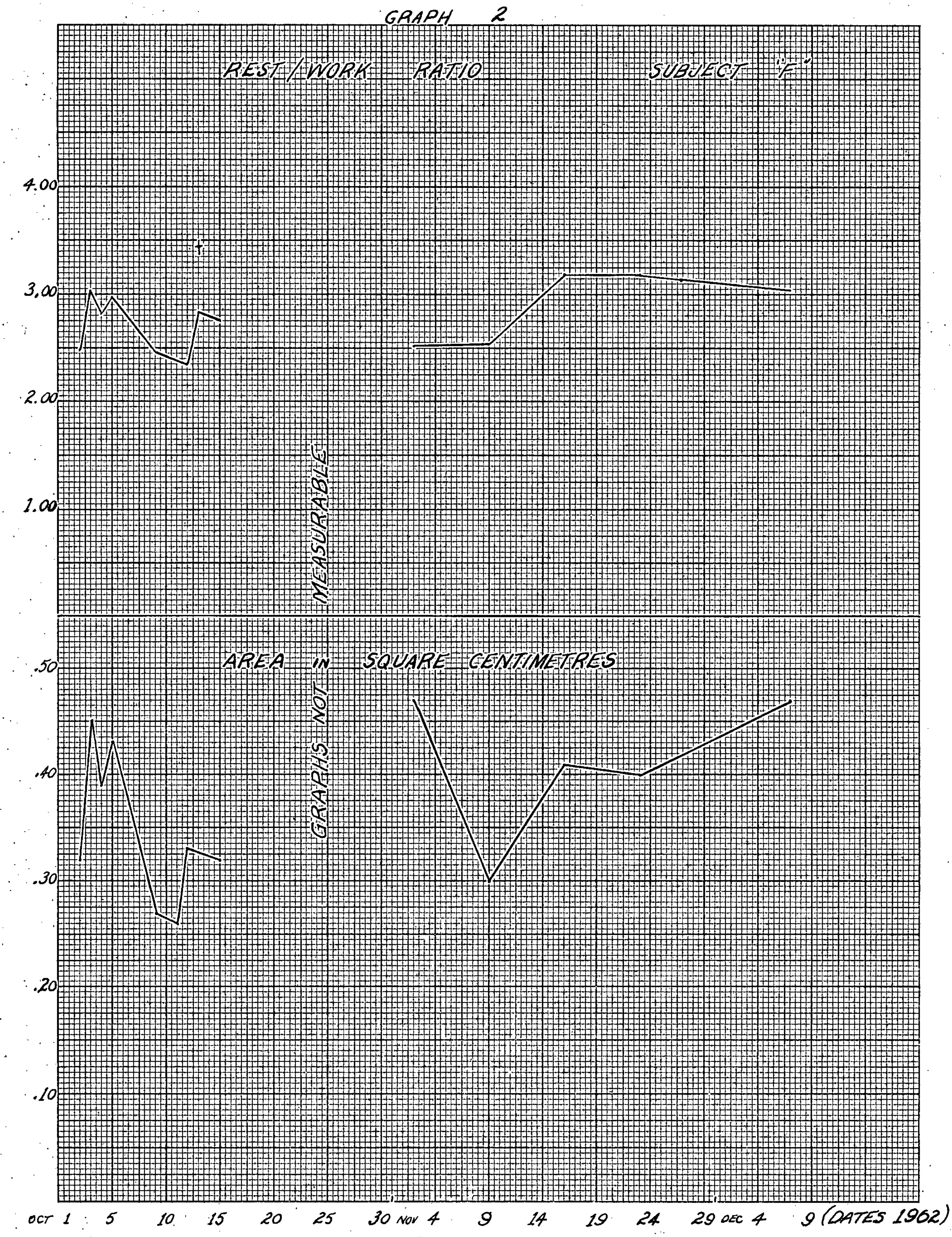
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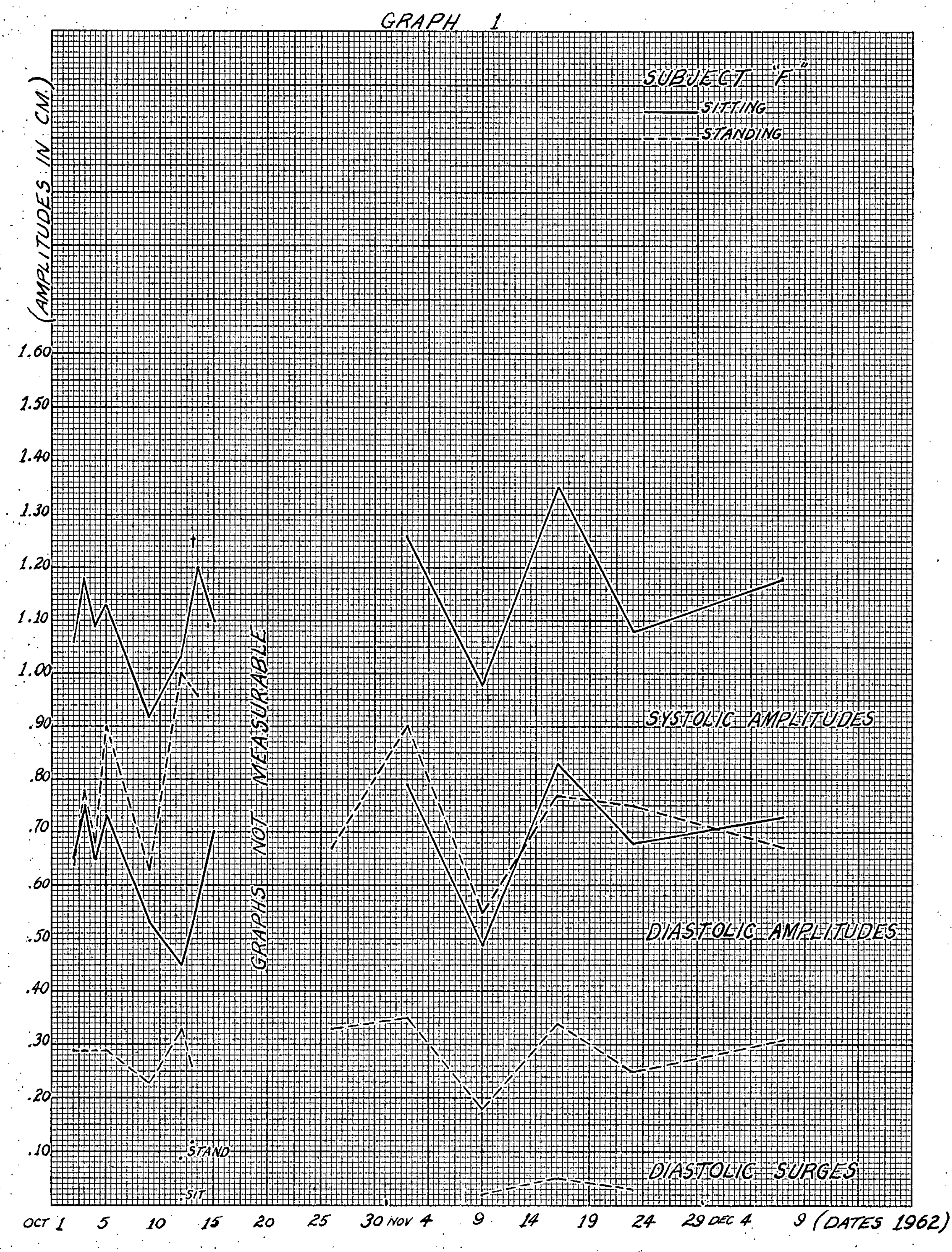
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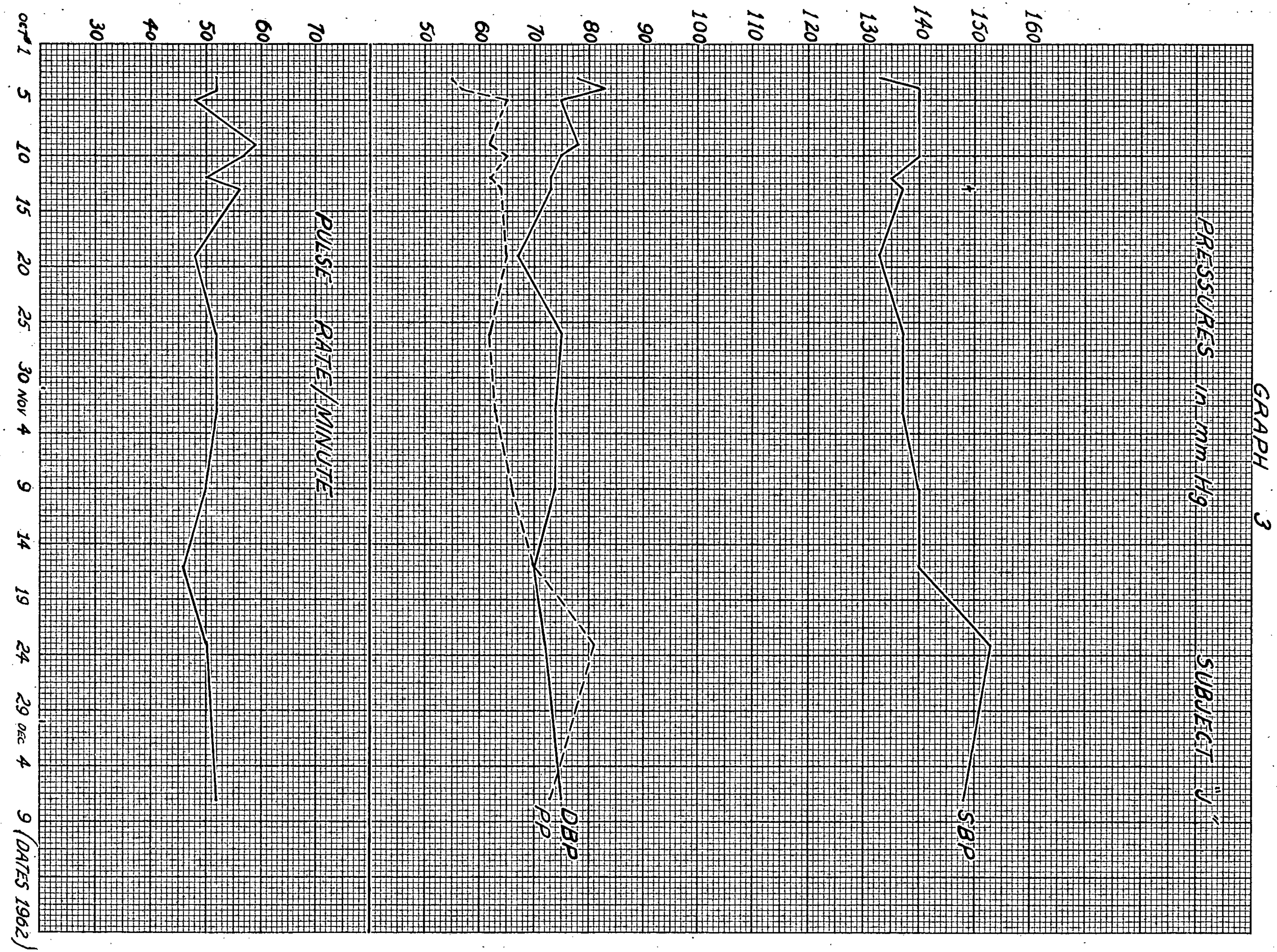
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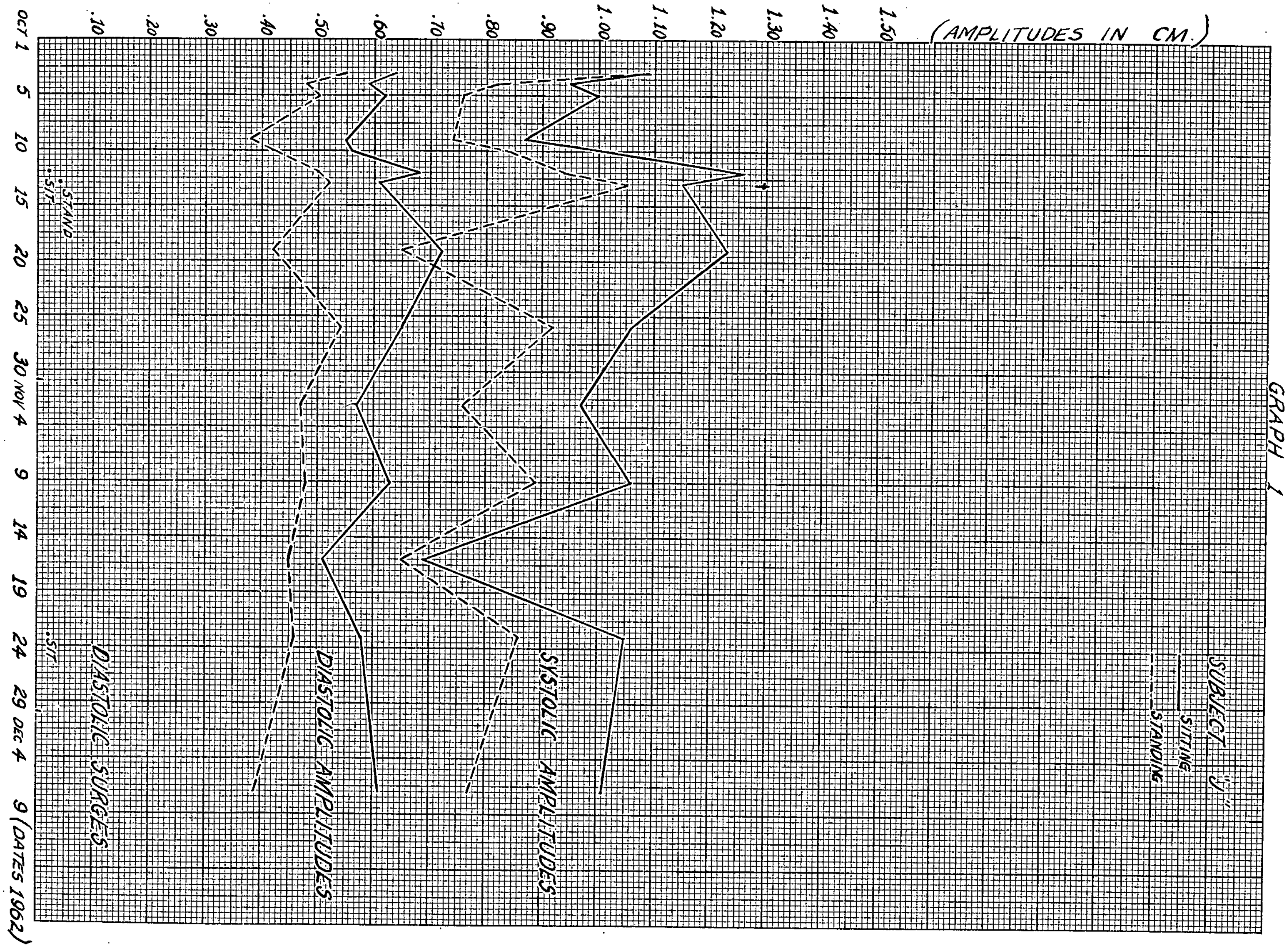
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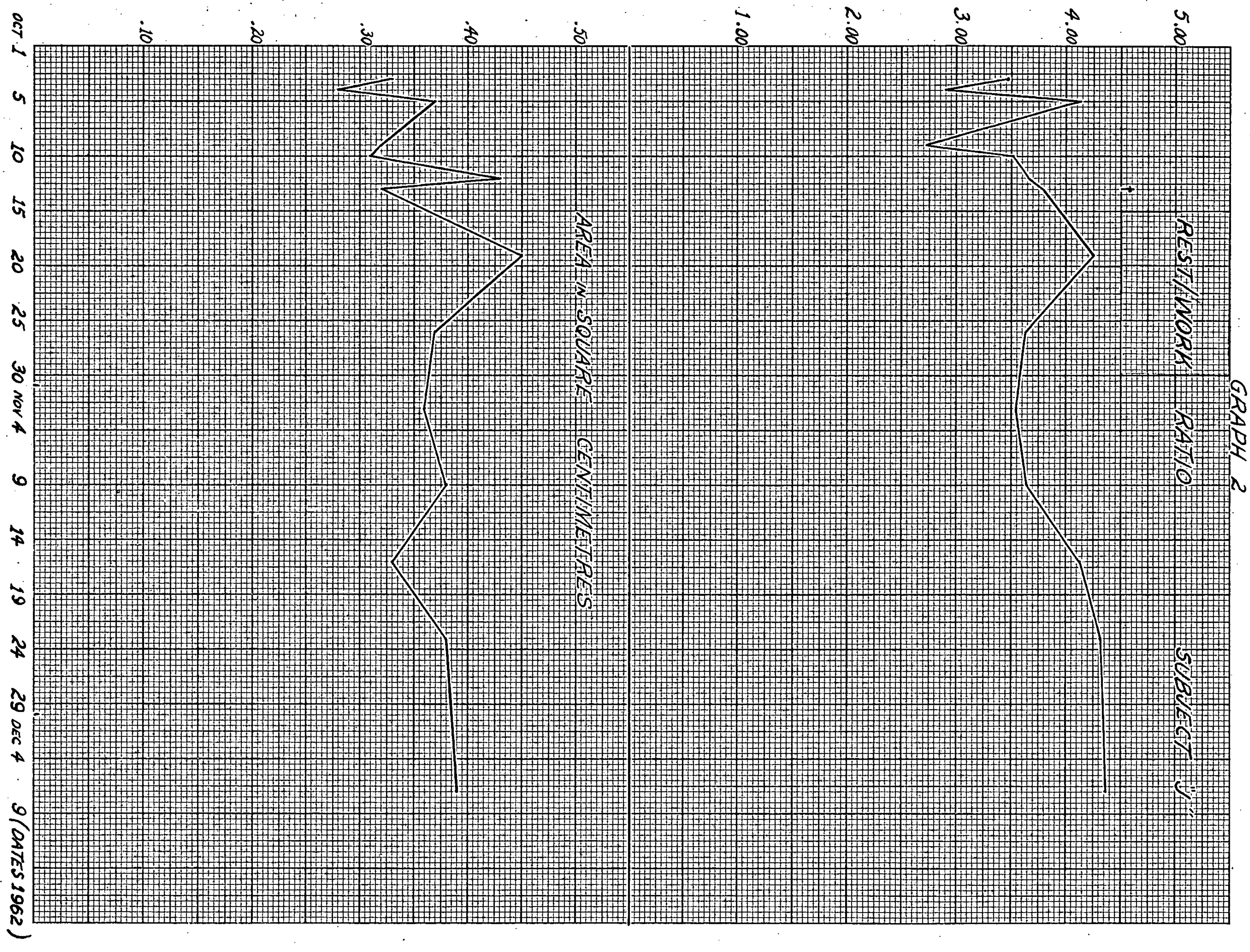
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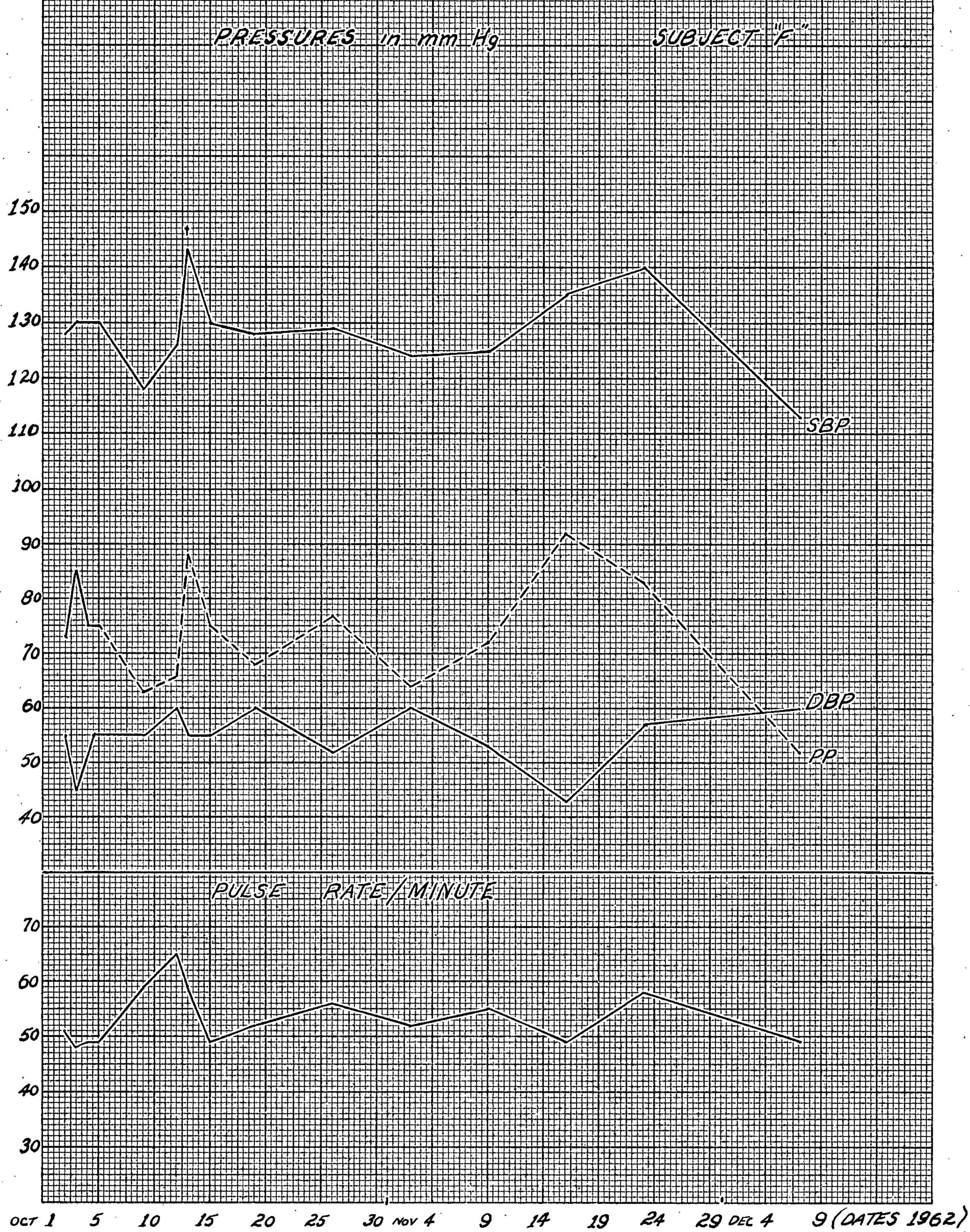
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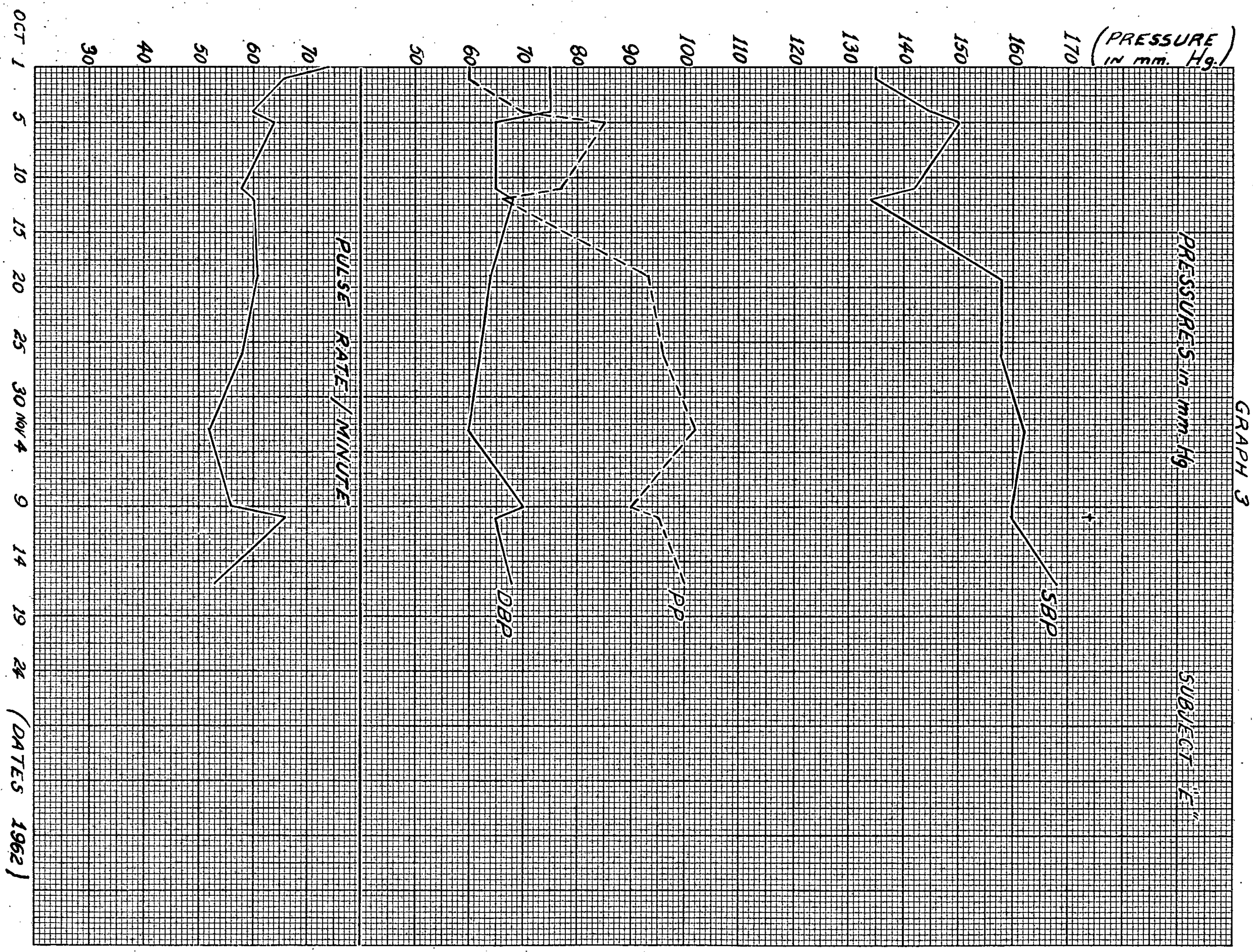
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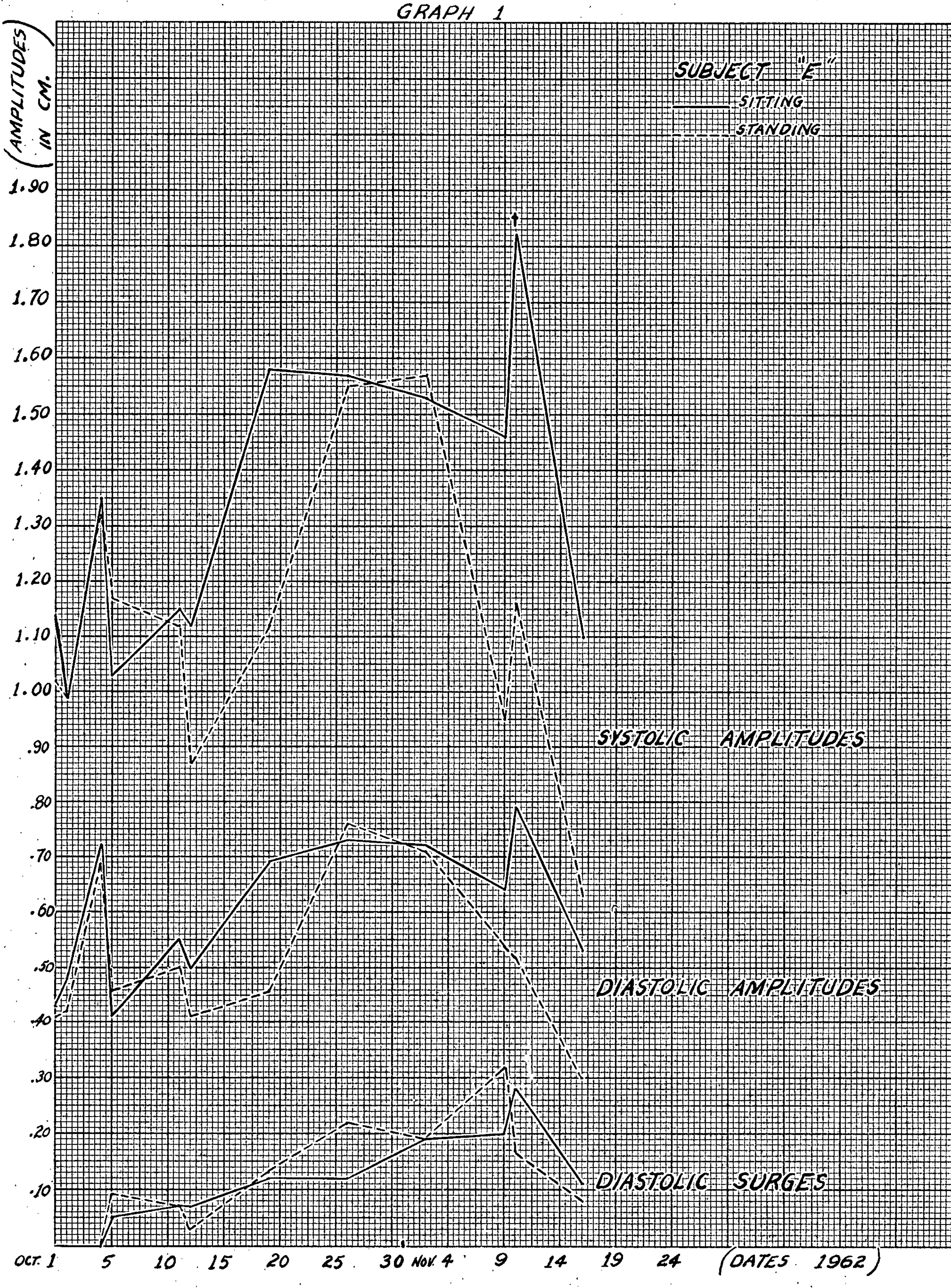
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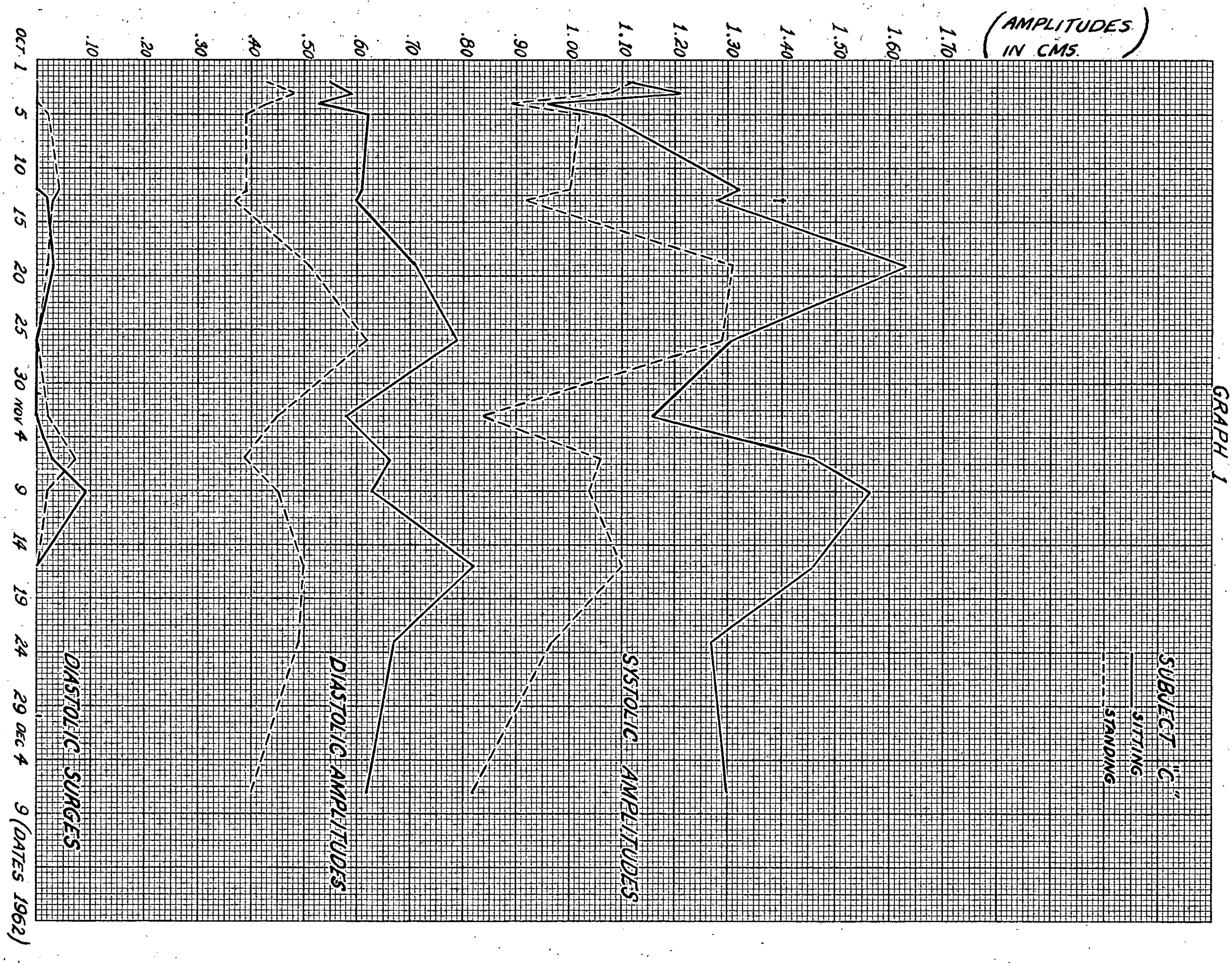
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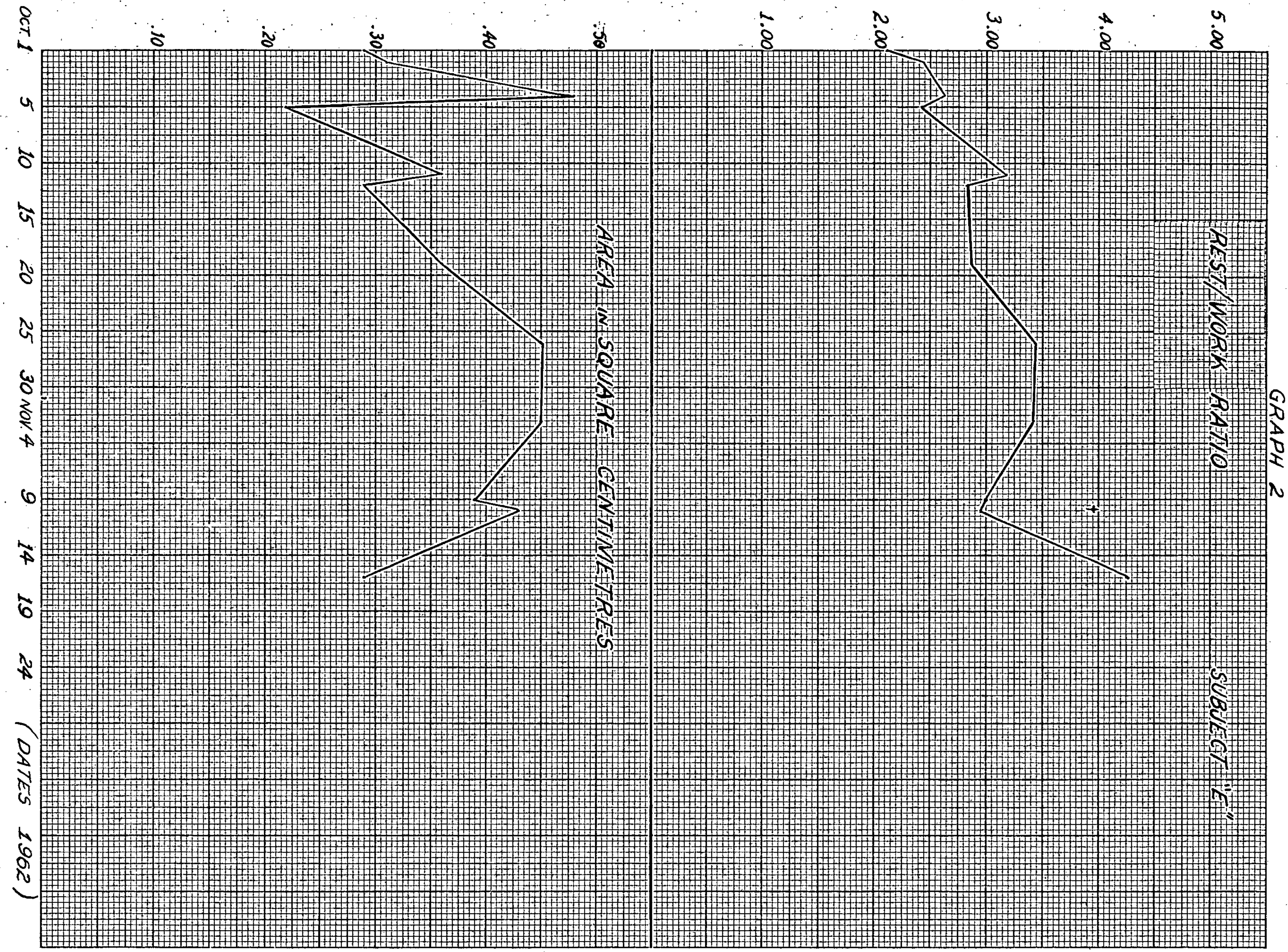
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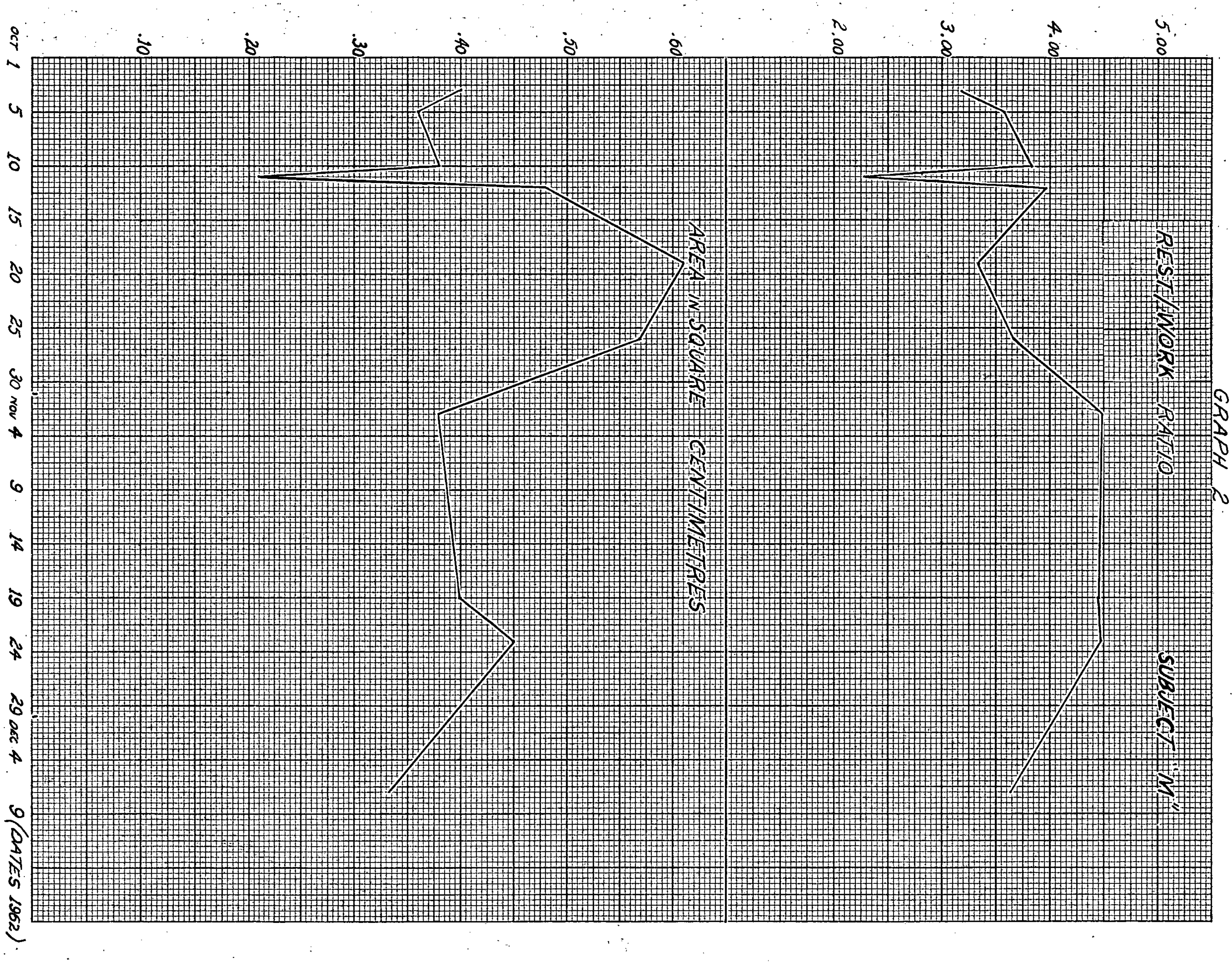
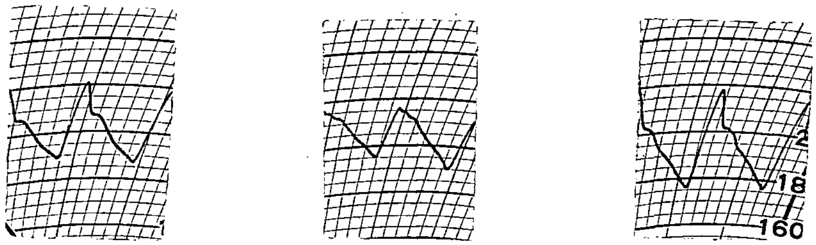


APPENDIX B



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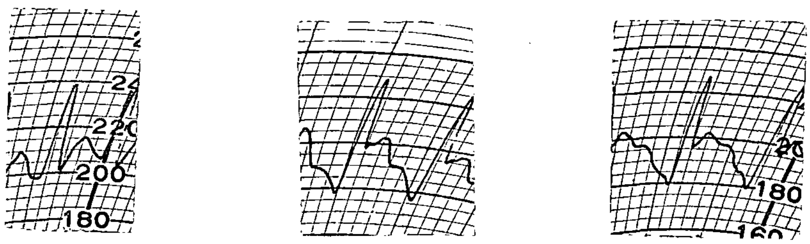
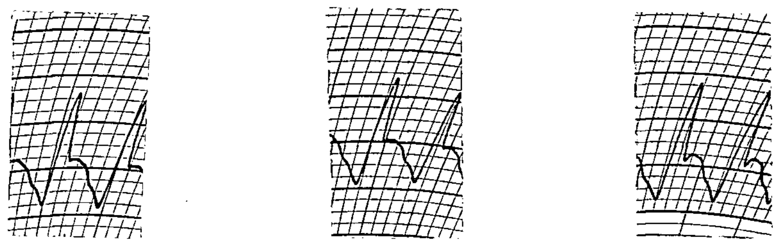
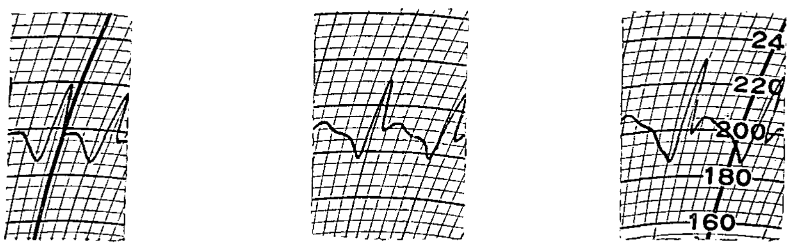


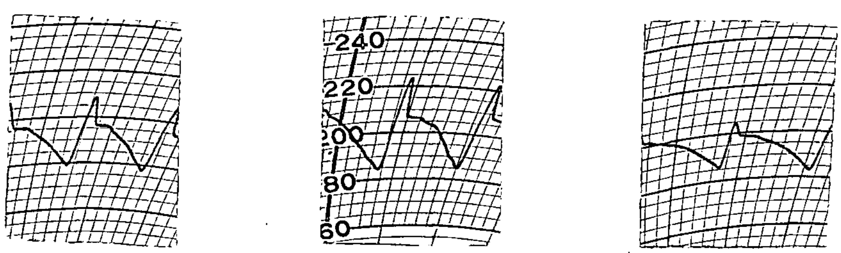
SUBJECT "M" OCT. 11 OCT. 19 OCT. 26



SUBJECT "C" OCT. 19 NOV. 6 NOV. 9



SUBJECT "E" OCT. 1 OCT. 11 NOV. 2 (STAND)



SUBJECT "J" OCT. 3 OCT. 19 NOV. 16