EVALUATION OF BONE
BY NON-INVASIVE MEASUREMENT OF THE
VELOCITY OF ULTRASOUND

by

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Submitted to the Department of Electrical Engineering and Computer Science on September 8, 1983 in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

An investigation was carried out on the viability of evaluating human bone _in vivo_ by measuring the velocity of ultrasound transmitted through the bone. Non-invasive transmission velocity measurements were taken regularly over a period of several months from a group of athletes in training. Information on injury and training regimen was also collected.

Knee injuries and tibial "shin splints" were detectable by this method, although stress fractures were not. Low velocities within a population distribution correlated with injuries. Changes in an individual's velocities over time corresponded with fitness and activity; in some cases, a decrease in velocity preceded an injury. Injury was also indicated by erratic changes in velocities.

The transmission method of measuring the velocity of ultrasound is a practical technique which provides useful information on fitness affected by bone strength.

Thesis Supervisor: Prof. George W. Pratt, Jr.

Title: Professor of Electrical Engineering

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CHAPTER 1

INTRODUCTION

1.1. Background

Evaluation of the quality of bone is essential for the diagnosis and monitoring of skeletal injury. An accurate determination of bone health could be used to follow the progression of bone diseases, such as osteoporosis (1), or to detect a weakness which may lead to injury, as in the development of stress fractures (2).

Bone is a structural element; evaluation methods for bone are often based on techniques which were developed to determine the mechanical characteristics of materials (3-5). These techniques usually destroy or permanently alter the material tested, and, therefore, are unsuitable for clinical applications. An exception is a method, used for the evaluation of concrete, to determine structural integrity by measuring the propagation velocity of ultrasound through a material (6).

Ultrasonic evaluation of materials is based on the theory that the velocity of ultrasound is dependent on the elastic properties and density of the transmission medium (7). Abendschein and Hyatt (5) have shown that the velocity of ultrasound in bone bears a direct linear relationship to the elastic modulus, as determined by mechanical tests. The modulus of elasticity is a measure of a material's resistance to structural deformation. Since the elastic modulus of bone is related to its breaking strength (8), the velocity of ultrasound is a measure of the strength of bone: comparison of similar bones reveals higher ultrasonic velocities in stronger bones (5).

Non-invasive measurement of the velocity of ultrasound can be a valuable clinical tool for evaluating bone. Velocity is determined by dividing the distance over which an ultrasonic signal travels by the transit time of the signal. A reflection technique has been used to take *in vivo* velocity measurements on humans (4,9). In this method, the pathlength of ultrasound in the bone is measured from a radiograph, and the transit time is determined from echoes off the inner and outer surfaces of the bone cortex. The studies show ultrasonic velocities in diseased bone are lower than velocities in healthy bone (4).

An alternate procedure for measuring velocity *in vivo* is a transmission technique (6,10). In this method, an ultrasonic pulse propagates through the bone, between transducers placed on diametrically opposite skin surfaces: pathlength is taken to be the distance between the transducers, and the transit time is the interval between the ultrasonic signal's transmission from one transducer and its reception at the other. This technique has been used successfully on horses; a lower velocity is measured at a fracture site than is measured in normal bone (11).

1.2. Scope of Thesis

This thesis investigates the viability of evaluating human bone <u>in vivo</u> by using an ultrasonic transmission technique. This method is more practical for routine clinical use than is the pulse-echo method (4,9) because X-rays are not used to take the velocity measurement; hence, patients are not exposed to radiation, the expense and delay of obtaining an X-ray are avoided, and the measurement equipment is more portable.

A study is described in which transmission velocity measurements were taken regularly over a period of several months from a group of athletes in training. Information on injury and training regimen was also collected. The results are analyzed to determine if the transmission method produces meaningful data; that is, does a relation exist between fitness and the velocity measured by this technique.

The transmission method developed in this thesis is applicable to clinical use: it is safe, fast, practical, and reliable with skilled operators. Placement in a distribution of measured velocities was found to be a possible indication of the injury-prone members of a population. Changes in an individual's velocities over time corresponded with injury and activity. The data showed that injury may be predictable from the velocity of ultrasound, allowing a chance for warning and preventive action.

In summary, this thesis develops a non-invasive diagnostic procedure to quantitatively evaluate bone health in humans.

CHAPTER 2

HARVARD STUDY

2.1. Subjects

A study was undertaken to collect a series of velocity measurements from a population, and correlate these measurements with known information on injury and activity. It was desirable that the population include individuals who had bone-related injuries, those who would become injured during the course of the study, and those who would remain uninjured. The athletic program of Harvard University provided an excellent group for this study.

31 subjects participated in the study. 28 subjects were on the track team; one was a water polo player; one played field hockey and lacrosse; and one was an athletic trainer who ran. With the subjects who ran track, a variety of events were represented: sprints, distance, jumping, racewalking, etc. The group was evenly divided by sex (16 females, 15 males). All but one of the subjects were of college age.

Several subjects had chronic leg injuries: the most common complaints during the study were of "shin splints" (22 cases), although knee injuries (14 cases), Achilles tendinitis (10 cases), and stress fractures (5 cases) were also reported. All of the subjects were in active training.

2.2. Study Protocol

The subjects were measured bilaterally. The terms used to identify the sites which were measured are listed below, along with a description of the anatomic location of the transducers at each site:

1. Humeral shaft - The transducers were placed anteriorly/posteriorly over the humeral shaft at the insertion of the deltoids.
2. Humeral condyle - With the subject's elbow bent, the transducers were placed slightly proximal to the humeral condyle, over the humeral shaft as close to the condyle as was possible.
3. Tibial shaft - This location is the tibial midshaft. The transducers were placed with one on the side of the tibial crest, and the other over the flat anterior surface of the tibia at midshaft.
4. Proximal tibial shaft - The transducers were placed in the same way as for the tibial shaft reading, but were located proximally to the midshaft.
5. Distal tibial shaft - The transducers were placed in the same way as for the tibial shaft reading, but were located distally to the midshaft.
6. Patella - The transducers were placed medially/laterally across the midpoint of the patella.
7. Tibial metaphysis - The transducers were placed at the proximal tibial and fibular metaphyses, medially/laterally over the tibia at the location where the fibula joins the tibia.
8. Calcaneus - The transducers were placed medially/

laterally across the bulb of the calcaneus.

9. Metatarsal - The transducers were placed cranially/caudally across the foot pad over the second metatarsal.

10. Fibula - The transducers were placed anteriorly/posteriorly as close to the fibula as was possible; the fibula was often not palpable under the tissue.

In order to keep the measurement sessions short, not all sites were measured on all the subjects. Of the tibial shaft readings, the tibial midshaft was commonly the only measurement taken--the proximal and distal tibia measurements were taken when a subject complained of tibial pain near those locations. Readings of the metatarsal and fibula were taken on only one subject each.

The arm sites (humeral shaft and condyle) were included, even though the subjects were stressing predominantly their legs in training, as a control on the measurement technique, and also to collect data to determine if overall fitness affects the strength of unstressed bones.

Each measurement session included the recording of injury and training information volunteered by the athlete, to be used for correlation with the measurement data. On the average, the subjects were measured once every two weeks. This study spanned five months, from December, 1982, to May, 1983.

CHAPTER 3

VELOCITY MEASUREMENT

3.1. Equipment

A transmission method was used to determine the velocity of ultrasound for the study described in chapter 2. The ultrasonic transducers used were standard contact transducers for flaw detection, manufactured by Panametrics, Inc. of Waltham, Massachusetts. They were 0.50 inches in diameter, and had a fundamental frequency of 1 MHz. The transducers were mounted on the movable arms of calipers so as to face directly opposite each other; the calipers were graduated to measure the separation between the caliper arms to within one thousandth of an inch.

The transducers were connected to the transmit and receive ports of a Panametrics model 5055PR pulser-receiver. The pulser-receiver was set as follows:

Repetition rate	maximum
Energy	4
Attenuation	0 dB
HP filter	1 MHz
Damping	6
Gain	40 dB
Setting	2

The pulser section generated electrical pulses of approximately 350 volts amplitude, of duration 250 ns, at a rate of 1.9 KHz. These signals were converted into short ultrasonic pulses by the transmitting transducer. The second transducer received the ultrasonic signal which propagated through the measurement site, and converted the wave into an electrical signal, which was amplified by the receiver section of the pulser-receiver. The signal output of the pulser-receiver was amplified through a Panametrics Ultrasonic Preamplifier with gain set to 40 dB, and then displayed on a storage oscilloscope. External triggering for the scope was provided by the SYNC output from the pulser-receiver. The oscilloscope input section was set for AC coupling, vertical scale was set to 0.5 volts/division, and the time scale was set to 10 μs/division for the tibial metaphyseal measurement, and to 5 μs/division for all other sites.

3.2. Measurement Technique

Ultrasonic transmission gel was applied to the transducers' surface to facilitate the coupling of the ultrasound at the body/transducer interface. The transducers were then placed on the skin surface on opposite sides of the site being measured, and the caliper arms were moved together to minimize the distance between the transducers as much as possible without causing discomfort for the subject. Once the transducers were properly placed, unmoving, and as close to the bone as was possible, the signal displayed on the storage oscilloscope was sampled 32 times and averaged; the average was than saved for inspection. The averaging procedure was used to smooth the signal and minimize the effect of transients due to transducer movement and noise. A typical averaged signal is shown in figure 1.

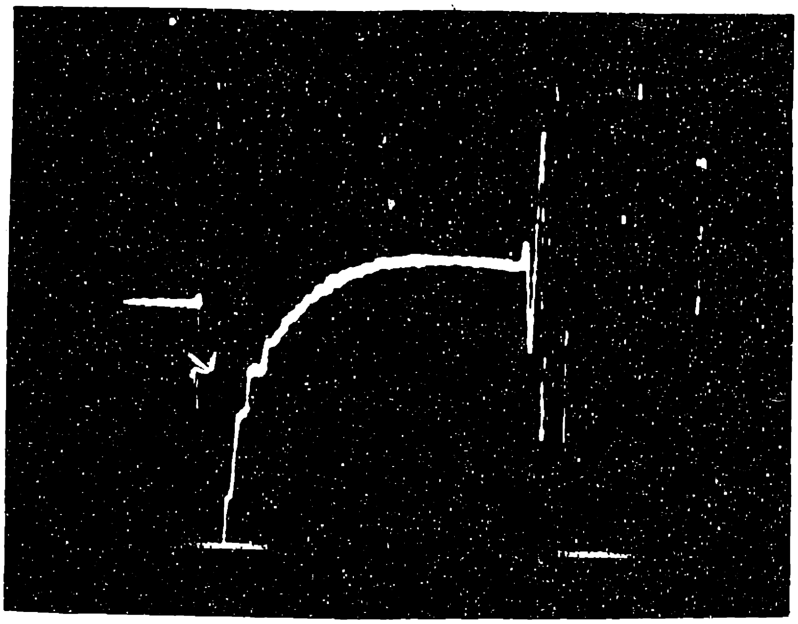

Fig. 1. Typical oscilloscope trace after averaging. Horizontal time scale is 5 μs/division.

The first signal spike seen at the left of the trace (figure 1) is the "main bang"--the electrical pulse, generated from the pulser-receiver, which launched the ultrasonic pulse. During the relatively flat region* in the middle area of the trace, the ultrasound propagated through the medium. The next major disturbance in the trace

*The gradual increase to steady state in the flat region is caused by the frequency response of the preamplifier.

represents the arrival of the signal at the receiving transducer.

The transit time measurement was determined from inspection of the oscilloscope trace. Movable cursors were available on the oscilloscope, and were used to mark the two significant points on the trace--the start of the "main bang," and the first indication of the received signal. The time between the cursors, i.e., the travel time of the ultrasound, was then read from a digital display on the oscilloscope. Inspection of the trace in figure 1 shows a travel time of approximately 5.7 divisions x 5 μs/division = 28.5 μs.

A noisy or weak signal would make the arrived signal difficult to distinguish. The operator could improve the signal by moving the transducers slightly, or by applying more transmission gel to achieve better signal coupling, or by re-sampling the signal.

The distance measurement was read from the graduated calipers. The transducer mountings caused an offset in the caliper readings; this distance offset, called "DO," was noted before each measurement session, to be subtracted from the recorded distances before calculations were performed. DO tended to vary by several thousandths of an inch from day to day.

A measurement at each site consisted of two or three separate readings of both time and distance. Two pairs of readings (a pair is the time measurement and corresponding distance) were taken initially; if they were not nearly identical, both in distance and in time, a third pair was read to improve the reliability of the measurement.

3.3. Velocity Calculation

A velocity was calculated for every pair of readings by the formula

$$v = \frac{d - DO}{t}$$

where v is the velocity, t is the time measurement, d is the distance measurement, DO is the distance offset of the calipers, and d-DO is the actual distance between the transducers.

Each site measurement had two or three calculated velocities, one for each pair of readings. The mean and standard deviation of these velocities were computed to obtain an average velocity for the site measurement. A low standard deviation resulted from similar velocities, and implied a high confidence that accurate readings had been taken. For a set of three velocities at a site (when three pairs of readings were taken), if the standard deviation was high (that is, if the relative standard deviation was greater than 2.5%), then the data was inspected to determine whether one pair of readings was inaccurate. Inaccurate readings were neglected in subsequent computations, reducing the set of calculated velocities for the measurement to two, and the average velocity was computed again.

3.4. Reproducibility of Velocity Measurement

Reproducibility, in the context of the velocity measurement, means that two pairs of readings taken for the same measurement (i.e., taken at the same site, on the same day, from the same subject) should result in the same calculated velocity.

A statistical analysis was done to determine if the data obtained from the Harvard study possessed the quality of reproducibility. The test was patterned after a treatment effect matched-pairs analysis (12). The hypothesis tested was:

> The difference of two velocities, calculated from two independent pairs of readings at one site, from one subject, on one day, is zero.

Two velocities for every measurement taken during the study were collected for this analysis. If a measurement included three velocities (after the data selection described in the previous section), the two extreme velocities were chosen in order to provide the worst case. The differences of the matched pairs of velocities were calculated, and the statistics of the differences were computed. The number of measurements in this analysis was 2614; the mean of the differences was 3.11; and the sample standard deviation of the differences was 66.10. A Student's t test determined that the hypothesis above was confirmed at the 0.05 level of significance.

3.5. Characteristics of Various Sites

The measurement technique presented in section 3.2 required the operator to capture the signal displayed on the oscilloscope when the transducers were properly placed, unmoving, and as close to the bone as was possible. Determination of proper placement of the transducers depended on the operator's familiarity with the characteristics of the signals of various measurement sites.

The importance of distinguishing a poor signal from a valid signal was most evident in patellar measurements. Figures 2 and 3 show signals from the same patella, taken on the same day, with the transducers' separation constant. The signal in figure 3 appears to be faster than the signal in figure 2--calculation from figure 2 resulted in a velocity of 1643 m/s, while calculation from figure 3 lead to a velocity of 1980 m/s. The only cause of the difference between the two signals was that the transducers were rotated slightly: this was found to cause the small waves of the patellar signal to shift, disappear completely, or increase in strength. It was decided that a valid signal was the fastest obtainable (see page 22); hence, the signal of figure 3 was captured with the transducers properly placed.

The signals of the various measurement sites had their own characteristics. Signals from each of the major sites are shown in figures 4-9. All photographs were taken with the oscilloscope set with a horizontal time scale of

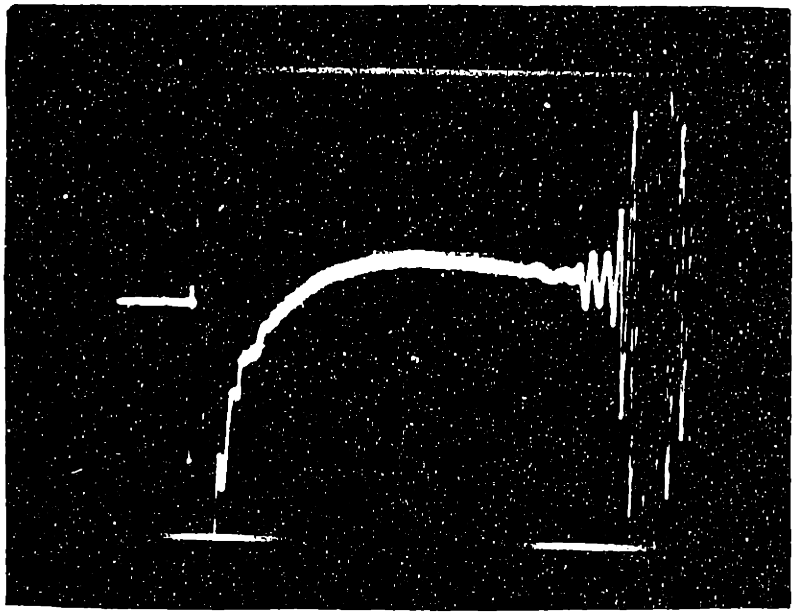

Fig. 2. Patellar signal.
DO = 1.208 in, d = 3.200 in, t = 30.80 μs.

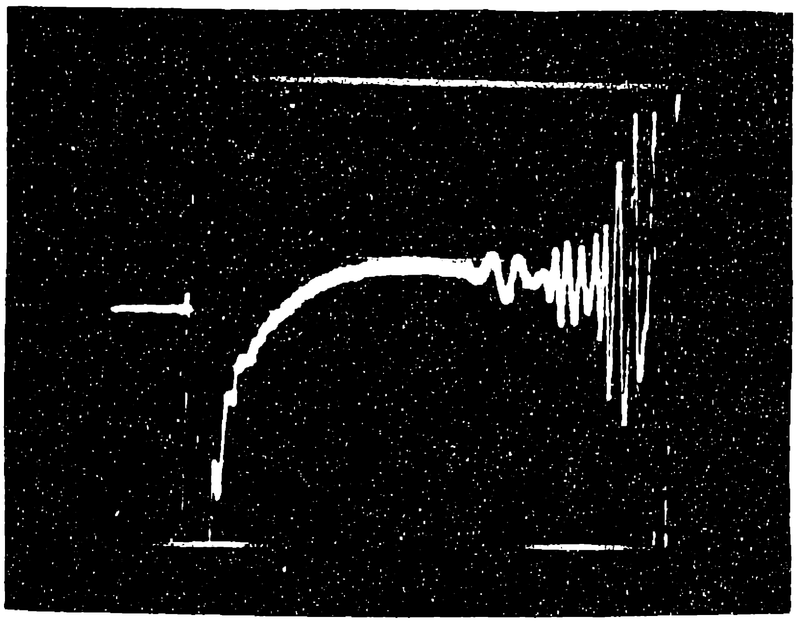

Fig. 3. Patellar signal.
DO = 1.208 in, d = 3.200 in, t = 25.55 μs.

5 μs/division except for Figure 8 (tibial metaphysis), where the time scale was 10 μs/division.

3.6. Discussion

The measurement technique described here was found to be practical with one or two operators. Commonly, two operators took the measurements presented in this thesis; one placed and read the calipers, and the other worked the oscilloscope and recorded the data. The procedure was fast--a measurement took less than one minute to complete. The equipment was conveniently portable. The technique was non-invasive--contact with the skin by the transducers was all that was required. No exposure to radiation was necessary, unlike the pulse-echo velocity measurement technique (4,9). As far as ultrasonic hazards are concerned, no adverse biological effects at the frequency used have been demonstrated (13). Ultrasound is routinely used on humans for diagnostic medical imaging and for the therapeutic warming of muscles.

The decision to use the fastest signal obtainable when taking time measurements was based on the relative velocities of ultrasound through bone and through tissue. As the ultrasound propagated, the signal was partially transmitted through, and partially reflected from, each tissue interface (7). Thus, several signals were formed, which traveled along different paths and impinged on the receiving transducer at different times. For example, one signal may

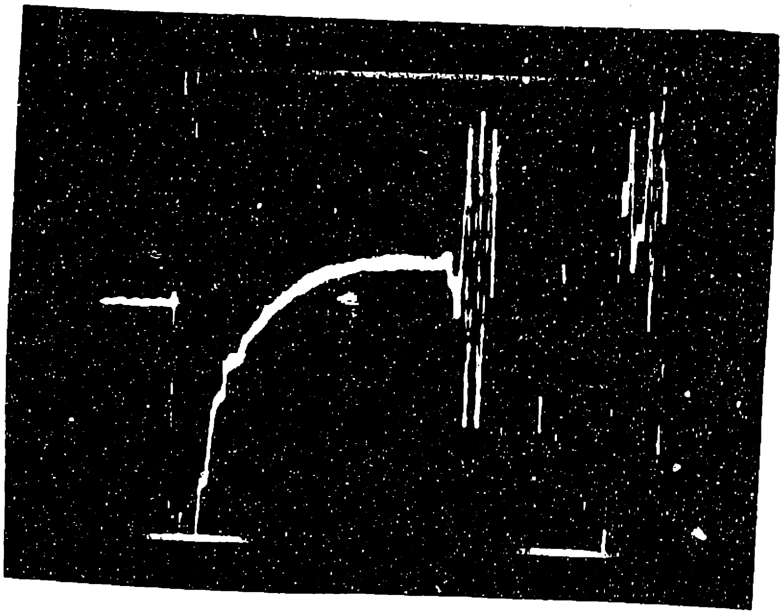

Fig. 4. Signal from humeral shaft.

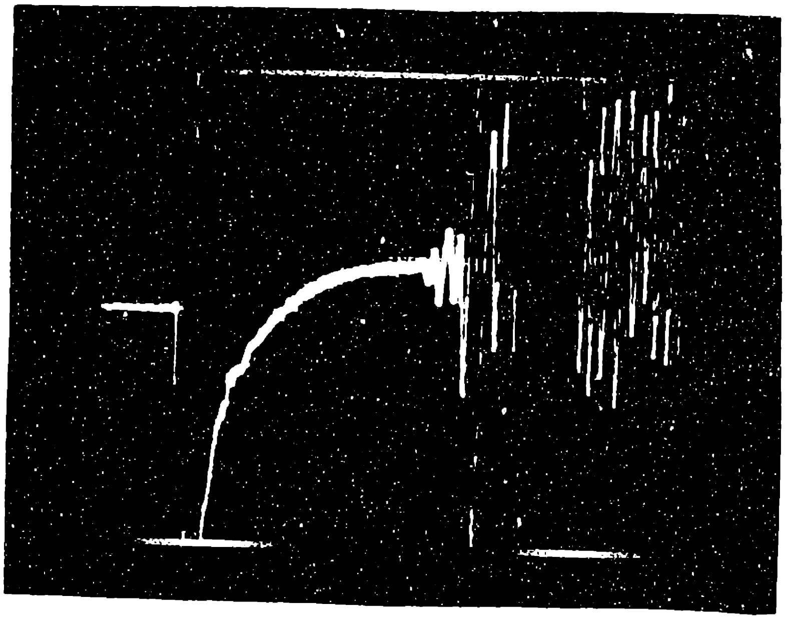

Fig. 5. Signal from humeral condyle.

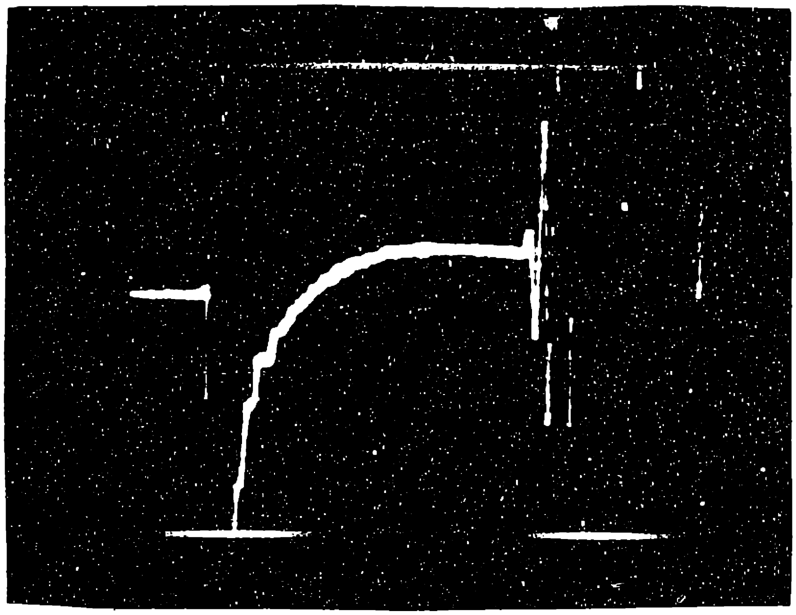

Fig. 6. Signal from tibial shaft.

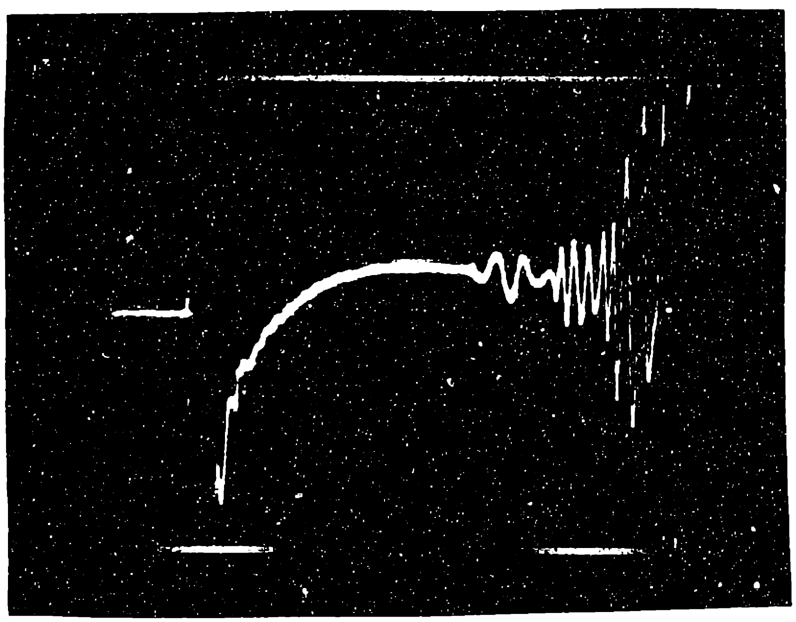

Fig. 7. Signal from patella.

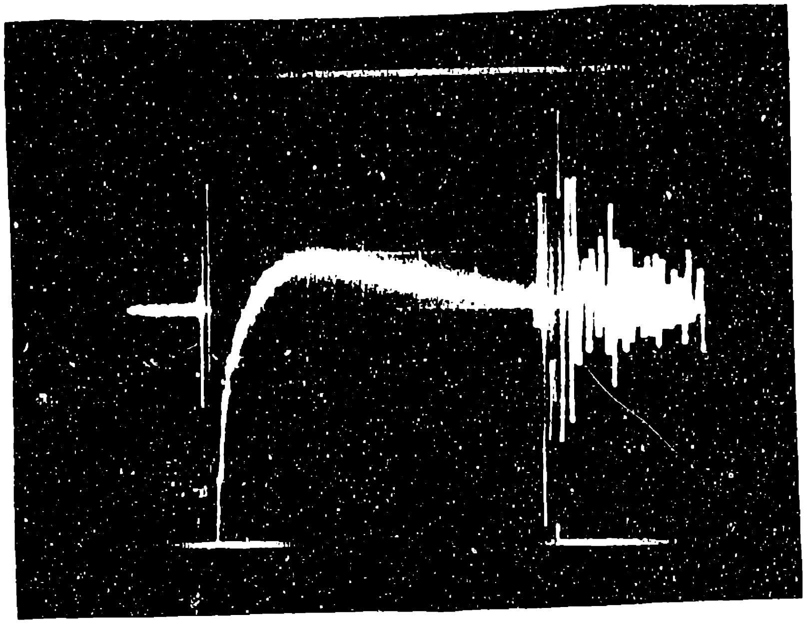

Fig. 8. Signal from tibial metaphysis.

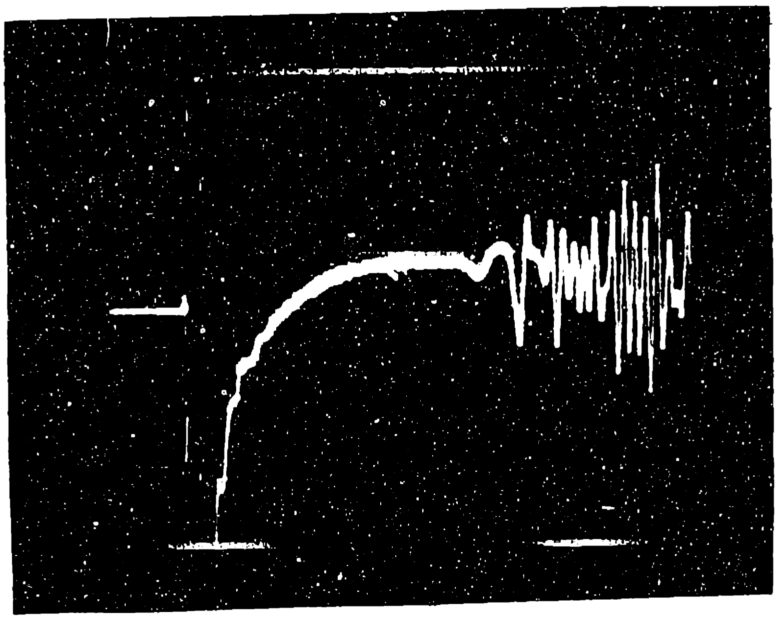

Fig. 9. Signal from calcaneus.

have traveled completely through soft tissue, around the bone, to the receiving transducer. The desired signal, however, took the shortest path through soft tissue, was transmitted into the bone, traveled through the bone, and propagated through a short path of tissue before arriving at the receiving transducer. The velocity of ultrasound through bone is much higher than that through tissue--Wells (7) reports a mean velocity in human tissue of 1540 m/s and a velocity in skull-bone of 4080 m/s. The fastest path for the ultrasound was through the bone; therefore, the earliest indication of an arriving signal was the correct one.

The reproducibility of the velocity measurement was upheld by statistical methods.

The signals of various measurement sites had their own characteristics. As seen in the photographs of representative signals (figures 4-9), the first arriving signal was smaller in amplitude than subsequent signals. This was because transmission through bone attenuates ultrasound much more than transmission through soft tissue (14); the first signal traveled through more bone, so it was faster and more attenuated. Note that the signal of the tibial metaphysis (figure 8) exhibited the least attenuation; at this site, the ultrasound passed through less bone that at other sites.

Signal characteristics can be related to the structure of the bone. The small waves of the patellar signal (figure 7) were the most distinctive characteristic. This unusual shape may have been due to the uniqueness of the patellar site: the patella is a large, thin, curved expanse of trabecular bone. The waves in the signal of the trabecular patella (figure 7) can be contrasted with the signal of the compact bone of the tibial shaft (figure 6). Note that the compact bone resulted in a sharply defined arriving signal. The characteristics which appeared to be specific to trabecular or compact bone were exhibited at other sites as well. The calcaneus is trabecular bone, and its signal (figure 9) had waves similar to the patella's. The humeral shaft is compact bone, and its arriving signal (figure 4) was sharply defined. Figure 5 shows the signal of the humeral condyle, which was measured at a transition area between compact bone and trabecular bone. The signal showed the characteristics of both types of bone; it had early waves (a trabecular characteristic) which were more sharply defined (a compact bone characteristic) than those in completely trabecular bone.

Experience with the transmission technique, and familiarity with signal characteristics, lead to accuracy and speed in measurement.

CHAPTER 4

VELOCITY CORRECTION ALGORITHM

4.1. Apparent Velocity

The parameters used for the velocity calculation were the separation of the transducers (the measured distance minus the distance offset), and the time for the ultrasound to travel between the transducers. Note, however, that the velocity which was calculated in this way was not the real velocity through the bone at that site. The pathlength of the ultrasound was not accurately known (the path was not really a straight line because of the medullary cavity of the bone), and the transit time was the sum of propagation times through the bone and overlying tissue. The calculated velocity was merely an apparent velocity. As long as pathlength remained constant, the apparent velocity was a valid parameter to indicate changes in the quality of the bone (assuming that the velocity through tissue did not change).

Inspection of the data reveals that the distance readings for a subject, at one site, varied throughout the study by as much as half an inch. The distance readings within one measurement session were nearly identical at each site. The variation in distance between sessions was attributed to a difference in the pressure applied to the calipers by the operator, or to swelling at the measurement site. The size of the bone was assumed to remain constant. Therefore, this variation in distance was due solely to a change in the amount of soft tissue included in the measurement, a change which must have affected the travel time of the ultrasound. For example, an increase in the soft tissue pathlength would increase the time measurement (recall the relatively slow velocity of ultrasound in tissue (7)), and result in a much lower apparent velocity than if there were less soft tissue. This effect was minimized by moving the transducers as close to the bone as possible, but the distance variation still existed. The velocities for one subject over the course of the study cannot be compared without taking the tissue difference into account.

4.2. Correction Algorithm

A velocity correction algorithm was developed to adjust the time readings relative to a standard distance reading, for each site, for each subject. It assumes that the velocity of ultrasound in tissue remains constant at 1540 m/s (7), and that the pathlength through the bone does not change. The algorithm is:

Choose $d_{standard}$

Let $t_{correction} = \dfrac{d_{standard} - d_{observed}}{1540\ \text{m/s}}$

Let $t_{corrected} = t_{observed} + t_{correction}$

Then $v_{corrected} = \frac{d_{standard}}{t_{corrected}}$

The algorithm states that the time reading is offset by a certain amount due to the change in tissue. This offset can be eliminated by the addition of a correction (positive or negative) to the time reading. The corrected velocity is then calculated from the standard distance and the corrected time.

Recall that each measurement consists of two or three pairs of readings (after data selection). Averages of the readings were used when the correction algorithm was applied, so that each measurement had one time and one distance value: $d_{observed}$ at each measurement was the average of the distance readings minus the distance offset; and $t_{observed}$ was the average of the time readings at each measurement.

To apply this algorithm to the Harvard data, a standard distance first had to be selected. It might seem most accurate to take the smallest distance reading as the standard--this distance included the least amount of tissue, and was the reading in which the transducers were closest to the bone. However, from a practical standpoint, the first measurement should be the standard: in a clinical application, the data would be analyzed after each session; it would not be feasible to collect all of the data in order to select the smallest distance. For this reason, the first measurement of each site was chosen as the standard; that is,

$d_{standard}$ was $d_{observed}$ at the first reading.

Corrected velocities were computed from the Harvard study data using the velocity correction algorithm described here. These corrected velocities were used in the data analyses.

CHAPTER 5

DATABASE ORGANIZATION

5.1. Overview

A computer-based system was developed to handle the information collected during the Harvard study. This system consisted of a database in which the information was stored, and programs which manipulated the database. The programs could be used and the database accessed without a detailed knowledge of the data-handling system; instructions for the user are contained in appendix A, "User's Guide for the Harvard Study Database."

This chapter presents an in-depth description of the database and the programs. Section 5.2 describes the contents of the database; it explains what information was contained in the various files. Section 5.3 provides details about the structure of the files: it contains filetype and filesize specifications, and a description of where the information was stored in the files. This knowledge is useful in understanding how the programs accessed the files. Section 5.4 describes the programs.

5.2. Contents of Data Files

A set of 8 data files was created for each subject in the Harvard study. Each file contained a different type of data; separate files were used so that only the files which contained necessary information would be opened, thus preserving database integrity. The names of the data files were "HAR##," where "##" denoted the subject number (each subject was assigned a number to simplify data storage and retrieval). Different files for the same subject were distinguished by the filename extension, a three letter code following a period after the filename. For example, the file HAR12.INF was the information file for subject #12. The extensions for the various files and the file contents are described below:

1. INF - information file

   This file contained information to classify subjects according to 15 criteria, which were:

   Race: black or white
   Sex: male or female
   Age
   Handedness: lefthanded or righthanded
   Height in inches
   Weight in pounds
   Cycle: regular, irregular, or none
   Event type: sprint, mid distance, distance, other
   Time in training: recently began, since fall, long
   Any injury: yes or no
   Knee injury: yes or no
   Shin splints: yes or no

Stress fractures: yes or no
Achilles tendinitis: yes or no
Foot injury: yes or no

2. SEQ - sequential file

This file contained descriptive information about the subject, in the categories of:

Cycle
Event
Time in training
Injuries (descriptions for each measurement date)
Training routine (descriptions for each date)
Comments (descriptions for each measurement date)

3. PAR - parameter file

This file contained the date of each measurement session for the subject, and the distance offset (DO) at each date.

4. DAT - data file

Distance and time readings were stored in this file.

5. MSK - mask file

This file contained a mask bit for each pair of readings stored in the DAT file. The mask designated the readings which were to be neglected because of inaccuracy (see section 3.3).

6. VEL - velocity file

This file contained the apparent velocities calculated for each pair of readings in the DAT file.

7. STA - statistics file

The means and sample standard deviations of the apparent velocities were stored in this file. The statistics were computed from the valid apparent velocities, taking the mask into account, i.e., inaccurate velocities were neglected.

8. STD - standard file

This file contained $d_{standard}$ at each site for use in the velocity correction algorithm (see section 4.2).

Besides the individual data files, there were 3 comprehensive data files which contained information for all subjects in the study. The file NAMNUM.HAR contained the names and subject numbers of the Harvard study participants. MEDIAN.HAR contained median velocities for all sites for all subjects in the study. VCORR.HAR contained all the corrected velocities from the study.

5.3. Structure of the Data Files

All but one of the data files for the Harvard study were virtual, or random-access, files. This type of file is efficient to access, but requires a filesize specification when it is created, and so is limited in size. The remaining file was a sequential file--this file is accessed sequentially, and must be completely re-written when changed; its advantage is that the filelength can remain unspecified. Further information on filetypes can be found in (15).

The specifications and structures for each data file are described below:

1. HAR##.INF

   Virtual string file. Filelength = 16.

   Maximum string length = 3.

   The information for each criterion was stored as a string (coded if necessary to fit) in the locations listed:

   location 0 - Race: "B" or "W"
   1 - Sex: "M" or "F"
   2 - Age
   3 - Handedness: "L" or "R"
   4 - Height in inches
   5 - Weight in pounds
   6 - Cycle: "REG," "IRR," or "NON"
   7 - Event type: "SPR," "MID," "DIS," or "OTH"
   8 - Time in training: "BEG," "FAL," or "LNG"
   9 - Any injury: "Y" or "N"
   10 - Knee injury: "Y" or "N"
   11 - Shin splints: "Y" or "N"
   12 - Stress fracture: "Y" or "N"
   13 - Achilles tendinitis: "Y" or "N"
   14 - Foot injury: "Y" or "N"

   When this file was created, locations 0-8 were initialized to " " and locations 9-14 were initialized to "N."

2. HAR##.SEQ

   Sequential file.

   The first line of this file was an integer which was the number of lines of string information in the file. When this file was created, it was initialized to contain strings for the description headings and delimiters as follows:

```
12
"CYCLE"
"END"
"EVENT"
"END"
"TIME IN TRAINING"
"END"
"INJURIES"
"END"
"TRAINING ROUTINE"
"END"
"COMMENTS"
"END"
```

As descriptive information was added (using the database programs), it was inserted between the appropriate heading and delimiter, and the integer describing the number of lines in the file was adjusted.

Descriptions of injuries, training routine, and comments were associated with the date of the measurement session at which the information was collected. Entries after these headings would consist of a line specifying the date, the lines of descriptive information for that date, and a delimiting blank line. This information was inserted in the file in chronological order within each heading.

3. HAR##.PAR

Virtual string file. Filesize = 20 x 1.*

Maximum string length = 9.

This file stored the dates of each measurement session, in chronological order, as a string in the form DD-MON-YY (e.g., "28-DEC-82"). The dates were stored in the (#,0) locations of the array; DO for the date was stored in the (#,1) locations. A maximum of 20 measurement dates was allowed, starting from location (0,0). The file was initialized with "EOF" at location (0,0); this end of file indication was moved down as information was inserted in the file.

4. HAR##.DAT

Virtual number file. Filesize = 1200 x 1.

Distance readings, in inches, were stored in the (#,0) locations (starting from (0,0)), and time readings, in microseconds, were stored in the (#,1) locations in this file. It reserved space for 3 readings at 20 sites**, for a maximum of 20 measurement sessions, in chronological order. In other words, the first 60 locations pertain to the first session; the first 3 locations of each

*The filesize specification denotes the highest location number. Since 0 is also a location, "filesize = 20 x 1" signifies an array that is 21 locations long by 2 locations wide. Locations in an array are designated by specifying coordinates in the notation (#,#).

**The maximum number of sites which could be read in the Harvard study was 20.

measurement session block pertain to the readings from the first measurement site (left humeral shaft). The entire file was initialized with values of zero; if data for a measurement session was incomplete (for example, if a site was not read on a particular subject, or if only two readings at a site were necessary), then the values stored in locations for which there was no data would remain zero.

5. HAR##.MSK

Virtual integer file. Filelength = 1200. Each location of this file corresponded to a pair of readings in the DAT file. The contents of any location was either "0," indicating that the corresponding readings were to be neglected, or "1," which indicated that the readings were valid. At initialization, zero was stored in every location.

6. HAR##.VEL

Virtual integer file. Filelength = 1200. Each location of this file contained the apparent velocity calculated from the pair of readings in the corresponding location in the DAT file. This file was initialized to zero in all locations.

7. HAR##.STA

Virtual integer file. Filesize = 400 x 1. Means of apparent velocities for each measurement were stored in the (#,0) locations of this file, and the associated sample standard deviations were stored in the (#,1) locations. The statistics were calculated with respect to the masks stored in the MSK file. The STA file had space for 20 sites, for 20 measurement sessions, in chronological order. In other words, the first 20 locations (starting from location 0) pertain to the 20 sites of the first measurement session. All locations of this file were initialized to zero.

8. HAR##.STD

Virtual number file. Filelength = 20.

Locations 0-19 of this file contained the $d_{standard}$ values for the 20 sites.

9. NAMNUM.HAR

Virtual string file. Filesize = 40 x 1.

Maximum string length = 25.

Subjects' names were stored in locations (#,0), and their associated numbers were stored in locations (#,1). This file served as a lookup table, enabling a subject's number to be obtained from the name and vice versa. At initialization, "EOF" was stored in location (0,0) and "0" was stored in location (0,1); these end of file indicators were moved, so as to remain at the end of the list, as names were inserted.

10. MEDIAN.HAR

Virtual number file. Filesize = 33 x 20.

This array file reserved space for the median velocities for 33 subjects in locations (1,#) through (33,#). It had space for the medians at 20 sites, for each subject, in locations (#,1) through (#,20). The "0" locations, (0,0) through (0,20) and (0,0) through (33,0), were unused. All locations were initialized to zero.

11. VCORR.HAR

Virtual integer file. Filesize = 33 x 220. This array file reserved space for the corrected velocities for 33 subjects in locations (1,#) through (33,#). It had space for the velocities of 20 sites for a maximum of 11 measurement sessions, in chronological order. In other words, locations (1,1) through (1,20) contained the velocities at 20 sites for the first measurement session of subject #1. The "0" locations, (0,0) through (0,220) and (0,0) through (33,0), did not contain velocities. Locations (0,1) through (0,20) were used, however, as temporary storage in the program CHANGE.BAS. All locations in this file were initialized to zero.

5.4. Programs

There were two types of programs for the Harvard study: database programs, which maintained the database and allowed the display of information, and analysis programs, which manipulated the data.

The 7 database programs were all controlled from one master program using the "chaining" principle of BASIC (15)--

the master program requested a selection from among several operations, and the branch to execute the desired operation involved calling another program. Branch programs eventually returned control to the master program. The names of the database programs are listed below, along with a short description of their function.

MASHAR.BAS was the master program for the Harvard database. It controlled the flow of execution to other programs.

STAHAR.BAS started a new subject's data files (created and initialized them), and inserted the new name and subject number into the comprehensive data file NAMNUM.HAR, maintaining numerical order.

MODHAR.BAS modified information already stored in the database. Classification information (in the HAR##.INF files), descriptive information (in the HAR##.SEQ files), DO (stored in the HAR##.PAR files), or data (affecting the HAR##.DAT, .MSK, .VEL, and .STA files) could be changed.

MODDAT.BAS modified the data from a specific site. This program was called from MODHAR.BAS and returns control to the beginning of MODHAR.BAS.

ADDHAR.BAS added information and data to the data files. This was the usual program called when new data from a measurement session was entered.

SELHAR.BAS was called when data was to be displayed. A display could be generated for any group of subjects, and this program compiled the list of subjects. It allowed the user to choose the names to be included, specify the entire group, or choose selection criteria which a subject had to satisfy in order to be included in the display. This program passed control to DISHAR.BAS.

DISHAR.BAS created a sequential file for display. The user selected the type of information to be displayed. The program then compiled the desired information for the group of subjects selected during SELHAR.BAS. The program passes control to MASHAR.BAS for the actual display of the file.

Several programs were developed to assist in the analysis of the Harvard study data.

TRTEFF.BAS calculated statistics for the treatment effect reproducibility test discussed in section 3.4.

MEDIAN.BAS was used for the population data analysis of chapter 6. It maintained the comprehensive file of the median velocities of the Harvard study group, MEDIAN.HAR, and calculated statistics and histogram groupings for any sub-population.

CHANGE.BAS was used in the individual trend analysis of chapter 7. This program maintained the comprehensive file of all the corrected velocities (VCORR.HAR), and calculated changes in velocity.

Listings of all programs, both the database and the analysis programs, are in appendix B.

CHAPTER 6

POPULATION DATA

6.1. Characterization of Population

Statistics for the Harvard study population were compiled from characteristic velocity values, one at each measurement site (left and right) for each subject. This characteristic velocity was the median of the corrected velocities measured throughout the study. The median was selected for use as a typical value because it is an accepted measure of central tendency, largely insensitive to extreme velocities (12).

Characteristic velocities at each site for the entire population are listed in table 1. Histograms of the characteristic velocity distributions are in figures 10-17.

The velocities measured by the transmission technique were below velocities measured directly through bone (4), but were well above 1540 m/s, the average velocity of ultrasound through soft tissue (7). The sound must have traveled through some soft tissue, since it was coupled into the skin, but to achieve the measured velocities, the ultrasound must also have propagated through a medium of much higher velocity than tissue, in other words, the bone. The measured velocities justified the assumption that the ultrasound

TABLE 1

CHARACTERISTIC (MEDIAN) VELOCITIES FROM THE HARVARD STUDY
(Velocities are in meters/second)

Site	Mean ± Sample Standard Deviation	Minimum	Maximum
Humeral shaft	1935 ± 69	1795	2077
Humeral condyle	1677 ± 56	1571	1818
Proximal tibial shaft	2415 ± 134	2142	2588
Tibial midshaft	2308 ± 183	1730	2721
Distal tibial shaft	2230 ± 168	1955	2590
Patella	2092 ± 106	1845	2269
Tibial metaphysis	1660 ± 26	1605	1721
Calcaneus	1762 ± 71	1626	1969

traveled through the bone, although the actual path of the ultrasound was unknown.

The velocities of the tibial metaphysis were the most closely distributed (see table 1 and figure 16); standard deviation for this distribution was only 26. The tibial metaphysis was useful as a control site--while velocities measured at other sites varied, velocities at the tibial metaphysis were consistently within a small range.

As seen in table 1, and by comparing figures 12, 13, and 14, the velocities of the proximal tibial shaft were the highest of the tibial velocities, followed by the velocities of the midshaft, and those of the distal tibial shaft were the lowest. A Student's t test revealed a statistically significant difference between the mean velocities of the

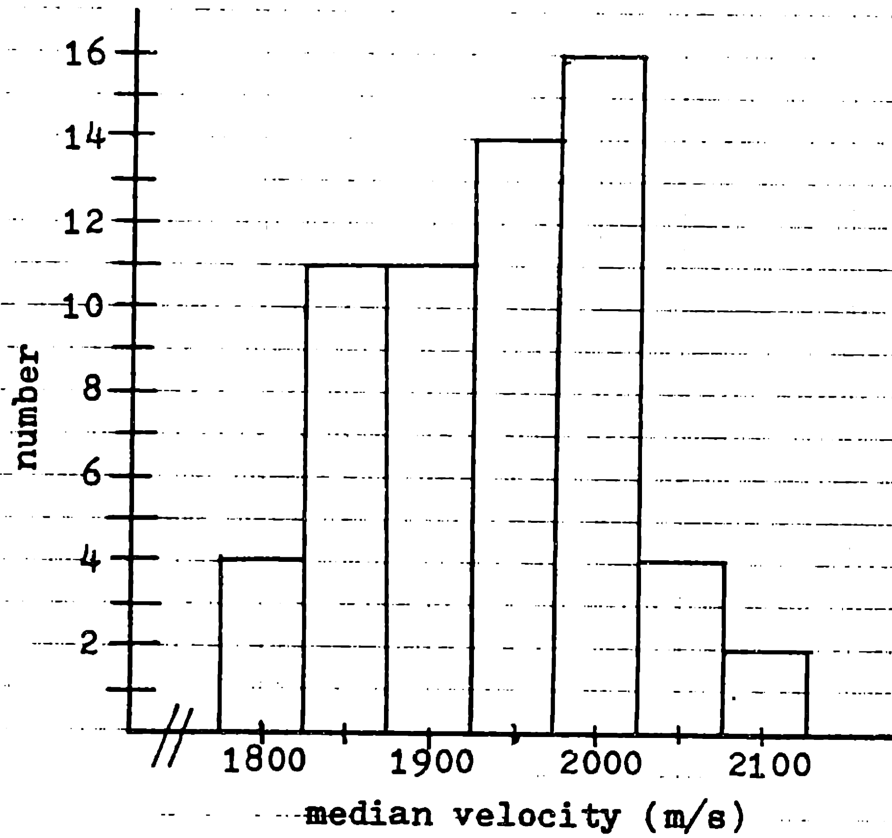

Fig. 10. Distribution of median velocities from humeral shaft.

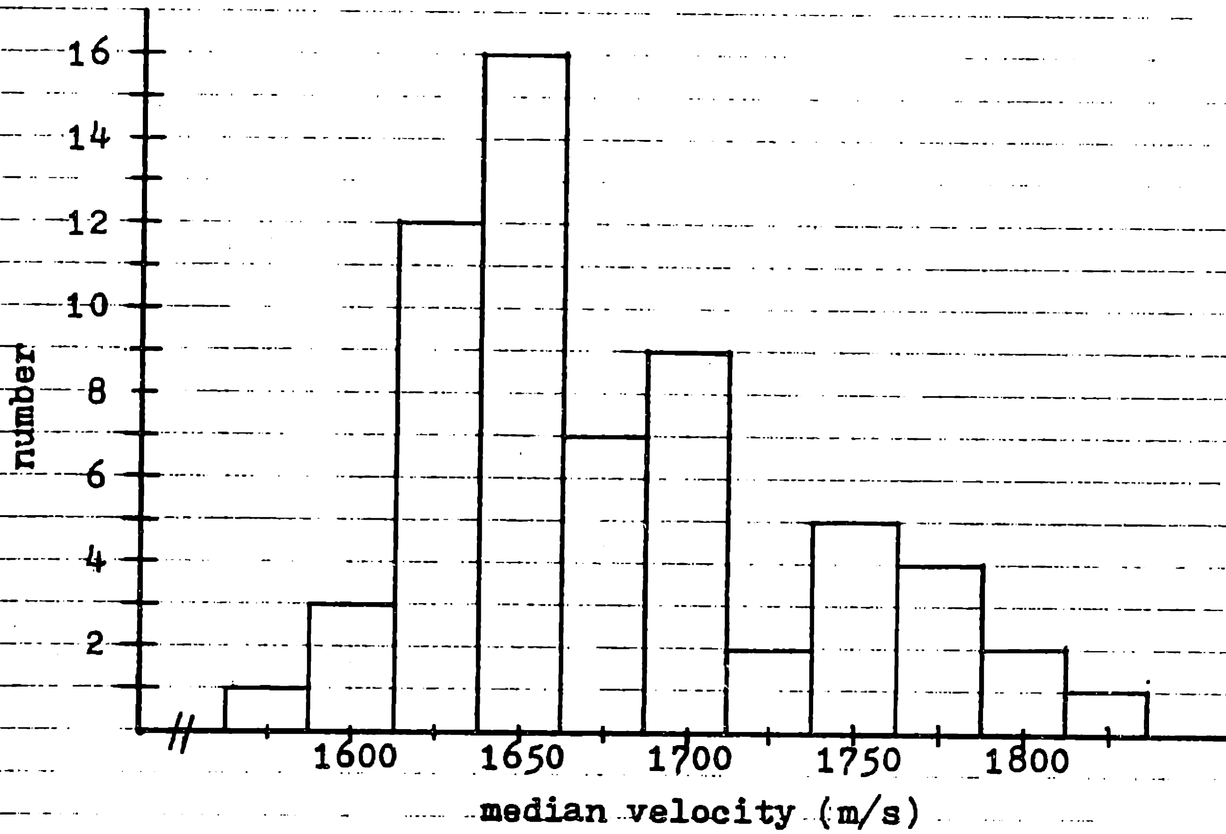

Fig. 11. Distribution of median velocities from humeral condyle.

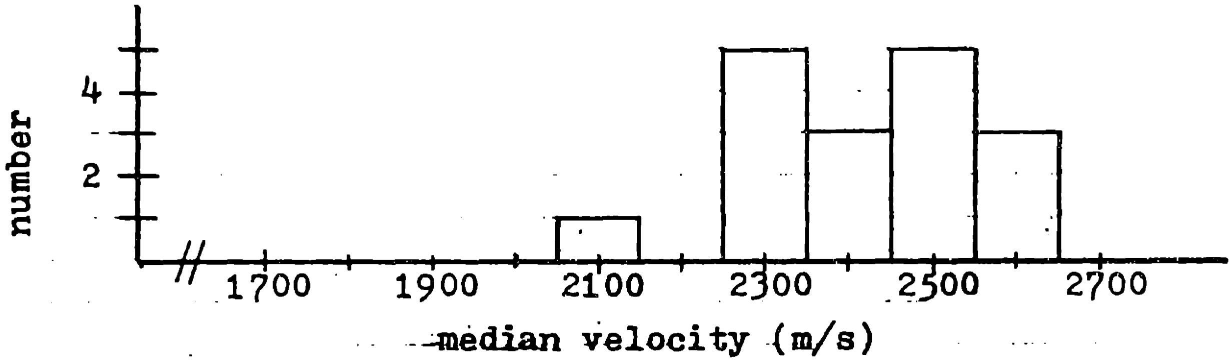

Fig. 12. Distribution of median velocities from proximal tibial shaft.

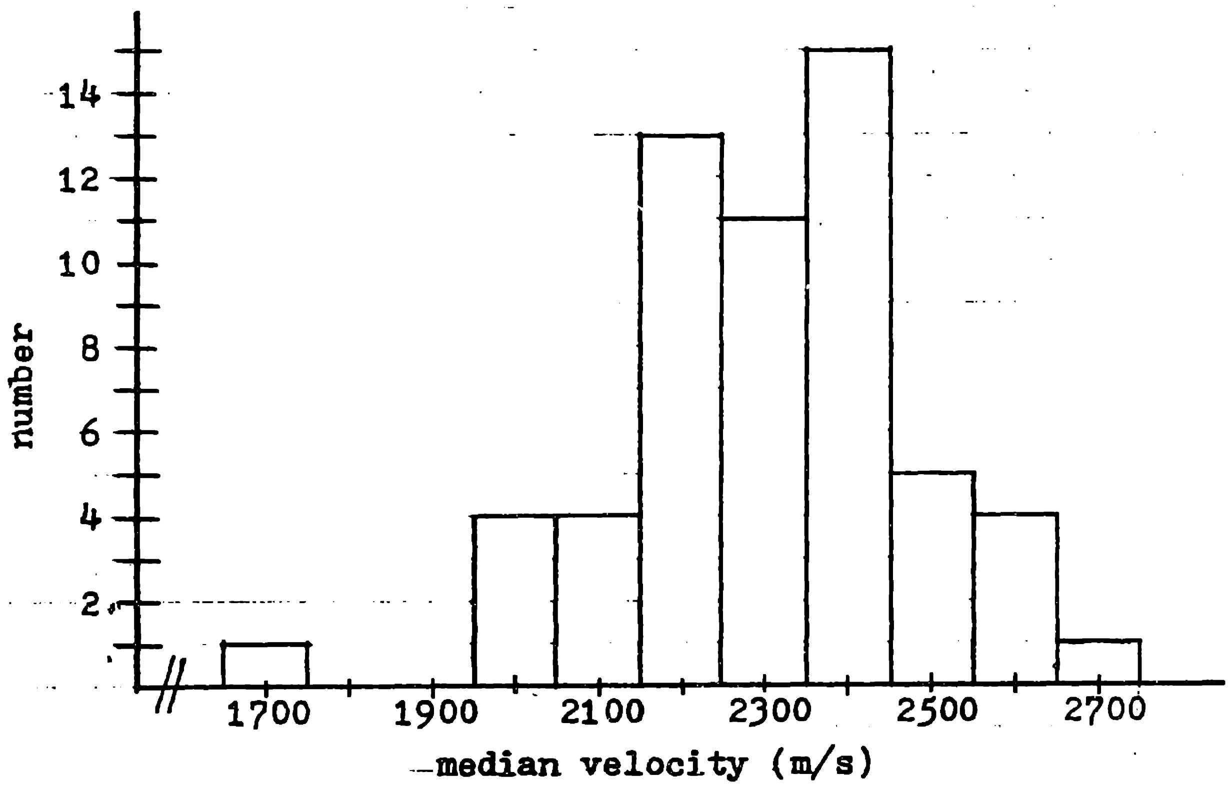

Fig. 13. Distribution of median velocities from tibial midshaft.

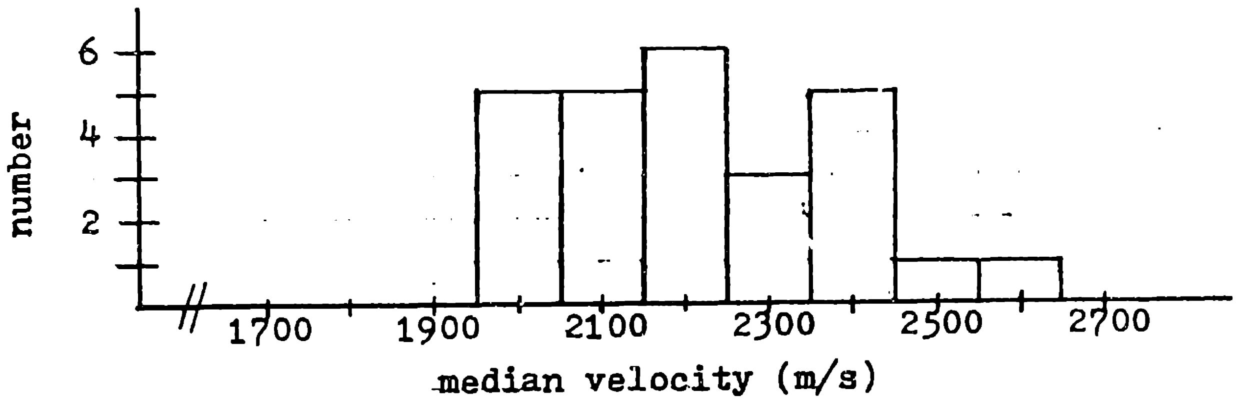

Fig. 14. Distribution of median velocities from distal tibial shaft.

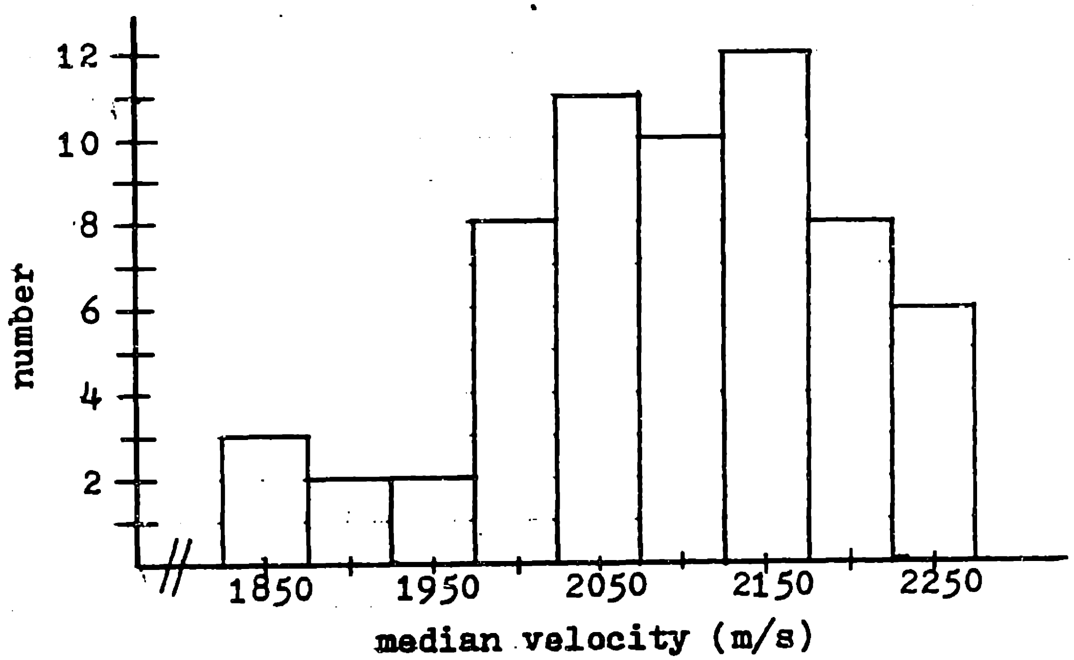

Fig. 15. Distribution of median velocities from patella.

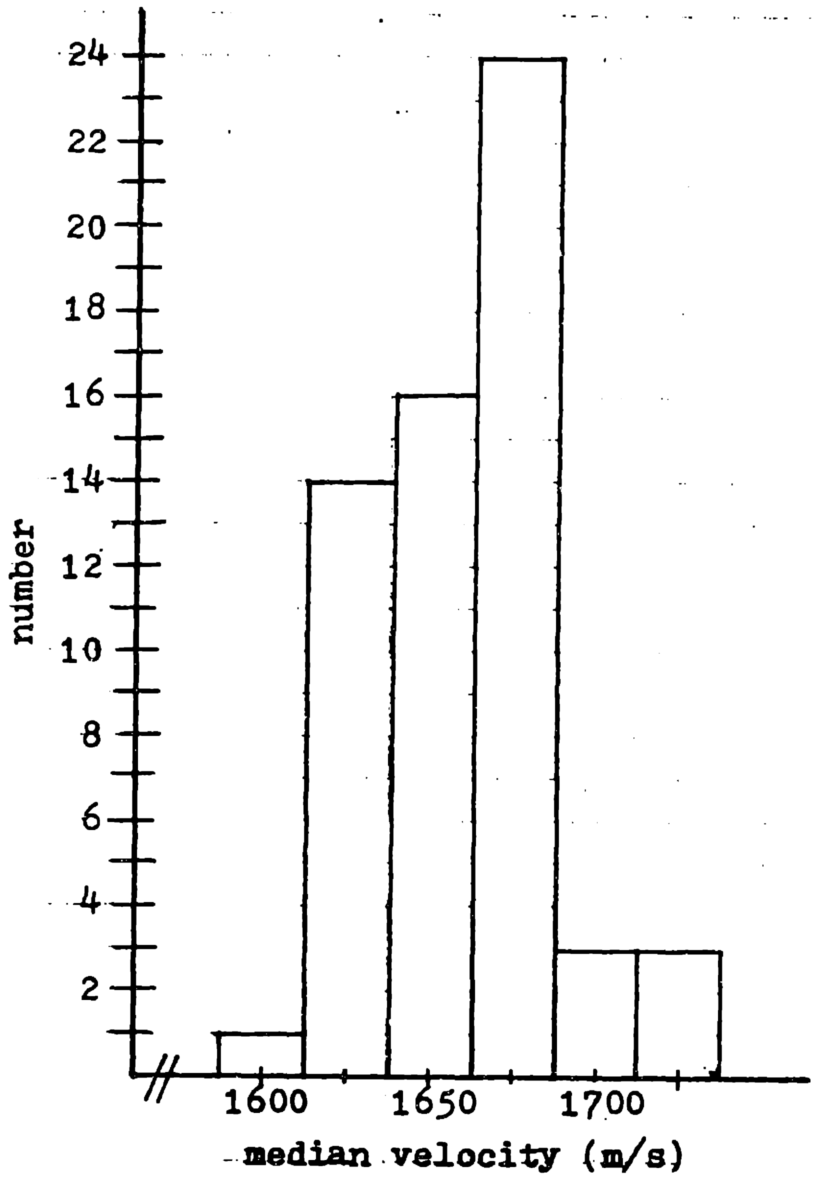

Fig. 16. Distribution of median velocities from tibial metaphysis.

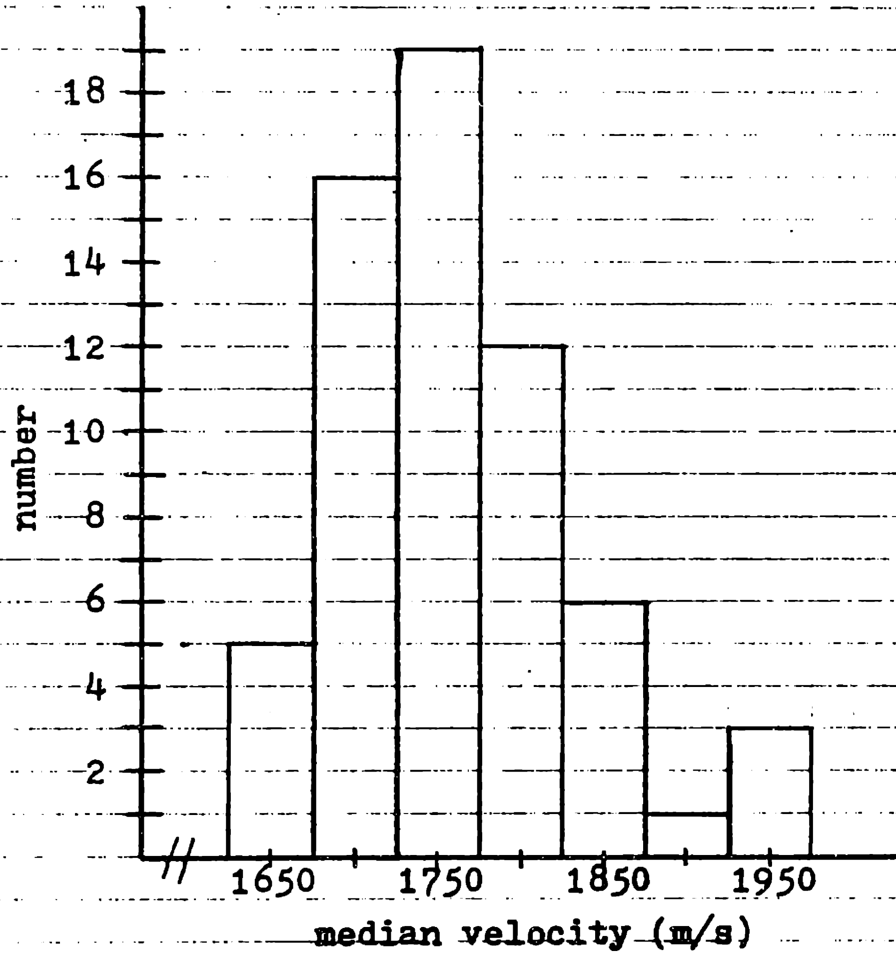

Fig. 17. Distribution of median velocities from calcaneus.

proximal and distal tibial shafts, at the 0.05 level of significance. The pattern of the tibial velocities correlated with injury information: only 1 case of shin pain was reported as being located proximally; 2 cases were at the midshaft; most shin pain was distal (8 cases) or located centrally to distally (11 cases).

6.2. Comparison of Sub-populations

A statistical analysis was performed to compare various divisions of the study population. The Student's t test was used to evaluate the hypothesis that the means of the velocities of two sub-populations were statistically equivalent. A significance level of 0.05 was the basis for decision. The results of the comparisons within the Harvard group are summarized below. Numbers in brackets are the sample sizes.

Male [15] vs. Female [16]:

There were statistically significant differences in velocities at the tibial metaphysis and all tibial shaft sites--males had higher velocities than did females.

Black [8] vs. White [23]:

No significant differences were demonstrated.

Left humeral shaft vs. Right humeral shaft for righthanders [24]:

Statistically significant difference--velocity of right humeral shaft greater than that of left.

Left humeral shaft vs. Right humeral shaft
for lefthanders [4]:
No significant difference.

Sprinters [9] vs. others [22]:
No significant differences.

Middle distance runners [10] vs. others [21]:
No significant differences.

Distance runners [6] vs. others [25]:
No significant differences.

Track athletes [28] vs. others [3]:
No significant differences.

Sprinters [9] vs. Distance runners [6]:
No significant differences.

Jumpers [3] vs. Non-jumpers [28]:
There were statistically significant differences in the velocities of the left tibial shaft and left patella--the jumpers had higher velocities than did the non-jumpers.

Left side vs. Right side for banked-track-runners [19]:
No significant differences.

Left side vs. Right side for non-banked-track-runners [12]:
No significant differences.

Major statistical differences existed between the velocities of males and females; therefore, any comparison of individuals in this study against a velocity distribution should use the distribution specific to the individual's gender. Histograms for the male and female sub-populations are in appendix C.

Lateral differences in the humeral shaft were exhibited in righthanders, but not in lefthanders. That is, the lefthanders in the Harvard study were more ambidextrous than were the righthanders. Ambidexterity in natural lefthanders can be a result of the need for lefthanders to adapt in order to function in an essentially righthanded environment (16).

Jumpers showed statistical differences from non-jumpers just for the left leg. Note that only 3 jumpers were included in the study; the results may be inconclusive because of the small sample size. However, 2 of the 3 jumped with a left leg lead; that is, the left leg worked harder, and may have developed bone strength to compensate for the additional stress.

6.3. Correlation of Injuries and Population Distributions

The velocity of ultrasound in diseased bone is less than the velocity in healthy bone (5). Velocities from the Harvard study were measured with a non-invasive transmission technique; they were average velocities through an aggregation of bone and tissue. The velocity distributions from the Harvard data were analyzed to determine if a correlation existed between abnormally low transmission velocities and injury susceptibility.

Subjects were compared to the appropriate distributions with respect to gender. Abnormally low velocities were defined to be velocities lower than half a standard deviation below the mean of the distribution. Since no arm injuries were reported, the arm sites (humeral shaft and condyle) were not included in the correlation. Distributions of the patella, tibial midshaft, tibial metaphysis, and calcaneus were included in the analysis. Velocities of the proximal and distal tibial shafts were not included because those sites were measured only on subjects who reported pain at those locations, and the resulting small population would be biased toward injury. Correlation was sought between low velocities and knee injuries, shin pain, and Achilles tendinitis. All cases of stress fractures coincided with shin splints, and thus were not included in the correlation.

There were two aspects to the analysis: determining whether a low characteristic velocity signified an injury, and determining whether known injuries were associated with low velocities. In evaluating the significance of low velocities, several terms were used. A "confirming velocity" was a low velocity which corresponded to an injury t that site. For example, a confirming velocity for a knee injury was a low patellar velocity; for shin pain, low velocity at the tibial shaft; and for Achilles tendinitis, low velocity at the calcaneus. A velocity at the tibial metaphysis could not be a confirming velocity, since no reported injury corresponded with that site. An "inferring velocity" was a low velocity which corresponded to an injury on the same side, but not at that measurement site; e.g., an inferring velocity for a left knee injury was a low velocity at the left tibial shaft, tibial metaphysis, or calcaneus. A "false positive indication" was a low velocity which did not correspond to any injury. Confirming and inferring velocities were successes; a false positive indication was a failure. Table 2 show how many injuries were associated with all of the abnormally low velocities included in the analysis.

The low velocities of the tibial metaphysis had a high failure rate; velocities from this site, when compared to a distribution, did not adequately indicate injury. Low velocities at other sites correlated well with injury; approximately two-thirds of the low velocities at the patella, tibial shaft, and calcaneus indicated injury on the same side.

The correlation of known injuries to low velocities was performed using terms similar to those used in the preceding analysis (the correlation of all low velocities to injuries). A "confirmed injury" was an injury at the site of a low velocity; e.g., a knee injury was a confirmed injury if the velocity at the patella was abnormally low. An injury was an "inferred injury" if a velocity on the same side, but not at that measurement site, was abnormally low; e.g., a left knee injury was inferred if the velocity of the left tibial shaft was abnormally low. A "false negative indication" referred to a known injury which did not match a low velocity. Confirmed and inferred injuries were successes; a false negative indication was a failure. Table 3 shows how many low velocities were found from reviewing all of the injured sites. The velocities of the tibial metaphysis were excluded from this analysis because of the high failure rate of this sites's velocities in the preceding analysis.

TABLE 2

CORRELATION OF LOW VELOCITIES TO INJURIES

	Patella	Tibial Shaft	Tibial Metaphysis	Calcaneus
No. of velocities in distribution	62	58	62	62
No. of abnormally low velocities	17	22	18	19
No. of confirming velocities	6	9	--	4
No. of inferring velocities	5	5	9	9
No. of false positive indications	6	8	9	6
Success rate	65%	64%	50%	68%
Failure rate	35%	36%	50%	32%

TABLE 3

CORRELATION OF INJURIES TO LOW VELOCITIES

	Knee Injury	Shin Pain	Achilles Tendinitis
No. of injuries	14	22	10
No. of confirmed injuries	6	9	4
No. of inferred injuries	6	6	3
No. of false negative indications	2	7	3
Success rate	86%	68%	70%
Failure rate	14%	32%	30%

Success rates, shown in table 3, are excellent. The greatest success in directly confirming injuries (with a low velocity at the site of an injury) was in correlating shin pain and tibial velocities.

In summary, approximately 75% of known injuries were associated with low velocities of the patella, tibial shaft, or calcaneus. This indicated that not only the real velocity of ultrasound in bone, but the transmission velocity (the velocity, measured non-invasively, through a site which included the bone) was lower for injured than for healthy bone. The importance of inference is seen in both tables 2 and 3; bones other than those directly at the injury site were weaker than normal, as evidenced by their lower velocities. Approximately two-thirds of the abnormally low velocities of the distribution were associated with injury. This indicated the potential of this method for identifying injury-prone members of a population.

CHAPTER 7

INDIVIDUAL DATA

7.1. Trends

The corrected velocities of each subject in the Harvard study were examined to determine whether the velocity pattern throughout the course of the study reflected the subject's physical condition. Changes in velocity at the leg sites were compared with injury and training information. The velocity pattern was declared to correspond with the individual's condition if there were velocity decreases with injury, increases with healing or improvement, or no significant changes in velocity with no apparent changes in fitness. 100 m/s in two weeks was arbitrarily chosen to be a significant change in velocity.

Velocities from the tibial metaphysis were very constant over time, and did not reflect fitness. Velocities from the calcaneus also did not follow a subject's condition. Patellar velocities corresponded with the subject's physical history in 32 out of 62 cases, for a success rate of 52%. Tibial velocities were successful in following fitness and injury in 42 out of 62, or 68% of the cases. Three cases of stress fractures (medically diagnosed by X-ray) occurred during this study, but were not reflected in tibial velocity patterns.

Velocity patterns at the tibia and patella were indicative of a subject's condition. Several interesting case studies are described in the next section.

7.2. Case Studies

Subject #10 was male, 19 years of age, white, righthanded; he was a water polo player. He had had an arthroscopy on his injured right knee on 8/28/82, and was working hard on conditioning. His first measurement session (day 0) was on 12/13/82. His injury and fitness information follows.

Day 0: Currently lifting weights and swimming.

Day 42: Tendinitis in arthroscoped knee (right knee), but feeling stronger.

Day 70: Right knee feels good.
Out last 2 weeks--sick in bed.

Day 114: Right knee holding up; tendinitis not bad. Increasing intensity of training; running and swimming.

Day 142: Right knee feels good.

Figures 18a-f are graphs of velocity vs. time for all sites measured on subject #10. The graphs for the humeral shaft (figure 18a), tibial metaphysis (figure 18d), and calcaneus (figure 18f) show that the velocities at these sites were fairly constant over time. The levelness of these graphs show that the velocity measurement can be extremely accurate, and lends support to the belief that changes in velocity are an indication of changes in the bone and not merely measurement errors.

The graph for the patella (figure 18e) shows a strong correspondence to subject #10's fitness information. On day 0, the velocity of the right patella was much lower than the velocity of the left patella--the right knee was the injured knee. On day 42, the subject was feeling stronger, and the patellar velocities increased, especially in the injured knee. On day 70, the velocity of the right patella continued to increase, but the velocity of the left patella dropped. The subject reported that his hurt knee was feeling good, but that he had not been training for two weeks while sick in bed. It seems that disuse because of bedrest weakened the uninjured patella, while the injured knee contimued to heal. On day 86, the subject's right knee was sore; the velocity of the right patella had dropped, and the velocity of the left patella had increased now that the subject was back in training. Days 114 and 142 show a gradual increase in patellar velocities, while subject #10 reported that his right knee was feeling good and getting stronger.

The graph from the tibial midshaft (figure 18c) shows that the velocity of the left tibial shaft remained fairly constant, but the velocity of the right tibial shaft exhibited the same variation as that of the right patella (compare with figure 18e). Similarity between the patterns of tibial and patellar velocities was observed in several other subjects.

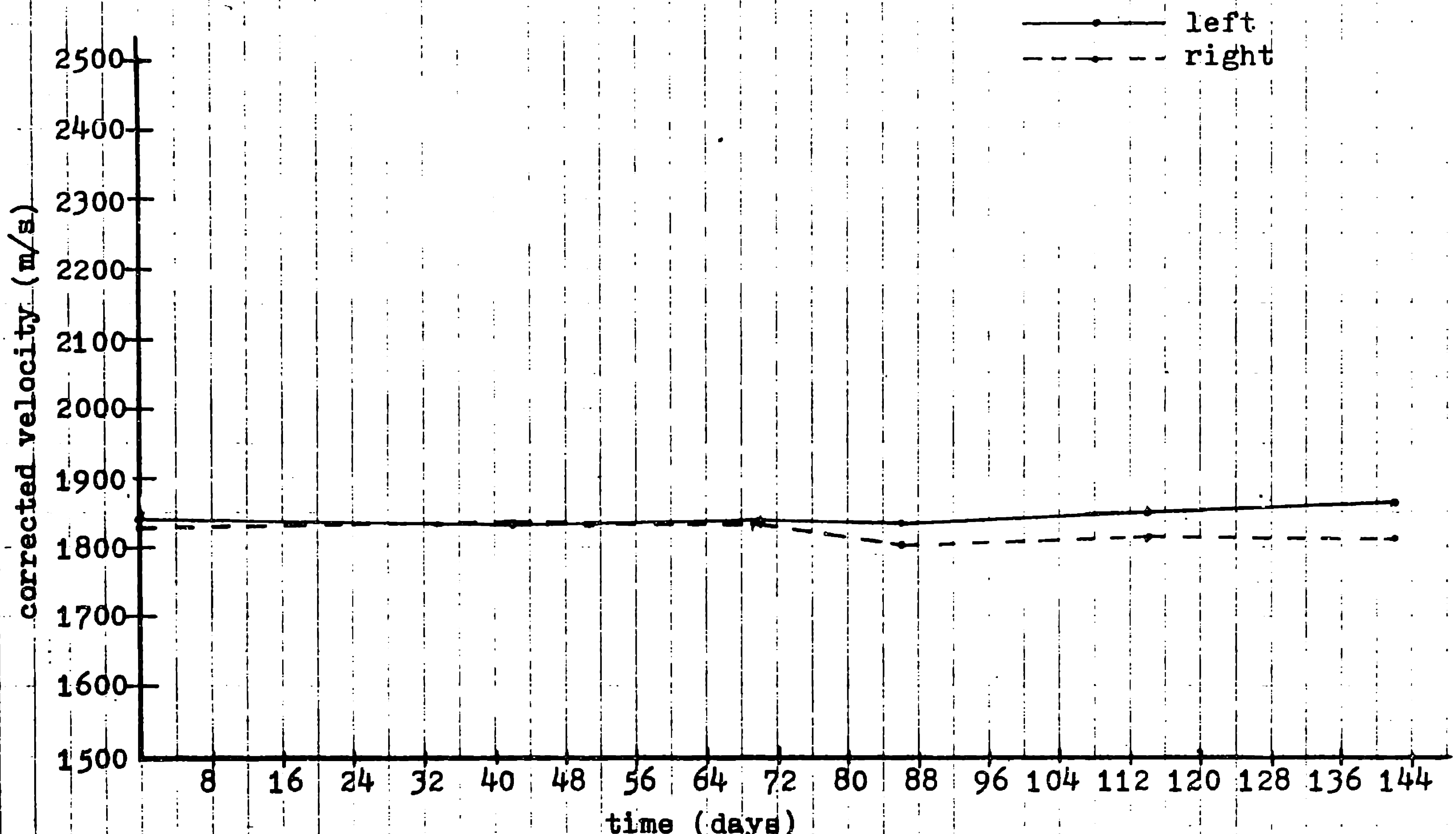

Fig. 18a. Velocity vs. time for subject #10. Humeral shaft.

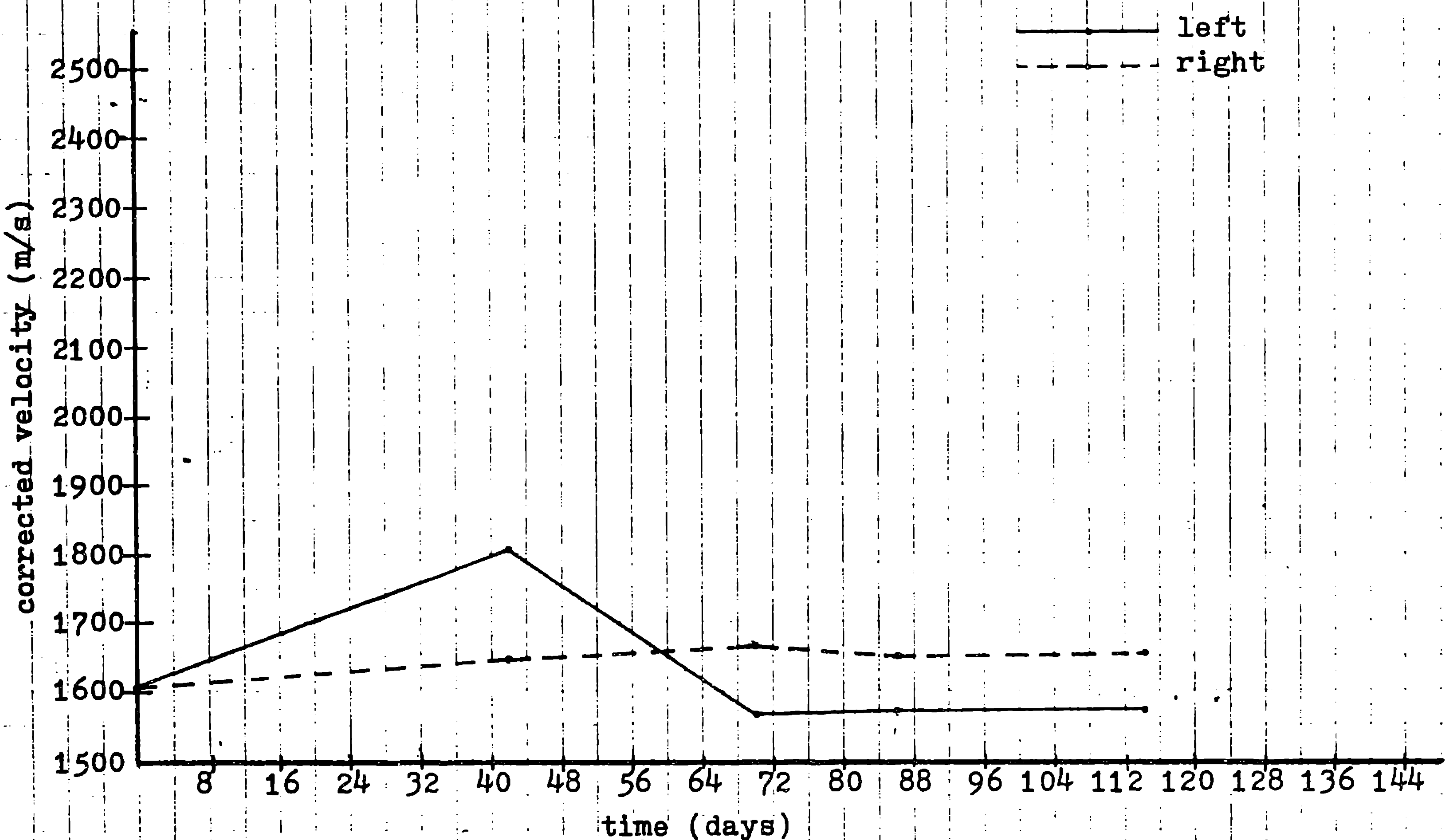

Fig. 18b. Velocity vs. time for subject #10. Humeral condyle.

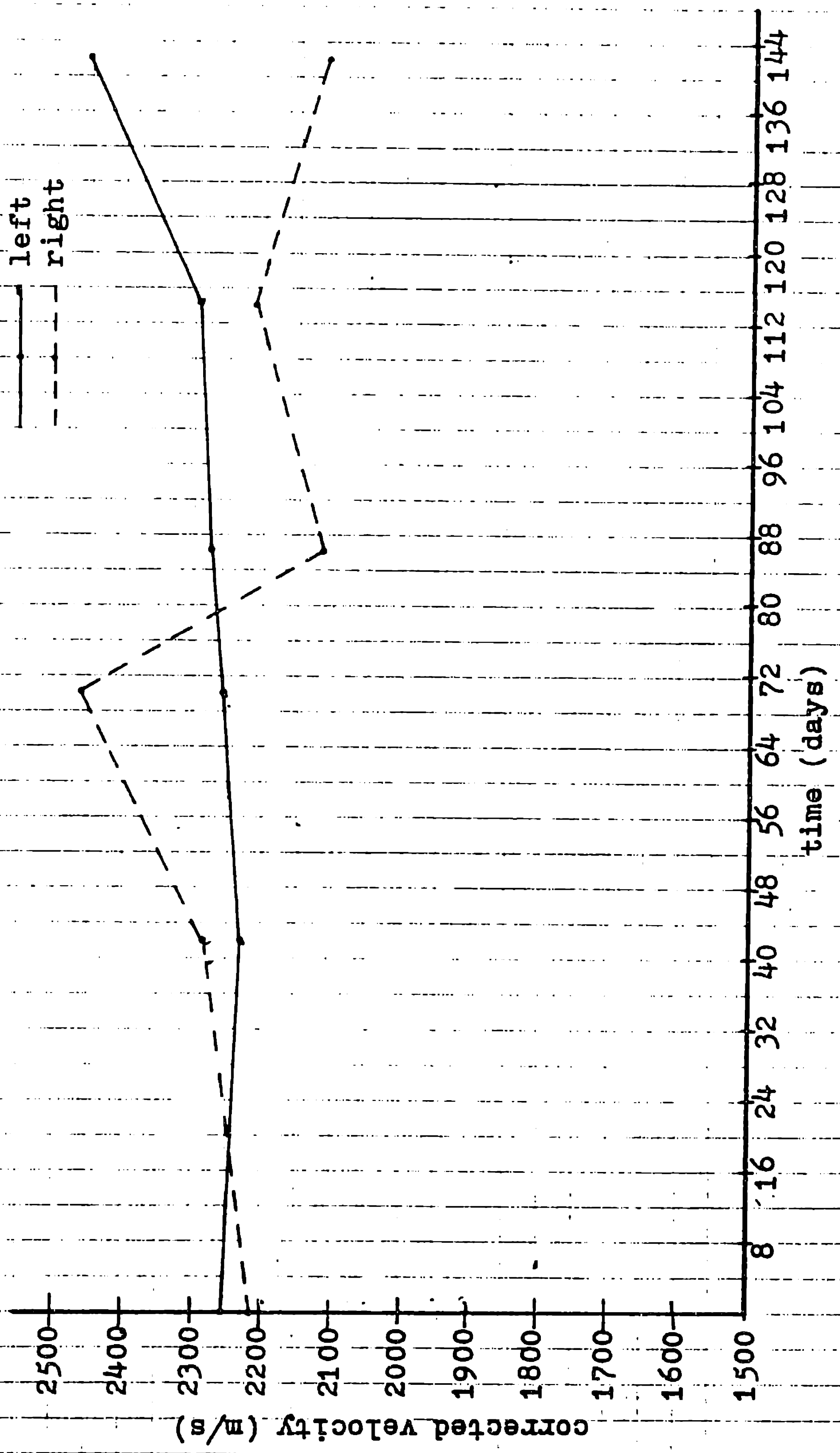

Fig. 18c. Velocity vs. time for subject #10. Tibial midshaft.

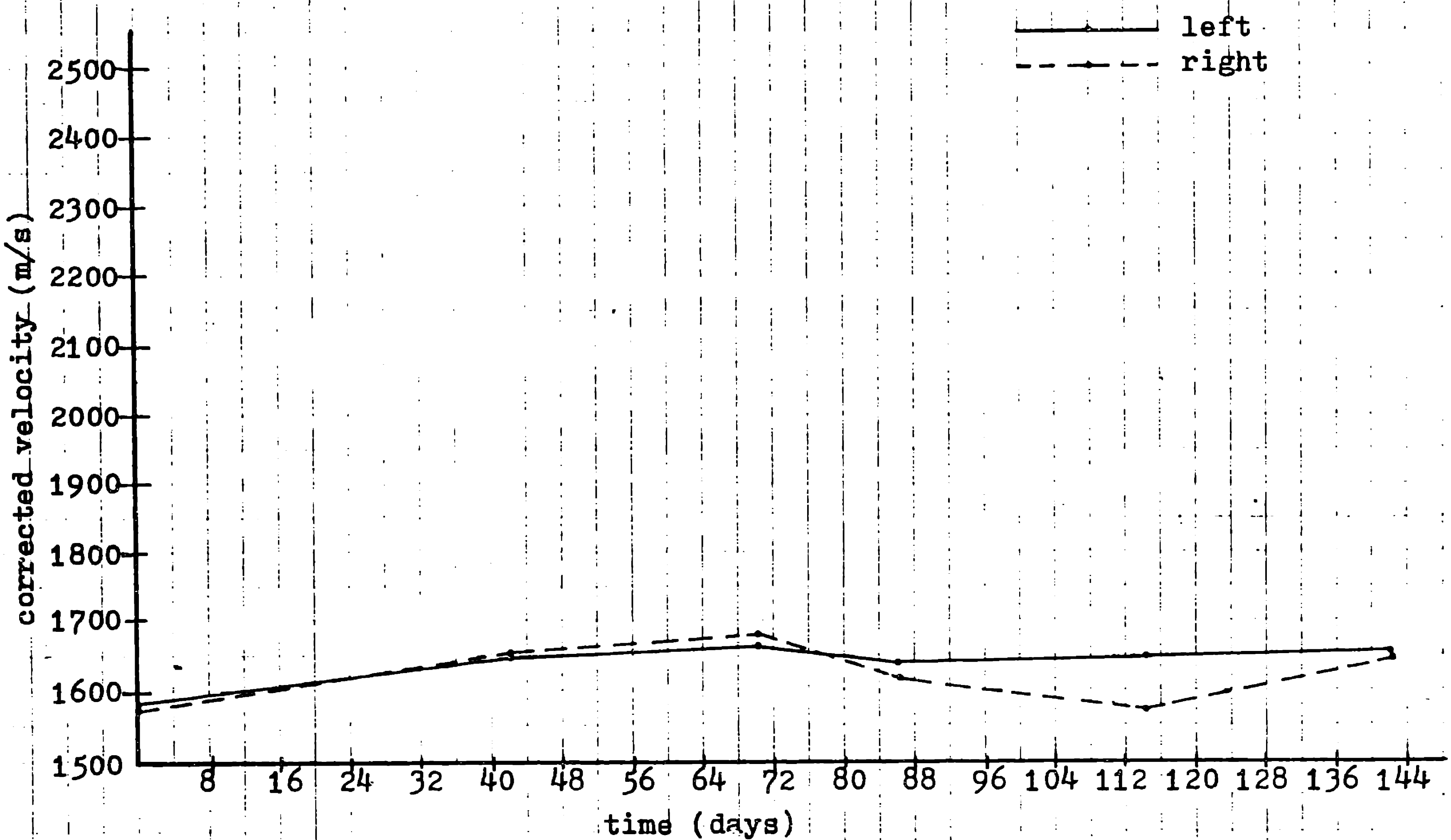

Fig. 18d. Velocity vs. time for subject #10. Tibial metaphysis.

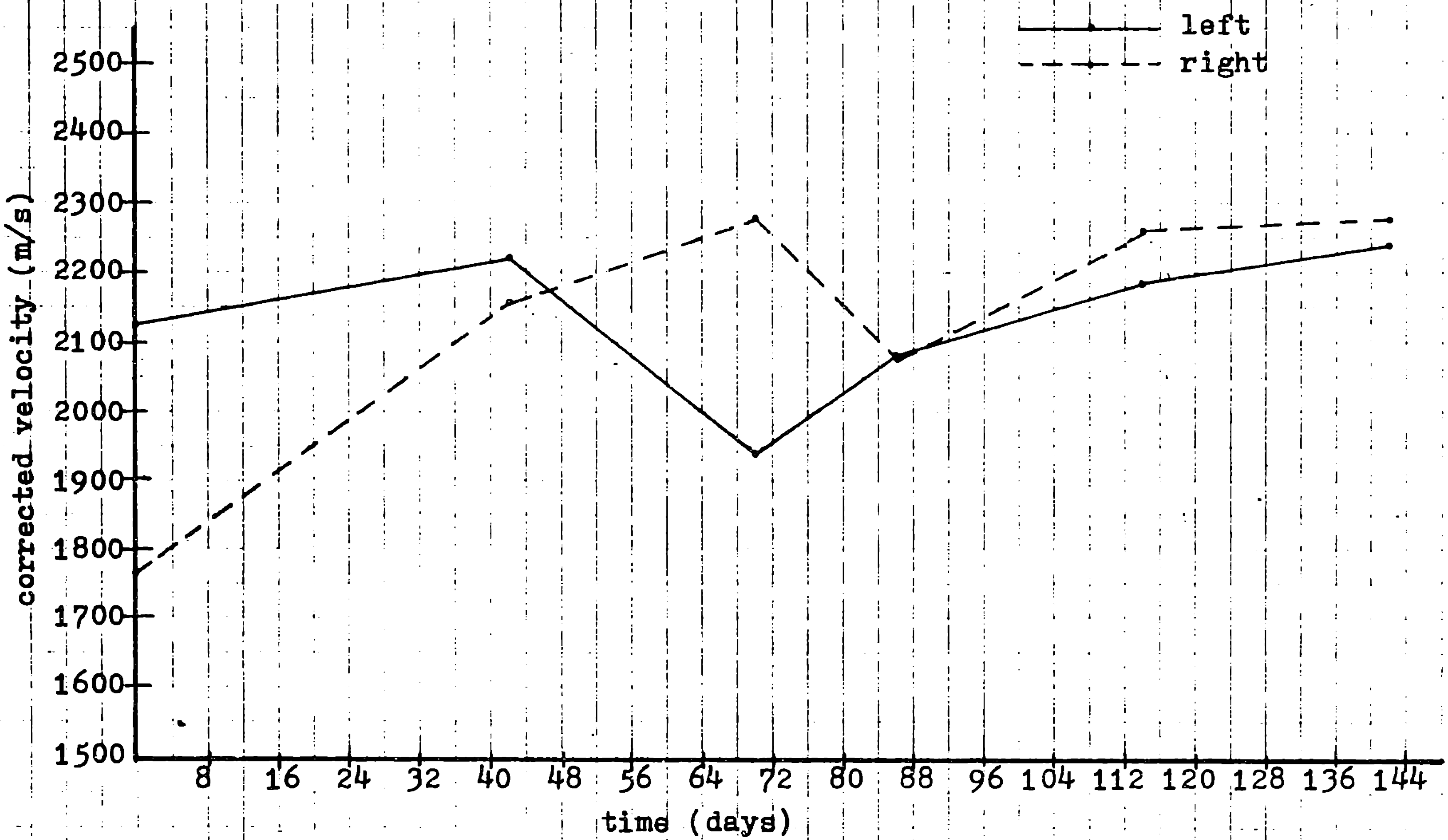

Fig. 18e. Velocity vs. time for subject #10. Patella.

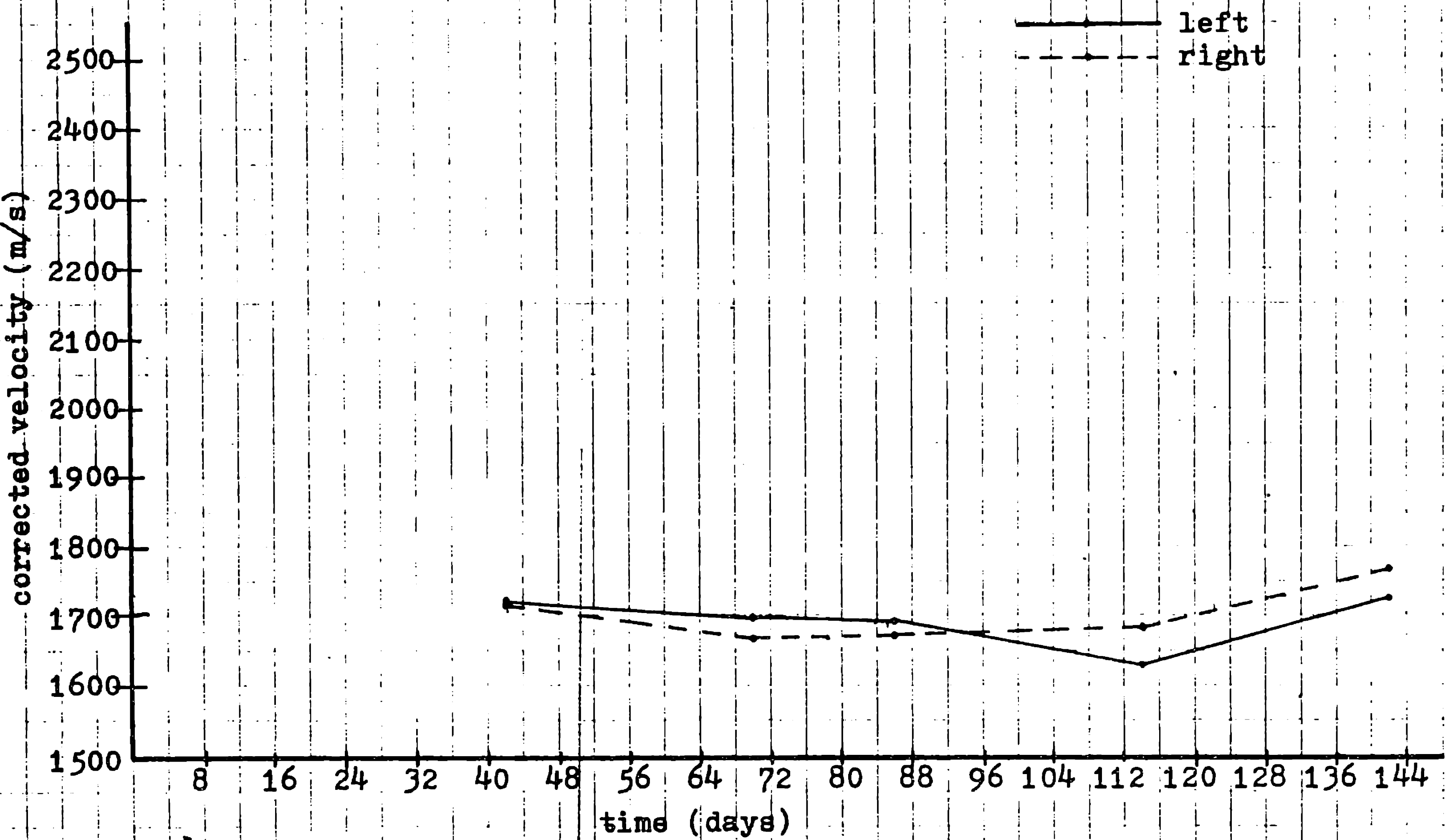

Fig. 18f. Velocity vs. time for subject #10. Calcaneus.

This correspondence lends credence to the practice of inferring knee injuries from tibial velocities, and shin pain from patellar velocities.

Subject #16 was male, 20 years of age, white, righthanded; he competed in the triple jump using a right leg lead. The subject suffered from "shin splints" located distally on the tibias of both legs, but the right leg was the more painful; two years ago he had had a stress fracture in his right tibia. His fitness information follows.

Day 0: Legs hurt after practice.
Day 8: Legs hurt after practice.
Day 42: Legs usually sore after practice.
Day 63: Sore shins getting worse.
Day 70: Legs feel worse than last time.
Day 77: Shins are the same as last time.
Day 83: Shins feel better--took 3 days off.
Day 91: Shin pain is less than usual.
Day 97: Shins feel better.
Day 139: No pain in legs.

The graph of velocity vs. time for the distal tibias of subject #16 is shown in figure 19. Tibial velocities were fairly steady through day 63, corresponding with no changes in the pain which thesubject regularly felt after practice. On day 70, the pain was much worse, and the "shin splints" remained severe through day 77--the velocities dropped sharply during this period. On day 83, the subject reported that the pain was alleviated after resting from training for 3 days, and the velocities increased. From then until the end of the study, subjects #16's shin pain lessened, and on day 139, he reported that he did not have shin pain; meanwhile, the tibial velocities increased after some variation during days 83-97.

Figure 19 shows that the velocities of both tibias varied according to the same pattern, although the right exhibited more dramatic changes. (Section 7.3 discusses the significance of erratic velocities.) This corresponds with subject #16's injury history, in that the pain in both shins varies similarly; but the right tibia had once suffered a stress fracture, the "shin splints" were more severe on the right, and the right leg took the most stress as the lead leg in jumping. The erratic velocities of the right tibia reflected the relative instability of the right leg.

Subject #18 was male, 18 years of age, white, righthanded; he was a racewalker. The subject had no injury problems until day 91 of the study; his information follows.

Day 91: Left knee sore after running.

Day 105: Left knee hurts after walking.
No running or walking since pain started.

Day 119: Knee still hurts in practice.

Day 133: Still cannot run on knee.

The graph of velocity vs. time for thepatella of subject #18 is shown in figure 20. The large increase in velocities between days 0 and 28 is most likely due to error by the measurement operators, who learned about the quirks of the patella measurement (see section 3.5) during the study. The velocity of the left patella decreased steadily

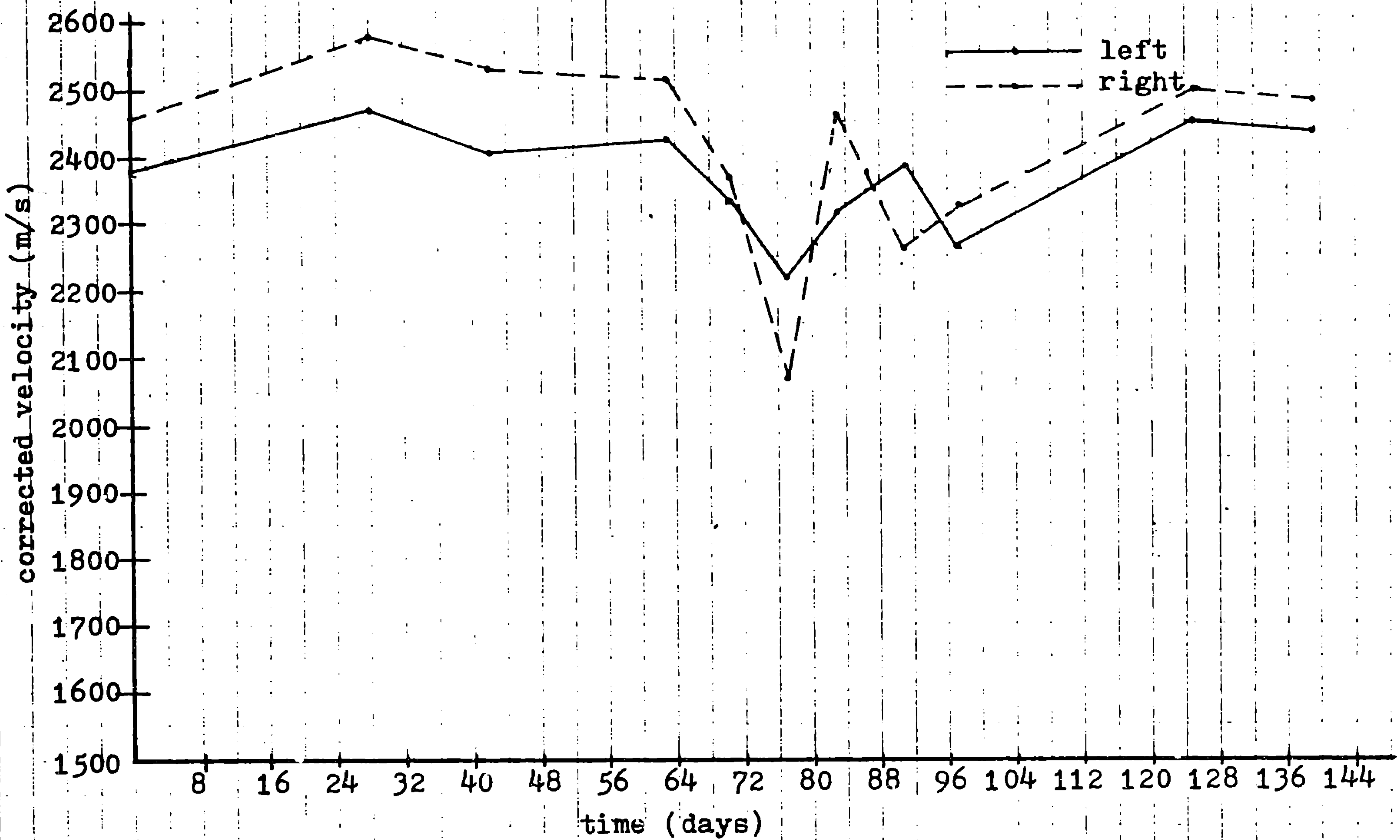

Fig. 19. Velocity vs. time for subject #16. Distal tibial shaft.

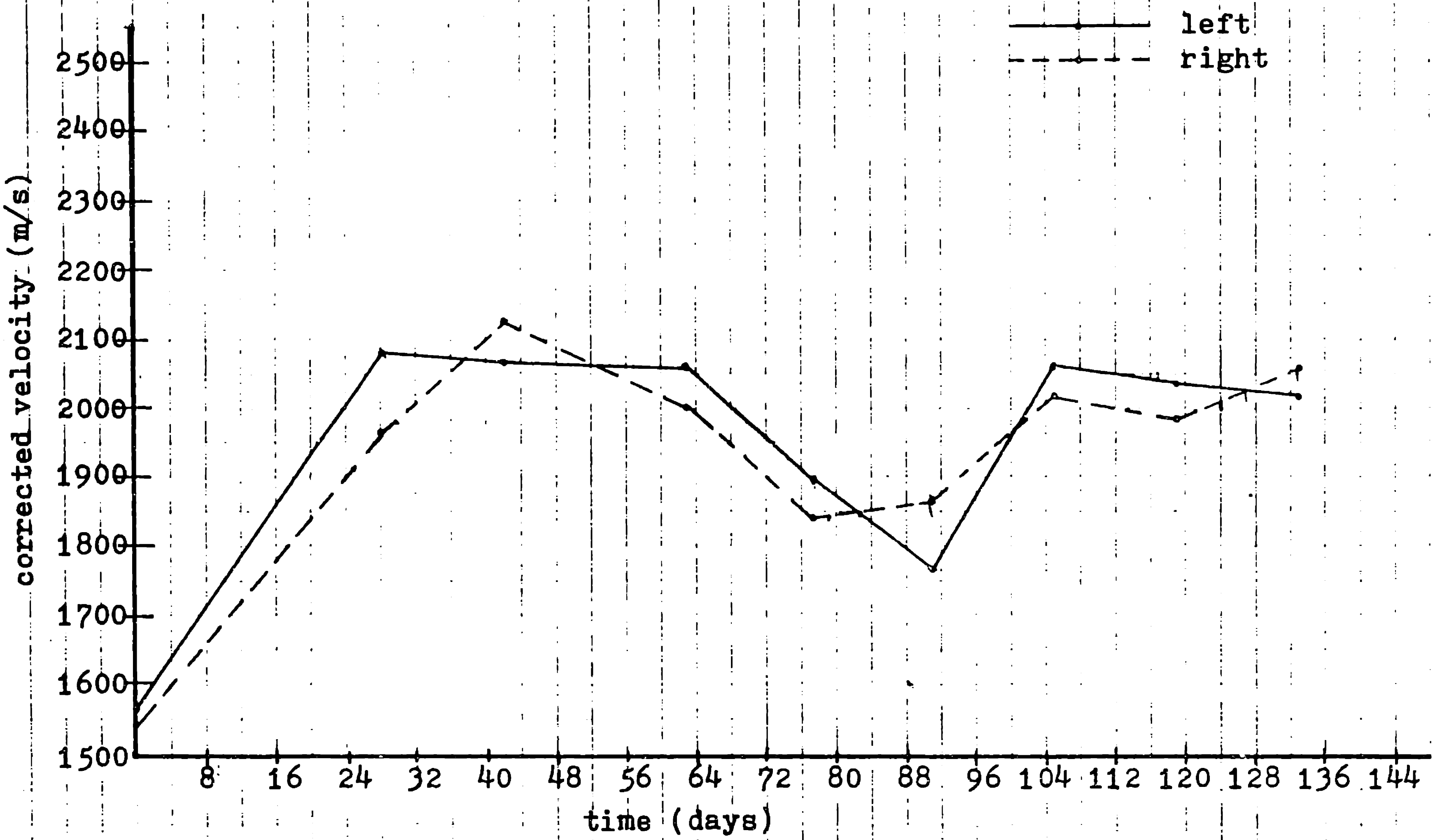

Fig. 20. Velocity vs. time for subject #18. Patella.

before day 91, when injury was reported. By day 105, the velocity had increased because the knee was being rested. The last two measurement sessions resulted in a small decline of the velocity of the left patella, while the subject still reported pain.

Following an individual's tibial and patellar velocities over time provided information on injury and activity. The patterns of some subjects, however, could not be related to their information. Of particular interest is the potential to predict imminent injury by monitoring these velocities regularly (the case of subject #18 is an example of injury prediction). "Shin splints" were fairly well traced, as were knee injuries, by velocity patterns; stress fractures could not be detected.

7.3. Erraticism

The Harvard data was examined to determine whether an erratic velocity pattern for a subject indicated injury. An equation for the erraticism, E, of a set of corrected velocities over time was developed, based on the average of the magnitude of the second difference of the velocities (17). Erraticism was the average of the magnitudes of the changes in slope of the corrected velocities vs. time, or

$$E = \frac{1}{N} \sum_{n=1}^{N} \left| \left(\frac{\Delta V}{\Delta t}\right)_{n+1} - \left(\frac{\Delta V}{\Delta t}\right)_{n} \right|$$

where V is the corrected velocity, t is the time in days, N is the number of points in the graph of V vs. t at which the slope could change (i.e., the number of measurements sessions minus 2), and V'_{t_n} represents the n^{th} slope in the graph (i.e., the slope between points n and n+1).

E was computed for all leg sites for all subjects in the study. E ranged from less than 1.0 to 41.15. A typical erraticism value for an uninjured site was 6, and for an injured site was 14. Choosing E=10 as a significant level of erraticism gave the most consistent results. Therefore, erratic sites were defined to be sites with an E value greater than 10. In general, the tibial metaphysis had very low E values, while the calcaneus had high E values, independent of injury status.

Correlation was sought between high E values (at the patella, tibial ~~midshaft,~~ and proximal and distal tibial shafts), and injuries (knee injuries and shin pain). There were two aspects to the analysis: determining whether an erratic site was injured, and determining whether injured sites were erratic. Terms used in the analysis were similar to those used in the low velocity analysis of section 6.3. A "confirming E value" corresponded to an erratic site which was injured. An "inferring E value" was a high E value which coincided with an injury on the same side, but not at that measurement site. A "false positive indication" was an erratic site which did not correspond to any injury. A "confirmed injury" was an injury at an erratic site. An injury was "inferred" if a site on the same side, but not the injured site, was erratic. A "false negative indication"

TABLE 4

CORRELATION OF ERRATIC SITES TO INJURIES

	Patella	Tibial Midshaft	Proximal Tibial Shaft	Distal Tibial Shaft
No. of sites measured	62	58	17	26
No. of erratic sites	31	8	3	6
No. of confirming E values	10	3	1	4
No. of inferring E values	12	2	2	0
No. of false positive indications	9	3	0	2
Success rate	71%	62%	100%	67%
Failure rate	29%	38%	0%	33%

TABLE 5

CORRELATION OF INJURIES TO ERRATIC SITES

	Knee Injury	Shin Pain	Total
No. of injuries	14	22	36
No. of confirmed injuries	10	8	18
No. of inferred injuries	0	9	9
No. of false negative indications	4	5	9
Success rate	71%	77%	75%
Failure rate	29%	23%	25%

referred to a known injury which did not match an erratic site. Confiming and inferring sites or injuries were successes; false indications were failures. Table 4 shows how many injuries were associated with all of the erratic sites; table 5 shows how many erratic sites were found to coincide with injuries, from reviewing all of the injuries.

The erraticism of patellar velocities inferred shin pain. No knee injuries were inferred from erratic tibial velocities. 75% of known knee and shin injuries were associated with erratic velocities of the tibial shafts and patella. 71% of the erratic sites were associated with injury. The erraticism of a set of velocities was a useful value, with the potential for detecting injury.

CHAPTER 8

CONCLUSION

8.1. Results

A non-invasive technique for measuring the transmission velocity of ultrasound was developed for clinical applications. This technique was safe, fast, practical, and reliable with skilled operators.

The velocities measured with this method were velocities through both bone and overlying tissue. Correlation of these velocities with injury and antivity information from a study group showed that the transmission velocity was indicative of fitness, as fitness affected the strngth of bohe and, thus, the velocity of ultrasound in the bone.

Several methods were used for data analysis: population comparison, trend analysis, and erraticism calculation. Population comparison showed that abnormally low velocities indicated injuries--two-thirds of the abnormally low velocities at the patella, tibial midshaft, and calcaneus were accompanied by a knee injury, shin pain, or Achilles tendinitis. 75% of these injuries were associated with abnormally low velocities.

Trend analysis revealed a connection between the changes in velocities measured from an individual and fitness; when health declined, velocities decreased as bones weakened, and velocities increased as bones strengthened. Declining velocities were sometimes observed before an injury occurred.

Erraticism calculation analysis showed that injured bones tended to exhibit erratic velocity changes. 71% of erratic tibias and patellas indicated injury of the knee or shin; 75% of knee and shin injuries were associated with erratic velocities at the tibia or patella.

The application of this method to clinical use has great potential. Population comparisons could identify those who are more susceptible to injury so that appropriate training schedules could be developed, or cautionary measures taken. Trend analysis and erraticism calculations could be used to monitor an individual over a period of time and predict imminent injury, allowing a chance for preventive action.

8.2. Suggestions for Further Work

More work is necessary before the procedure developed here can be used diagnostically. Additional studies should be undertaken, using better controlled and more representative groups. Conditions could be better regulated; for example, by standardizing diet or activity. More frequent measurements are vital to trend analysis to obtain an accurate picture of velocity changes.

The transmission velocity measurement technique presented here has potential for injury diagnosis and prediction and should be developed further.

APPENDIX A

USER'S GUIDE
FOR THE
HARVARD STUDY DATABASE

TABLE OF CONTENTS

INTRODUCTION

This User's Guide contains instructions for the use and support of the Harvard study programs and files. It endeavors to require no familiarity with computers or programming. This Guide does not attempt to explain the full capabilities of the system, equipment, or programming language used. It is specifically tailored for the Harvard study system.

Further information can be found in the RT-11 System User's Guide, and the BASIC-11 Language Reference Manual, by Digital Equipment Corporation, Maynard, MA.

The set of 13 floppy disks contains the operating systems, programs, and data for the Harvard study. The contents of a disk are stored as individual files.

The main system disk is labeled "RT-11 V3, BASIC V2 O/S AND PROGRAMS FOR HARVARD TRACK BONE DENSITY". It has the main operating system (RT-11 version 3), a few comprehensive files containing data compiled from the entire Harvard study group, the programs that control the Harvard study database, and the version of the BASIC language that runs those programs. This disk will be referred to in this Guide as the "version 3 system disk".

Unfortunately, the version 3 operating system on the system disk is incapable of communicating with the printer. In order to produce a hardcopy, a version 2 operating system must be used. This system is stored on the disk labeled "HARVARD PROGRAM BACKUP, RT11 VERSION 2 FOR PRINTING". As the name implies, this disk also includes the backups for the Harvard study programs and comprehensive data files. Backups are merely copies of files; it is always a good idea to have the contents of a disk copied on another disk to prevent disaster due to accidental erasure or alteration. This disk will be called the "backup and printing disk"; in summary, it is a copy of the version 3 system disk, except version 2 instead of version 3 of the operating system is included to enable printing.

The disk labeled "RT-11 VERSION 3, BASIC, MASTER" contains master copies of the RT-11 version 3 operating system programs, and of several versions of BASIC. The user of the Harvard study database does not require this disk at any time; it is included only as system support.

Complete data for each individual in the Harvard study is stored on 3 disks labeled "HARVARD STUDY DATA FILES, DATA DISK 1 (or 2 or 3)". This data is backed up on disks which are designated by the same labeling, with the addition of the work "BACKUP". The data disks are identical to their backup disks.

The 4 disks labeled "HARVARD STUDY .DIS FILES (ALL SITES + HEADING + INFO)" contain display files for each individual in the Harvard study, compiled from the data disks using the database and analysis programs. These programs and their results are described in a later section of this Guide. The display files can be generated at any time using only the version 3 system disk and the data disks; they have been stored on separate disks for convenience, as they may now be printed directly without re-compiling.

EQUIPMENT

A processor and a terminal are required to run the Harvard study programs, and a printer is desirable should hardcopy be needed.

The processor which has been used is a Digital Equipment Corporation rx01 processor. This has dual disk drives, access to which is provided on the front side of the processor. The disk drive doors latch close; they can be opened by depressing the latch on the underside of the door handle, and are latched by closing the door. The door should be kept closed, when not inserting or withdrawing disks, to prevent dust from entering the drives. The lefthand drive is named DX0; DX1 is the righthand drive. The power switch for the processor is at the back. It is preferable, although not necessary, for the drives to be empty (i.e., no disks inside) when power is switched.

A Digital Equipment Corporation Decscope terminal sits on top of the processor. This has a CRT screen, a typewriter-style keyboard, and a numeric keypad. All commands are entered through this keyboard. The terminal power switch is located on the right side. When power is turned on, a cursor (underline symbol) will flash in the upper left corner of the screen after a few seconds of warmup time.

The printer is a Decwriter II teletypewriter. The keyboard of the Decwriter is not used to send commands to the processor. At the left of its panel are the power switch and 8 setting buttons, arranged in 2 rows. All of the buttons should always be in the up position except the leftmost and rightmost buttons of the top row. The top rightmost button, labeled "300", should always be down. The top leftmost button is labeled: LINE/LOC● . When this button is in the up position, the printer is "on line"; that is, it can communicate with the processor. The Decwriter's keyboard has no effect when it is in this mode. When the button is depressed, the Decwriter is in local mode; it is isolated from the processor and functions as a simple typewriter.

All components should be powered on when a work session begins.

OPERATING SYSTEM

The operating system controls the processor. Booting the system means activating it. Either system (version 3 on the version 3 system disk, or version 2 on the backup and printing disk) can be booted from either disk drive (DX0 or DX1).

There are three switches on the front of the rx01 processor. The leftmost is labeled "DC ON/OFF"; the middle, "ENABLE/HALT"; and the rightmost, "LTC ON/OFF".

To boot a system:

1. Make sure all 3 switches are down.
2. Insert the disk with the desired system into a disk drive. (Disks are inserted by holding them by the labeled edge, label facing up.) Close the drive door.
3. Flick the middle switch up.
4. Flick the leftmost switch up.

At this point a dollar sign ("$") should appear on the screen.

5. Type in the name of the disk drive containing the system ("DX0" or "DX1"), and hit the carriage return.*

The processor responds by announcing the system version:

RT-11 SJ V03-02 (for version 3), or

RT-11 SJ V02C-02 (for version 2),

followed by a period (".") on the next line. The system is

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*All input should be terminated by hitting the RETURN key. (Use of this key will be implied in the remainder of this Guide.)

now booted. The period is a prompt, indicating that the processor is at the system level and is ready to execute commands. The first command after bringing up the system should set the date:

6. Enter the date with the DAT command: type "DAT" and the date in a dd-MON-yy format; for example, "DAT 03-DEC-83".

After the date has been entered, typing only "DAT" at the system level prompt (".") will cause the system to display the given date.

To shut down a system:

1. The period prompt should be displayed; i.e., the processor should be waiting for a system level command.
2. Flick the middle switch down.
3. Flick the leftmost switch down.

A six-digit number and an at sign ("@") will appear on the screen. The system is now down.

FILES

A filename has two parts: the name, which is limited to a maximum of 6 letters; and an extension, which is a period followed by 3 letters. The extension usually denotes the function of the file.

The directory of files on a disk can be listed on the screen. To list the directory while running RT-11 version 3:

1. The period prompt should be displayed; i.e., the processor should be waiting for a system level command.
2. Type "DIR", a space, and the name of the disk drive containing the disk in question, followed by a colon. I.e., type "DIR DX0:" or "DIR DX1:".

To list the directory while running RT-11 version 2:

1. The period prompt should be displayed; i.e., the processor should be waiting for a system level command.
2. Type "R PIP"--an asterisk ("*") should appear as a prompt.
3. Type "DX0:/L" or "DX1:/L", for the appropriate disk drive. The directory will be listed, followed by an asterisk prompt.
4. To return to system level from the asterisk prompt, hit CTRL C.* The period prompt will appear.

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*CTRL C is a special command. It is issued by holding down the key labeled "CTRL" on the terminal, simultaneously hitting the key for the letter "C". Sometimes, to achieve a desired result (usually to get a prompt), hit "C" twice while holding down "CTRL"--in any case, this practice will not hurt anything.

A typical directory listing is shown below (this is the directory of the version 3 system disk):

```
 30-JUL-83
 DXMNSJ.SYS   86 14-AUG-77
 TT    .SYS    2 14-AUG-77
 NL    .SYS    2 14-AUG-77
 PIP   .SAV   16 14-AUG-77
 DUP   .SAV   17 14-AUG-77
 DIR   .SAV   17 14-AUG-77
 BASIC .SAV   51 26-OCT-82
 LP    .SYS    2 27-SEP-78
 STARTS.COM    0 14-FEB-78
 NAMNUM.HAR    5 18-MAR-83
 VCORR .HAR   30 29-JUN-83
 MEDIAN.HAR    6 29-JUN-83
 ADDHAR.BAS   17 18-MAR-83
 MASHAR.BAS    9 21-MAR-83
 SELHAR.BAS   15 24-MAR-83
 STAHAR.BAS    6 28-MAR-83
 MODDAT.BAS    9  8-MAR-83
 MODHAR.BAS   21  8-APR-83
 STDHAR.BAS    3  7-JUN-83
 DISHAR.BAS   24  7-JUN-83
 CHANGE.BAS    8 29-JUN-83
 TRTEFF.BAS    8 30-JUN-83
 MEDIAN.BAS   21 30-JUL-83
 23 FILES, 375 BLOCKS
  105 FREE BLOCKS
```

The filenames are listed, along with their dates of creation, and a number which signifies the size of the file in blocks. Note that the list ends with information concerning free space on the disk.

PRINTING FILES

The processor must run RT-11 version 2 in order to communicate with the printer. The printer should be turned on before the system is booted: a quirk of the existing arrangement of components is that switching the printer can shut down the system. If this happens, simply re-boot.

To print a file (whose name is "filnam.ext") while running RT-11 version 2:

1. The printer should be turned on.
2. The period prompt should be displayed; i.e., the processor should be waiting for a system level command.
3. Type "R PIP"--an asterisk ("*") should appear as a prompt.
4. Set the top leftmost button on the printer's panel to LINE (the up position).
5. The disk containing the file to be printed should be in disk drive DX0 or DX1.
6. Type "LP:=DX0:filnam.ext" or "LP:=DX1:filnam.ext", depending on the appropriate disk drive.

The file should now be printing. If it is not, it is possible that the printer is set for local mode (top leftmost button in the down position). If this is the case, there is an option. Either: (1) wait for an asterisk prompt, then continue from step 4 above, or (2) if the file is long, there will be a long wait for the prompt, so hit CTRL C (see note on page 10) and continue from step 2 above.

An error message may result from the printing command.

The most common is "?FIL NOT FND", signifying "file not found". This usually means that the filename was misspelled or mis-typed, or that the file is not on the disk located in the specified disk drive. Check these possibilities, and try step 6 again.

7. To return to system level from the asterisk prompt, hit CTRL C (see note on page 10). The period prompt will appear.

COPYING FILES

To copy a file from one disk to another:

1. RT-11 version 3 should be running, and the period prompt should be displayed.

2. Type "R PIP"--an asterisk ("*") should appear as a prompt.

3. Insert the two disks involved in the file transfer into the disk drives. The system disk may be removed.

4. With an asterisk prompt, issue the copy command as detailed below. Disk drives must be specified--the first designation is the destination disk and filename, while the second designation is the source. E.g.:

   DX1:file1.ext=DX0:file2.ext

   copies the file file2.ext on the disk in DX0 to the disk in DX1 and names the new file file1.ext.

   DX1:file1.ext=DX1:file2.ext

   copies and names a file on the disk in DX1 so that two files of different names with identical contents are on the disk in DX1.

   Using the filename "*.*" for a destination will cause the copied file to have the same filename as the source file. E.g.:

   DX0:*.*=DX1:filnam.ext

   copies filnam.ext from the disk in DX1 to the disk in DX0; the new file is named filnam.ext.

   All the files with the same name or same extension may be copied by using the asterisk as a wildcard designation for the source file. E.g.:

   DX0:*.*=DX1:filnam.*

   copies all files on the disk in DX1 with the name "filnam", regardless of extension, to the disk in DX1; the new files have the same filenames as the old.

DX1:*.fil=DX0:*.ext

copies all files on the disk in DX0 with the extension ".ext" to the disk in DX1; the new files have the extension ".fil".

An asterisk will appear after the transfer is completed. Steps 3 and 4 can be repeated as needed.

5. If the system disk was taken out, it must be replaced in its disk drive before continuing.

6. To return to system level from the asterisk prompt, hit CTRL C (see note on page 10). The period prompt will appear.

If the system disk was removed and not replaced before attempting step 6, then the processor will make serious noise. It may shut down the system itself; if not, hit CTRL C (see note on page 10) until it does, then replace the system disk and re-boot.

The response to step 4 may be an error message. The most common is "File not found", followed by the filename which the processor seeks as a source for the file transfer. The filename includes the disk drive designation, DX0 or DX1.* The usual cause of this message is a misspelling or typographical error, or that the file is not on the disk located in the specified disk drive. Check these possibilities, and try again from step 4 above.

Another possible error message is "Device full", followed by the first filename which the processor could not

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*The disk drive designation may also be DK: this signifies the system disk.

fit onto the destination disk. If this occurs, it is necessary to make room on the destination disk. This can be accomplished in one of two ways: rearrange the disk to make more room available, or delete unnecessary files. First, complete steps 5 and 6 above to return to system level. You may want to see the directory of the destination disk (to list directories, see the section on files) in order to check the free space on the disk. If there is not enough space, another disk will have to be used as the destination, or files will have to be deleted, as described in the next section. If the directory listing indicates that there is sufficient room to copy the rejected file, then a re-arrangement, or squeezing, of the destination disk may help. See the section on squeezing disk space.

DELETING FILES

The delete command (issued at the period prompt in version 3) is "DEL", a space, and the filename with the disk drive specified. If no drive is specified the system disk is assumed. For example, "DEL DX1:filnam.ext" is the command to delete the file named "filnam.ext" from the disk in DX1. Note that this command could result in a "File not found" error message similar to that described in the previous section (on page 15). The system will request confirmation of the delete command by inquiring about each file named for deletion, e.g.: "DX1:filnam.ext?" (see note on page 15), to which a "Y" response is needed to execute the deletion.

Groups of files may be deleted by using the asterisk as a wildcard designation for name or extension, as described on page 14. Another useful procedure is zeroing an entire disk, that is, erasing all previous files. This procedure can also initialize a new disk:

1. RT-11 version 3 should be running, and the period prompt should be displayed.
2. The system disk should be in one disk drive, and the disk to be erased or initialized should be in the other.
3. Type "R DUP"--an asterisk ("*") should appear as a prompt.
4. Type "DX0:/Z" or "DX1:/Z" to erase the disk in the specified drive.
5. The system will ask for confirmation of this command by asking "DX0:/Init are you sure?" or "DX1:/Init are you

sure?" and an answer of "Y" is required to execute the initialization.

6. When the asterisk prompt appears, hit CTRL C (see note on page 10) to return to system level and a period prompt.

SQUEEZING DISK SPACE

The "squeeze" procedure compacts the files currently on the disk, and consolidates all the free space:

1. RT-11 version 3 should be running, and the period prompt should be displayed.

2. The system disk should be in one disk drive, and the disk to be squeezed should be in the other (unless the system disk is the one to be squeezed).

3. Type "R DUP"--an asterisk ("*") should appear as a prompt.

4. Type "DX0:/S" or "DX1:/S" to squeeze the disk in the specified drive.

5. The system will ask for confirmation by asking "DX0:/ Squeeze are you sure?" or "DX1:/Squeeze are you sure?" and an answer of "Y" is required to execute the procedure.

If the version 3 system disk is squeezed, step 6 is not necessary because the processor will automatically return to system level.

6. When the asterisk prompt appears, hit CTRL C (see note on page 10) to return to system level and a period prompt.

RUNNING BASIC

The Harvard study programs are written in the BASIC language. The BASIC level must be called from the version 3 system level:

1. RT-11 version 3 should be running, and the period prompt should be displayed.
2. Type "R BASIC". The following message should appear:
   BASIC-11/RT-11 V02-03S
   OPTIONAL FUNCTIONS (ALL,NONE,OR INDIVIDUAL)?
3. Type "ALL" (or "A" for short) to answer the question.
4. "READY" should appear. This is the BASIC level prompt: commands in BASIC are issued at this prompt.

Programs must be loaded into memory before they can be run. BASIC programs have the extension ".BAS". To load a program, get the BASIC level prompt ("READY"), type "OLD filnam", where "filnam" is the name of the program file, not including the extension (which is ".BAS"). After loading the program, a "READY" prompt will appear.

The command to run a program, issued from the "READY" prompt, is simply "RUN".

To stop a program while it is running, hit CTRL C (see note on page 10) until the "READY" message appears. Before responding with "READY", BASIC may issue a STOP message which indicates the statement number at which the program was stopped.

To exit from the BASIC level, type "BYE" at the BASIC prompt. This will return you to system level, and a period prompt.

Common error messages in BASIC are "?SYNTAX ERROR" or "?FILE NOT FOUND", which usually mean a misspelling or typo has occurred.

HARVARD PROGRAMS

There are two types of programs for the Harvard study: database programs, which maintain the database and allow the display of information; and analysis programs, which handle statistical analysis. All programs are on the version 3 system disk, and require that this disk be booted from DX0. Also on this disk are 3 comprehensive data files (with a .HAR extension): these files each contain information for all subjects of the study, in contrast to the files on the data disks, which each contain data for one individual.

Database Programs

There are 7 database programs, but they are all controlled from one master program, called MASHAR.BAS. These programs were developed to be extremely user-friendly; that is, all steps are explained in detail. Subjects can usually be identified by name (it is useful to have a listing of the database's spelling of the names), and the program indicates the data disk that should be placed in DX1 when necessary.

To start the database program, load the master program by typing "OLD MASHAR" at the BASIC prompt ("READY"). When another prompt appears, type "RUN". A menu of available options will appear; your choices are:

1. START A NEW FILE - Choose this option when a new subject is to be added to the database. The name and number of the subject are stored, and data files are opened for the subject. A message will appear as each file is opened.

2. MODIFY AN EXISTING FILE - This option is used to modify the information stored on a subject. It is usually chosen to enter or change descriptive information on a subject, but can also be used to alter data (time and distance readings) which have already been entered for a specific date and site.

A menu of modification categories (AGE, HEIGHT, EVENT, etc.) is displayed when the modification procedure is chosen. Selection of any modification category, except DATA, results in the display of the currently stored information on the screen, so that it may be checked before altering.

The categories DO, INJURIES, TRAINING ROUTINE, and COMMENTS are stored by date; hence, the date for altering the information is requested.

Some modification categories (EVENT, TIME IN TRAINING, and CYCLE) include both type and descriptive information. Type information is a general classification which may be selected (for example, EVENT types are SPRINT, MIDDLE DISTANCE, DISTANCE, and OTHER). Descriptive information provides more detail, and may simply be typed in, with each line followed by a carriage return. A line containing only a carriage return signifies the end of the information.

Modification of DATA is possible only for a date which has previously been entered through option 3 from the top-level menu, "ADD A NEW SET OF READINGS". A menu of measurement sites will be displayed; any group of sites may be altered. Data is entered as described during the "ADD A NEW SET OF READINGS" option.

3. ADD A NEW SET OF READINGS - When this option is chosen, date and DO are requested. Questions regarding injuries, requiring a yes or no answer, are asked: this information is stored for use when selection of a group of subjects,

based on the existence of an injury, is desired. Next, descriptive information on injuries, training routine, and comments is requested. A number of lines of this information may be typed in, with each line followed by a carriage return. A line containing only a carriage return signifies the end of the information.

The program describes how data (the time and distance readings) are to be entered. Each site in turn will be named; after each pair of readings is entered, the calculated velocity is displayed. The program can request 3 readings for a site, but will go on to the next site when "0,0" is entered. Before moving to the next site, the mean and standard deviation of the calculated velocities are displayed. If 3 readings were entered, there is an option to "mask", that is, throw out, one of the readings, if the standard deviation is unacceptably high. After selecting a reading to mask, the adjusted mean and standard deviations are displayed. Different maskings may be requested, and the resulting deviations observed, until the user enters a carriage return on an empty line.

It is important to let the program run through the list of sites once it has started; do not interrupt by entering CTRL C. An interruption at this point could corrupt the data files; if this inadvertantly occurs, the files of that subject could be restored from the data disk backup, but all new information or alterations for that subject since the last backup would have to be re-entered.

Once data is requested for all sites, the velocities, means, and standard deviations are stored. This operation can take a few minutes before it is completed.

4. DISPLAY INFORMATION - Data files are not in a form which can readily be displayed. This option creates

display files (with the extension .DIS) on the disk in DX0, that contain requested information for selected subjects in a form which can be displayed on the screen or printed on the Decwriter.

The program first inquires "DO YOU WANT TO SEE AN EXISTING DISPLAY FILE (Y OR N)?" An affirmative answer implies that there is already a file on the disk in DX0 which is suitable for display. This file, identified by name and extension, can be displayed on the screen or printed on the Decwriter. Note that a hardcopy of the display file can be obtained without calling this program, from the system level, using the procedure in the section on printing files (pages 12 and 13).

If a new display file is to be compiled, a name is requested (6 letters maximum); this designation, with a .DIS extension, will be the name of the file created on the disk in DX0. Care must be taken when choosing filenames: if a file already exists in DX0 with the name chosen, it would be eliminated.

The program requests the selection of subjects whose information is to be included in the display file. All subjects may be selected; the subjects may be specified by name; or selection criteria, which a subject must satisfy in order to be included, may be chosen. A file named SELEC.HAR is created on the disk in DX0: this file contains a temporary list of the selected subjects for use by the program, and may be deleted once the display file is completed.

Various types of information can be displayed; a chcice is made using a menu. The compilation of a display file for many subjects, or including much data (for example, a full display, which includes heading information and all data) may take a long time. When the compilation is finished, a new file, whose name was previously supplied by the user, with the .DIS extension, will exist on the disk in DX0. The program continues by inquiring whether the file should be displayed on the screen or printed. If the user selects screen display, the file will be shown one screenful at a time; the printing option gives instructions to print the file as detailed in this Guide.

Files have been compiled for each subject in the Harvard study, using the display routine. These files, which have the .DIS extension, have been saved on the disks labeled "HARVARD STUDY .DIS FILES (ALL SITES + HEADING + INFO)", and may be printed directly from the disks, using the procedure described on pages 12 and 13 of this Guide. The 6 letters of the filename reveal the information in the file: the first 2 letters are the subject's initials, while the last 4 letters describe the file. "HEAD" denotes a file with heading information; that is, name, age, height, event, etc. "INFO" represents a file containing date-related information: date of measurement, DO, injuries, training routine, and comments. Other designations represent a site for which the file contains data. "L" and "R" are left and right, respectively; "HUS" is humeral shaft; "HUC", humeral condyle; "TIS", tibial shaft; "PTI", proximal tibial shaft; "DTI", distal tibial shaft; "TIM", tibial metaphysis; "PAT", patella; "CAL", calcaneus; "FIB", fibula; "MET", second metatarsal.

5. EXIT - This option ends the database program, leaving the user at the BASIC "READY" prompt.

Analysis Programs

There are 3 statistical analysis programs for the Harvard study. To use one of these programs, load it by typing "OLD name" at the BASIC prompt ("READY"), where "name" is the program name (without the .BAS extension); when another prompt appears, type "RUN".

The program TRTEFF.BAS calculates statistics for a treatment effect analysis of calculated velocities. It calculates the sample standard deviation and mean of the differences of two velocity measurements taken at the same site on the same day. If 3 measurements exist at a site, the differences can be calculated in various ways. The program asks the user to make two decisions to determine the data used. A choice is given between "WORST CASE" and "FIRST TWO READINGS": "WORST CASE" causes the two extreme velocities, if there are three, to be used in the difference calculations; "FIRST TWO READINGS" causes the differences to be taken using the first two of the three velocities. The second choice presented is "WITH RESPECT TO MASK" or "IGNORING MASK". This determines whether the masked, or discarded, readings will be included in the differences.

The program includes all measurements at all sites for all subjects in the Harvard study. Messages inform the user to place the appropriate data disk into DX1. Results displayed are the mean, the sample standard deviation, ("S"), and the number of differences calculated ("N").

MEDIAN.BAS is used for population analysis, using median velocities as typical values at each site for each subject. The median values for the Harvard study are stored in a comprehensive data file, MEDIAN.HAR, which is on the version 3 system disk. The contents of this file can be altered using the program; however, the file is complete for the Harvard study, so the first option in the program menu, "ENTER MEDIAN VALUES", need not be chosen.

The second item in the menu, "DISPLAY MEDIAN VALUES FOR ONE SUBJECT", does just that. The program requests the subject's number, not name.

The next menu option is "DISPLAY AND FILE MEDIAN VALUES FOR ONE SITE". This allows a file to be formed, listing the median values for a group of subjects. The user first enters the subjects' numbers to be included (following each with a carriage return); a 0 (there is no subject whose number is 0) signifies the end. The median values may be listed in subject number order, or in numerical order from lowest to highest median velocity. This choice is presented as "LIST IN SUBJECT ORDER" versus "LIST IN NUMERICAL ORDER". The user next selects the site of interest, and a filename (maximum of 6 letters) for the file, to be opened on the disk in DX0, which will contain the list. This file will be given the extension .MED. The user is also allowed to type a line to the file, which may be used as an identifying heading if the file is printed. The list is then displayed on the screen as the file is created. On each line, the initials of the subject whose median velocity is listed is also displayed. When the list is completed, the same group may be used to form another file; if this is not desired, choose the option "RETURN TO TOP MENU".

The most valuable top level option is "CALCULATE STATS AND HISTOGRAM GROUPINGS". This option allows the user to select a group as in the previous option, then gives a choice for the calculation of statistics. "CALCULATE STATS FOR MEDIANS" uses the median velocities for one site; "CALCULATE STATS FOR DIFFERENCE OF MEDIANS" uses the differences of the medians of 2 sites. To calculate histogram frequencies, the program asks the user for information about the histogram divisions. The results are then displayed: the mean for the group, sample standard deviation ("S"), and number ("N")--note that N does not necessarily equal the number of subjects selected, since subjects may not have readings at all sites. These statistics are followed by the histogram frequencies, listed with the center velocity of each division. The procedure can be repeated, retaining the previous sub-population.

The program CHANGE.BAS is used for individual trend analysis; it maintains a comprehensive data file of corrected velocities (VCORR.HAR) and forms files of the change in velocities.

The options "ENTER CORRECTED VELOCITIES" and "ZERO VELOCITIES" (used to clear the file of old information) alter the contents of VCORR.HAR. This file is complete for the Harvard study and need not be changed.

The other option, "SET UP .CHG FILE", opens a file, on the disk in DX0, whose filename is the subject's initials, with the extension .CHG. This file contains the change in corrected velocities at each site for the subject chosen, with date-related information interspersed. The .CHG files for all subjects in the Harvard study have been compiled, and are saved on the disk labeled "HARVARD STUDY .DIS FILES (ALL SITES + HEADING + INFO) + ALL .CHG FILES"; that is, the .DIS disk #4. These files may be printed directly from this disk, using the procedure described on pages 12 and 13 of this Guide.

MISCELLANY

There is a red key labeled "COPY" located under the "RETURN" key on the Decscope terminal keyboard. If this key is hit inadvertantly, the terminal's copy mechanism goes into operation. The only apparent way to stop it is to turn off the terminal, and turn it back on. It is then necessary to shut down the system, and re-boot. If a data file was open for alteration when this happens, however, the data could be corrupted; it would then be necessary to copy the file from its backup.

It is vital that backups be kept current with changes. The Harvard database is fairly complete, so no major changes should need to be made. While the database was being entered, regular backups were made after starting a new subject's files, after modifying information, or after adding data. Usually, only the data disks were copied; if a new subject was added, the comprehensive file called NAMNUM.HAR on the version 3 system disk was backed up on the backup and printing disk. This file contains the table of all names and subject numbers in the Harvard study.

The computer system does not distinguish between upper and lower case letters in commands. In most cases, the keyboard is locked to all capitals, but if not, capitalization does not matter.

ADAPTATION OF PROGRAMS

The programs described in this Guide were developed specifically for the Harvard study. They could be used for other groups if: (1) the same measurement sites were used, (2) similar information was collected, (3) there were a maximum of 33 subjects, and (4) there were no more than 20 measurement sessions for any subject. New data disks should be used, and a new NAMNUM.HAR file, for the subjects' names and numbers, would have to be opened.

The Harvard study NAMNUM.HAR should be safely copied onto another disk. Boot version 3 from DX0, enter BASIC, and type the following:

```
NEW OPNFIL
10 DIM #1, A$(40,1)=25
20 OPEN "NAMNUM.HAR" FOR OUTPUT AS FILE #1
30 LET A$(0,0)="EOF"
40 LET A$(0,1)* "0"
50 CLOSE
60 END
RUN
```

When the above program is run, a clean NAMNUM.HAR file will exist on the disk in DX0. The database programs can now be used for a different study.

The analysis are more tailored to the Harvard study than are the database programs, and need some changes to be applicable to another study. TRTEFF.BAS needs some minor editing in the BASIC mode: lines 30-32 contain all subject numbers for which data exists. MEDIAN.BAS requires that lines 3110-3410 be edited to include the proper initials for the subject numbers represented by A%. Also, a new MEDIAN.HAR file must be set up on the version 3 system disk. Copy the Harvard study MEDIAN.HAR file onto another disk, and at the BASIC prompt, type:

```
NEW OPNMED
10 DIM #1, M(33,20)
20 OPEN "MEDIAN.HAR" FOR OUTPUT AS FILE #1
30 LET I%=0
40 LET J%=0
50 LET M(I%,J%)=0
60 LET J%=J%+1
70 IF J%<=20 THEN 50
80 LET I%=I%+1
90 IF I%<=33 THEN 40
100 CLOSE
110 END
RUN
```

The program CHANGE.BAS is set for a maximum of 11 readings. No changes need be made if this criteria is met, but a new file VCORR.HAR must be started to use it for another study. Copy the Harvard study VCORR.HAR file onto another disk, and at the BASIC prompt, type:

```
NEW OPNCOR
10 DIM #1, V%(33,220)
20 OPEN "VCORR.HAR" FOR OUTPUT AS FILE #1
30 LET I%=0
40 LET J%=0
50 LET V%(I%,J%)=0
60 LET J%=J%+1
70 IF J%<=220 THEN 50
80 LET I%=I%+1
```

```
90 IF I%<=33 THEN 40
100 CLOSE
110 END
RUN
```

To use the Harvard programs for a study involving more subjects or more measurements sessions than allotted for the Harvard study, extensive editing of the programs would be necessary. The size specifications for most files would need to be increased; this is not difficult, but must be done thoroughly, by someone familiar with BASIC, to alter filesize specifications consistently throughout the programs.

APPENDIX B

PROGRAM LISTINGS

MASHAR.BAS

```
10 REM -- THIS PROGRAM IS THE MASTER PROGRAM FOR THE HARVARD STUDY
20 REM -- DATA BASE.  IT CONTROLS THE FLOW OF EXECUTION TO
30 REM -- OTHER PROGRAMS.
40 PRINT
50 PRINT
60 PRINT "CODE";TAB(12);"OPERATION"
70 PRINT TAB(1);1;TAB(7);"START A NEW FILE"
80 PRINT TAB(1);2;TAB(7);"MODIFY AN EXISTING FILE"
90 PRINT TAB(1);3;TAB(7);"ADD A NEW SET OF READINGS"
100 PRINT TAB(1);4;TAB(7);"DISPLAY INFORMATION"
110 PRINT TAB(1);5;TAB(7);"EXIT"
120 PRINT
130 PRINT "SELECT AN OPERATION BY CODE NUMBER";
140 INPUT A% \ REM PREVENT CR ERROR
145 COMMON A$,B$
148 DIM #1,C$(40,1)=25
150 ON A% GO TO 160,230,280,320,2000
160 REM -- START A NEW FILE
165 PRINT
170 PRINT "NAME OF SUBJECT";
180 INPUT A$
181 IF A$="" THEN 40
183 OPEN "NAMNUM.HAR" AS FILE #1
184 LET I%=0
185 IF C$(I%,0)="EOF" THEN 195
186 IF C$(I%,0)=A$ THEN 189
187 LET I%=I%+1
188 GO TO 185
189 CLOSE #1
190 PRINT "FILES ALREADY OPENED FOR ";A$
191 GO TO 40
195 CLOSE #1
200 PRINT "NUMBER OF SUBJECT";
210 INPUT B$
215 GOSUB 1300
220 CHAIN "STAHAR.BAS"
230 REM -- MODIFY AN EXISTING FILE
240 GOSUB 1000 \ REM FIND NAME
250 IF F%=0 THEN 40
260 GOSUB 1300
270 CHAIN "MODHAR.BAS"
280 REM -- ADD A NEW SET OF READINGS
290 GOSUB 1000 \ REM FIND NAME
300 IF F%=0 THEN 40
305 GOSUB 1300
310 CHAIN "ADDHAR.BAS"
320 REM -- DISPLAY INFORMATION
330 PRINT
340 PRINT "DO YOU WANT TO SEE AN EXISTING DISPLAY FILE (Y OR N)";
350 INPUT Z$
360 PRINT
370 IF SEG$(Z$,1,1)="Y" THEN 430
380 PRINT "ENTER A NAME FOR THE DISPLAY FILE (MAXIMUM 6 LETTERS)."
390 PRINT "NOTE: IF A DISPLAY FILE OF THAT NAME ALREADY EXISTS,"
395 PRINT "      IT WILL BE DESTROYED."
```

```
400 INPUT F$
410 LET F$='DX0:'+SEG$(F$,1,6)+'.DIS'
415 COMMON F$
420 CHAIN 'SELHAR.BAS'
430 PRINT 'ENTER NAME OF FILE, INCLUDING EXTENSION (.DIS FOR DISPLAY FILI
440 INPUT F$ \ REM THIS WILL DISPLAY ANY SEQUENTIAL FILE ON DX0
450 LET F$='DX0:'+F$
460 PRINT
465 PRINT
470 PRINT 'CODE';TAB(14);'OPTION'
480 PRINT TAB(1);1;TAB(7);'DISPLAY ON SCREEN'
490 PRINT TAB(1);2;TAB(7);'PRINT HARDCOPY ON LINEPRINTER'
500 PRINT TAB(1);3;TAB(7);'EXIT TO TOP LEVEL MENU'
510 PRINT
520 PRINT 'SELECT OPTION BY CODE NUMBER';
530 INPUT A%
540 PRINT
550 ON A% GO TO 560,720,40
560 REM -- DISPLAY FILE F$ ON SCREEN; SCREENFUL IS 24 LINES
570 OPEN F$ FOR INPUT AS FILE #3
580 LET C%=1 \ REM LINE NUMBER COUNTER
590 IF END #3 THEN 680
600 INPUT #3,Z$
610 PRINT Z$
620 LET C%=C%+1
630 IF C%<24 THEN 590
640 PRINT 'MORE (Y OR N)';
650 INPUT Z$
660 IF SEG$(Z$,1,1)='N' THEN 700
670 GO TO 580
680 PRINT 'END OF FILE - HIT CARRIAGE RETURN TO CONTINUE';
690 INPUT Z$
700 CLOSE #3
710 GO TO 460
720 REM -- GIVE INSTRUCTIONS TO PRINT F$
730 PRINT 'TO PRINT A HARDCOPY, YOU MUST CHANGE OPERATING SYSTEMS.'
740 PRINT 'THE FILE FOR DISPLAY IS SAVED ON THE SYSTEM DISK'
745 PRINT '      UNDER THE NAME ';F$;'.'
750 PRINT
755 PRINT 'DO YOU WISH TO PRINT IT NOW (ELSE CONTINUE WITH PROGRAM)?'
760 PRINT 'Y OR N';
765 INPUT Z$
770 IF Z$='N' THEN 40
780 PRINT
785 PRINT 'EXIT FROM BASIC WITH THE 'BYE' COMMAND, THEN'
790 PRINT '      SHUT OFF THE PROCESSOR (MIDDLE THEN LEFTMOST SWITCHES).'
795 PRINT 'LEAVE SYSTEM DISK IN DX0.'
800 PRINT 'FOLLOW INSTRUCTIONS IN USER'S GUIDE TO BOOT RT11 VERSION 2'
805 PRINT '      FROM DX1 AND PRINT FILE ';F$;'.'
900 GO TO 2000
1000 REM -- THIS SUBROUTINE LOOKS FOR NAME IN NAMNUM
1010 REM -- AND GETS NUMBER (B$)..AND SETS FLAG (F%)
1015 PRINT
1020 PRINT 'NAME OF SUBJECT';
1030 INPUT A$
1040 IF A$='' THEN 40
1050 OPEN 'NAMNUM.HAR' AS FILE #1
1060 LET I%=0 \ REM LOOK FOR NAME IN NAMNUM
1070 IF C$(I%,0)='EOF' THEN 1110
1080 IF C$(I%,0)=A$ THEN 1190
1090 LET I%=I%+1
1100 GO TO 1070
1110 PRINT 'NAME NOT FOUND'
1120 CLOSE #1
1130 PRINT 'CHECK THE SPELLING'
1140 PRINT 'DO YOU WANT TO REENTER THE NAME (Y OR N)';
```

```
1150 INPUT Z$
1160 IF SEG$(Z$,1,1)="Y" THEN 1000
1170 LET F%=0 \ REM SET FLAG - NAME NOT FOUND
1180 RETURN
1190 LET B$=C$(I%,1) \ REM NAME FOUND, GET NUMBER
1200 CLOSE #1
1210 LET F%=1 \ REM SET FLAG - NAME FOUND
1220 RETURN
1300 REM -- THIS SUBROUTINE ANNOUNCES WHICH DATA DISK SHOULD BE USED.
1310 PRINT
1320 LET F%=1
1330 IF VAL(B$)>12 THEN LET F%=2
1340 IF VAL(B$)>24 THEN LET F%=3
1350 PRINT "DATA DISK";F%;"SHOULD BE IN DX1."
1360 PRINT "HIT CARRIAGE RETURN WHEN READY TO PROCEED";
1370 INPUT Z$
1380 PRINT
1390 RETURN
2000 END
```

STAHAR.BAS

```
1 REM -- THIS PROGRAM STARTS A NEW SUBJECT'S FILES ON DX1,
2 REM -- AND INSERTS THE NAME AND NUMBER INTO NAMNUM.HAR
3 REM -- IN NUMERICAL ORDER
10 COMMON A$,B$ \ REM A$ IS NAME, B$ IS NUMBER
20 DIM #1,C$(40,1)=25
30 OPEN 'NAMNUM.HAR' AS FILE #1
40 LET I%=0
50 IF C$(I%,0)='EOF' THEN 80
60 LET I%=I%+1
70 GO TO 50
80 LET C$(I%+1,0)='EOF' \ REM ADD EOF TO END
90 LET C$(I%+1,1)='0'
100 IF C$(I%-1,1)<B$ THEN 150 \ REM ASSUMES B$=1 IS FIRST
110 LET C$(I%,0)=C$(I%-1,0) \ REM MOVE NAME BACK
120 LET C$(I%,1)=C$(I%-1,1)
130 LET I%=I%-1
140 GO TO 100
150 LET C$(I%,0)=A$ \ REM INSERT NEW NAME, NUMBER
160 LET C$(I%,1)=B$
220 CLOSE #1
230 PRINT 'NAME ADDED TO NAMNUM FILE'
235 REM OPEN AND INITIALIZE .INF FILE
240 LET D$='DX1:HAR'+B$+'.INF' \ REM CONCATENATE TO FORM DX1:HAR##.INF
250 DIM #2,E$(16)=3
260 OPEN D$ FOR OUTPUT AS FILE #2
265 LET I%=0 \ REM INITIALIZE 0-8
270 IF I%>8 THEN 300
280 LET E$(I%)=''
285 LET I%=I%+1
290 GO TO 270
300 IF I%>14 THEN 330 \ REM INITIALIZE 9-14
310 LET E$(I%)='N'
315 LET I%=I%+1
320 GO TO 300
330 CLOSE #2
340 PRINT 'INFO FILE CREATED'
345 REM OPEN AND INITIALIZE SEQUENTIAL FILE
350 LET D$='DX1:HAR'+B$+'.SEQ'
360 OPEN D$ FOR OUTPUT AS FILE #3
370 PRINT #3,12
375 PRINT #3,'CYCLE'
378 PRINT #3,'END'
380 PRINT #3,'EVENT'
385 PRINT #3,'END'
390 PRINT #3,'TIME IN TRAINING'
395 PRINT #3,'END'
400 PRINT #3,'INJURIES'
405 PRINT #3,'END'
410 PRINT #3,'TRAINING ROUTINE'
415 PRINT #3,'END'
420 PRINT #3,'COMMENTS'
425 PRINT #3,'END'
430 CLOSE #3
440 PRINT 'SEQUENTIAL FILE CREATED'
445 REM OPEN AND INITIALIZE PARAMETER FILE
```

There is no text material missing here.
Pages have been incorrectly numbered.

```
450 LET D$='DX1:HAR'+B$+'.PAR'
460 DIM #4,F$(20,1)=9
470 OPEN D$ FOR OUTPUT AS FILE #4
480 LET F$(0,0)='EOF'
490 CLOSE #4
500 PRINT 'PARAMETER FILE CREATED'
505 REM OPEN DATA FILE
510 LET D$='DX1:HAR'+B$+'.DAT'
520 DIM #5,G(1200,1)
530 OPEN D$ FOR OUTPUT AS FILE #5
531 LET I%=0
532 LET G(I%,0)=0
533 LET G(I%,1)=0
534 LET I%=I%+1
535 IF I%<=1200 THEN 532
540 CLOSE #5
550 PRINT 'DATA FILE CREATED'
555 REM OPEN MASK FILE
560 LET D$='DX1:HAR'+B$+'.MSK'
570 DIM #6,H%(1200)
580 OPEN D$ FOR OUTPUT AS FILE #6
581 LET I%=0
582 LET H%(I%)=0
583 LET I%=I%+1
584 IF I%<=1200 THEN 582
590 CLOSE #6
600 PRINT 'MASK FILE CREATED'
610 REM OPEN VELOCITY FILE
620 DIM #7,J%(1200)
630 OPEN 'DX1:HAR'+B$+'.VEL' FOR OUTPUT AS FILE #7
631 LET I%=0
632 LET J%(I%)=0
633 LET I%=I%+1
634 IF I%<=1200 THEN 632
640 CLOSE #7
650 PRINT 'VELOCITY FILE CREATED'
660 REM OPEN STATISTICS FILE
670 DIM #8,K%(400,1)
680 OPEN 'DX1:HAR'+B$+'.STA' FOR OUTPUT AS FILE #8
681 LET I%=0
682 LET K%(I%,0)=0
683 LET K%(I%,1)=0
684 LET I%=I%+1
685 IF I%<=400 THEN 682
690 CLOSE #8
700 PRINT 'STATISTICS FILE CREATED'
710 CHAIN 'MASHAR.BAS' \ REM RETURN TO BEGINNING OF MASTER PROGRAM
```

MODHAR.BAS

```
10 REM -- THIS PROGRAM MODIFIES AN EXISTING FILE
20 COMMON A$,B$
30 PRINT
40 PRINT
50 PRINT "THE FOLLOWING INFORMATION ON ";A$;" MAY BE MODIFIED:"
60 PRINT
70 PRINT "CODE";TAB(20);"CODE"
80 PRINT TAB(1);1;TAB(7);"NAME";TAB(21);8;TAB(27);"EVENT"
90 PRINT TAB(1);2;TAB(7);"SEX";TAB(21);9;TAB(27);"TIME IN TRAINING"
100 PRINT TAB(1);3;TAB(7);"AGE";TAB(20);10;TAB(27);"DO"
110 PRINT TAB(1);4;TAB(7);"HANDEDNESS";TAB(20);11;TAB(27);"INJURIES"
120 PRINT TAB(1);5;TAB(7);"HEIGHT";TAB(20);12;TAB(27);"TRAINING ROUTINE"
130 PRINT TAB(1);6;TAB(7);"WEIGHT";TAB(20);13;TAB(27);"COMMENTS"
140 PRINT TAB(1);7;TAB(7);"CYCLE";TAB(20);14;TAB(27);"DATA"
145 PRINT TAB(20);15;TAB(27);"RACE"
148 PRINT TAB(20);16;TAB(27);"EXIT"
150 PRINT
160 PRINT "CODES 1-9,15 ARE INFORMATIONAL ITEMS ABOUT THE SUBJECT."
170 PRINT "CODES 10-14 PERTAIN TO A SPECIFIC TESTING DATE."
180 PRINT
190 PRINT "SELECT A MODIFICATION BY CODE NUMBER";
200 INPUT A%
210 IF A%=16 THEN CHAIN "MASHAR.BAS"
220 PRINT
221 IF A%<>15 THEN 230
222 OPEN "DX1:HAR"+B$+".INF" AS FILE #2 \ REM RACE
223 PRINT "CURRENT INFO IS RACE: ";E$(0)
224 PRINT "ENTER B OR W, OR CARRIAGE RETURN FOR NO CHANGE";
225 INPUT Z$
226 IF Z$="" THEN 510
227 LET E$(0)=SEG$(Z$,1,1)
228 GO TO 510
230 IF A%>9 THEN 1060
240 IF A%>1 THEN 400
250 PRINT "THE NAME SHOULD BE CHANGED ONLY TO CORRECT SPELLING."
260 PRINT "CURRENT INFO IS NAME: ";A$
270 PRINT "ENTER CORRECTION, OR CARRIAGE RETURN FOR NO CHANGE";
280 INPUT Z$
290 IF Z$="" THEN 30
300 DIM #1,C$(40,1)=25
310 OPEN "NAMNUM.HAR" AS FILE #1
320 LET I%=0
330 IF C$(I%,0)=A$ THEN 360
340 LET I%=I%+1
350 GO TO 330
360 LET A$=Z$
370 LET C$(I%,0)=A$ \ REM DOES NOT REALPHABETIZE
380 CLOSE #1
390 GO TO 30
400 LET D$="DX1:HAR"+B$+".INF"
410 DIM #2,E$(16)=3
420 OPEN D$ AS FILE #2
430 IF A%>6 GO TO 600
440 GOSUB 2000
```

```
450 PRINT 'CURRENT INFO IS ';G$;': ';E$(A%-1)
460 ON A%-1 GO TO 470,550,530,550,550
470 PRINT 'ENTER M OR F, OR CARRIAGE RETURN FOR NO CHANGE';
480 INPUT Z$
490 IF Z$='' THEN 510
500 LET E$(A%-1)=SEG$(Z$,1,1)
510 CLOSE #2
520 GO TO 30
530 PRINT 'ENTER L OR R, OR CARRIAGE RETURN FOR NO CHANGE';
540 GO TO 480
550 PRINT 'ENTER CORRECTION, OR CARRIAGE RETURN FOR NO CHANGE';
560 INPUT Z$
570 IF Z$='' THEN 510
580 LET E$(A%-1)=Z$
590 GO TO 510
600 PRINT 'THE ITEM REQUESTED FOR MODIFICATION IS STORED IN'
610 PRINT '      TWO PARTS: TYPE AND DESCRIPTION.'
620 PRINT 'THE TYPE INFO MAY BE CHANGED.'
630 PRINT 'THE DESCRIPTION INFO MAY BE ERASED OR ADDED TO.'
640 GOSUB 2000 \ REM GET ITEM HEADING
650 GOSUB 2200 \ REM READ .SEQ
660 LET P%=0 \ REM RESET POINTER
670 GOSUB 2400 \ REM POINT TO HEADING
675 PRINT
680 PRINT 'CURRENT INFO IS ';G$;':'
690 PRINT 'TYPE: ';E$(A%-1)
700 PRINT 'DESCRIPTION: ';
710 LET Z$='END'
720 GOSUB 2500 \ REM PRINT FROM HEADING+1 TO 'END'
730 PRINT
740 PRINT 'ENTER 1 TO CHANGE TYPE.'
750 PRINT 'ENTER 2 TO CHANGE DESCRIPTION.'
760 PRINT 'ENTER 3 FOR NO CHANGE.'
770 INPUT Z%
780 PRINT
790 ON Z% GO TO 800,1010,1005
800 PRINT G$;' TYPES ARE:'
810 ON A%-6 GO TO 820,860,910
820 PRINT 'REG -- REGULAR' \ REM CYCLE TYPES
830 PRINT 'IRR -- IRREGULAR'
840 PRINT 'NON -- NONE'
850 GO TO 940
860 PRINT 'SPR -- SPRINT' \ REM EVENT TYPES
870 PRINT 'MID -- MIDDLE DISTANCE'
880 PRINT 'DIS -- DISTANCE'
890 PRINT 'OTH -- OTHER'
900 GO TO 940
910 PRINT 'BEG -- JUST BEGINNING TRAINING' \ REM TIME IN TRAINING TYPES
9290PRIINT'FLNG---TRAINGINGSLONG BBEORELL SEASON'
940 PRINT
950 PRINT 'ENTER ';G$;' TYPE, OR CARRIAGE RETURN FOR NO CHANGE';
960 INPUT Z$
970 IF Z$='' THEN 1000
980 LET E$(A%-1)=SEG$(Z$,1,3)
1000 GO TO 730
1005 CLOSE #2
1008 GO TO 30
1010 CLOSE #2
1020 LET P%=0 \ REM RESET POINTER
1030 GOSUB 2400 \ REM POINT TO HEADING
1040 LET Z$='END' \ REM SET DELIMITER = 'END'
1050 GO TO 1490
1060 PRINT 'THE ITEM REQUESTED FOR MODIFICATION IS STORED BY DATE,'
1070 PRINT 'WHICH MUST BE ENTERED IN THE FORMAT DD-MON-YY,'
1080 PRINT 'FOR EXAMPLE: 03-DEC-82'
1090 PRINT
```

```
1100 PRINT 'DATE OF INFORMATION, OR CARRIAGE RETURN TO EXIT';
1110 INPUT H$
1120 PRINT
1130 IF H$='' THEN 30
1150 LET D$='DX1:HAR'+B$+'.PAR' \ REM FIND DATE
1160 DIM #4,P$(20,1)=9
1170 OPEN D$ AS FILE #4
1180 LET I%=0
1190 IF P$(I%,0)<>'EOF' THEN 1230
1200 CLOSE #4
1210 PRINT 'DATE NOT FOUND'
1220 GO TO 1100
1230 IF P$(I%,0)=H$ THEN 1260
1240 LET I%=I%+1
1250 GO TO 1190
1260 IF A%>10 THEN 1330 \ REM DATE FOUND
1265 PRINT 'CURRENT INFO IS DO: ';P$(I%,1) \ REM MODIFY DO
1270 PRINT 'ENTER CORRECTION, OR CARRIAGE RETURN FOR NO CHANGE';
1280 INPUT Z$
1290 IF Z$='' THEN 1315
1300 LET P$(I%,1)=Z$
1310 GOSUB 3000 \ REM SUBROUTINE TO RECALCULATE VEL, MEAN, SD
1315 CLOSE #4
1320 GO TO 30
1330 LET D$=P$(I%,1) \ REM GET DO
1331 CLOSE #4
1332 IF A%<14 THEN 1335
1333 COMMON I%,D$,H$ \ REM A%=14; MODIFY DATA
1334 CHAIN 'MODDAT.BAS'
1335 PRINT 'THE INFO MAY BE ERASED OR ADDED TO.'
1340 PRINT
1345 GOSUB 2200 \ REM READ .SEQ FILE
1350 GOSUB 2000 \ REM GET ITEM HEADING
1360 PRINT 'CURRENT INFO IS ';G$;':'
1370 PRINT H$
1380 LET P%=0 \ REM RESET POINTER
1390 GOSUB 2400 \ REM POINT TO HEADING
1400 LET G$=H$
1410 GOSUB 2400 \ REM POINT TO DATE
1420 LET Z$='' \ REM DELIMITER = BLANK
1430 GOSUB 2500 \ REM PRINT INFO
1440 GOSUB 2000 \ REM GET ITEM HEADING
1450 LET P%=0 \ REM RESET POINTER
1460 GOSUB 2400 \ REM POINT TO HEADING
1470 LET G$=H$
1480 GOSUB 2400 \ REM POINT TO DATE
1490 DIM T$(300)
1495 LET I%=0 \ REM TRANSFER UP TO POINTER TO T$()
1500 IF I%>P% THEN 1530
1510 LET T$(I%)=F$(I%)
1515 LET I%=I%+1
1520 GO TO 1500
1530 GOSUB 2600
1535 REM I%-1=LAST LINE TRANSFERRED; P%=NEXT DELIMITER
1538 REM N%=NUMBER OF LINES BETWEEN
1539 PRINT
1540 PRINT 'ENTER 1 TO DELETE INFO.'
1550 PRINT 'ENTER 2 TO ADD TO INFO.'
1560 PRINT 'ENTER 3 FOR NO CHANGE.'
1570 INPUT Z%
1580 ON Z% GO TO 1590,1640,30
1585 LET I%=P%
1590 IF I%>F%-1 THEN 1620 \ REM TRANSFER REST OF FILE
1600 LET T$(I%)=F$(I%+N%)
1605 LET I%=I%+1
1610 GO TO 1590
```

```
1620 LET T%=F%-N%
1630 GO TO 1820
1640 IF I%>P%-1 THEN 1670 \ REM TRANSFER SKIPPED PART
1650 LET T$(I%)=F$(I%)
1655 LET I%=I%+1
1660 GO TO 1640
1670 PRINT
1680 PRINT 'ENTER ADDITIONAL INFO (NO COMMAS), OR CARR RETURN TO STOP:'
1690 LET N%=0
1710 INPUT H$
1720 IF H$='' THEN 1775
1725 REM I%-1=LAST LINE TRANSFERRED TO T$; P%=DELIMITER
1730 LET I%=I%+1 \ REM INCREMENT T$ POINTER
1740 LET T$(I%-1)=H$
1750 LET N%=N%+1
1760 PRINT 'MORE';
1770 GO TO 1710
1775 LET I%=P% \ REM TRANSFER REST OF F$ FROM DELIMITER
1780 IF I%>F%-1 THEN 1810
1790 LET T$(I%+N%)=F$(I%)
1795 LET I%=I%+1
1800 GO TO 1780
1810 LET T%=F%+N%
1820 LET D$='DX1:HAR'+B$+'.SEQ'
1830 OPEN D$ FOR OUTPUT AS FILE #3
1840 PRINT #3,T%
1845 LET I%=0
1850 IF I%>T%-2 THEN 1880
1860 PRINT #3,T$(I%)
1865 LET I%=I%+1
1870 GO TO 1850
1880 PRINT #3,T$(I%)
1890 CLOSE #3
1900 GO TO 30
2000 REM -- THIS SUBROUTINE FETCHES THE ITEM HEADING FROM A%
2010 REM -- AND STORES IT IN G$
2020 LET I%=0
2030 RESTORE
2040 LET I%=I%+1
2050 READ G$
2060 IF I%<A%-1 THEN 2040 \ REM A% >= 2
2070 DATA 'SEX', 'AGE', 'HANDEDNESS', 'HEIGHT(IN)'
2080 DATA 'WEIGHT(LBS)', 'CYCLE', 'EVENT', 'TIME IN TRAINING'
2090 DATA 'DO', 'INJURIES', 'TRAINING ROUTINE', 'COMMENTS'
2100 RETURN
2200 REM -- THIS SUBROUTINE READS THE .SEQ FILE.  INPUT B$
2210 REM -- OUTPUT F%=NUMBER OF LINES IN F$()..ARRAY FILE
2220 LET D$='DX1:HAR'+B$+'.SEQ'
2230 OPEN D$ FOR INPUT AS FILE #3
2240 INPUT #3,F%
2250 DIM F$(300)
2255 LET I%=0
2260 IF END #3 THEN 2290
2270 INPUT #3,F$(I%)
2275 LET I%=I%+1
2280 GO TO 2260
2290 CLOSE #3
2300 RETURN
2400 REM -- THIS SUBROUTINE SCANS THE ARRAY FORMED FROM THE .SEQ FILE
2410 REM -- AND ADVANCES P% TO POINT TO G$ IN THE ARRAY F$()
2420 IF F$(P%)=G$ THEN RETURN
2430 LET P%=P%+1
2440 GO TO 2420
2500 REM -- THIS SUBROUTINE PRINTS A SECTION OF THE F$()..ARRAY FROM
2510 REM -- JUST AFTER THE POINTER TO THE INPUT DELIMITER Z$
2520 LET P%=P%+1
```

```
2530 IF F$(P%)=Z$ THEN RETURN
2540 PRINT F$(P%)
2550 GO TO 2520
2600 REM -- THIS SUBROUTINE MOVES THE POINTER P$ TO
2610 REM -- THE NEXT DELIMITER IN THE F$()..ARRAY.
2620 REM -- DELIMITER IS INPUT Z$
2630 REM -- OUTPUT IS N%, # OF LINES BETWEEN POINTER AND DELIMITER
2640 LET N%=0
2650 LET P%=P%+1
2660 IF F$(P%)=Z$ THEN RETURN
2670 LET N%=N%+1
2680 GO TO 2650
3000 REM -- THIS SUBROUTINE RECALCULATES VELOCITIES, MEANS, SD.
3010 REM -- THE RECALCULATION IS NECESSARY BECAUSE DO IS CHANGED.
3020 REM -- IT IS THE SAME ROUTINE AS IN ADDHAR.
3025 REM -- Z$=DO, I%=COUNTER FROM .PAR FILE
3030 PRINT
3040 PRINT 'CALCULATING AND STORING VELOCITIES, MEANS, AND SD'
3050 DIM #5,J(1200,1)
3060 OPEN 'DX1:HAR'+B$+'.DAT' AS FILE #5
3070 DIM #6,K%(1200)
3080 OPEN 'DX1:HAR'+B$+'.MSK' AS FILE #6
3090 DIM #7,L%(1200)
3100 OPEN 'DX1:HAR'+B$+'.VEL' AS FILE #7
3110 DIM #8,O%(400,1)
3120 OPEN 'DX1:HAR'+B$+'.STA' AS FILE #8
3130 LET T%=0
3140 LET C%=I%
3150 LET I%=C%*60+T%*3 \ REM LOCATION IN FILE(1200)
3160 LET J%=C%*20+T% \ REM LOCATION IN FILE(400)
3170 LET D1=J(I%,0)
3180 LET T1=J(I%,1)
3190 LET D2=J(I%+1,0)
3200 LET T2=J(I%+1,1)
3210 LET D3=J(I%+2,0)
3220 LET T3=J(I%+2,1)
3230 LET M1%=K%(I%)
3240 LET M2%=K%(I%+1)
3250 LET M3%=K%(I%+2)
3260 DEF FNV%(D,T)=INT((((D-VAL(Z$))*25400)/T)+.5) \ REM VELOCITY
3270 LET Z%=0 \ REM SUM OF VELOCITIES
3275 LET G=0 \ REM SUM OF SQUARED VELOCITIES
3280 IF M1%=1 THEN LET Z%=Z%+FNV%(D1,T1)
3285 IF M1%=1 THEN LET G=G+(FNV%(D1,T1))^2
3290 IF M2%=1 THEN LET Z%=Z%+FNV%(D2,T2)
3295 IF M2%=1 THEN LET G=G+(FNV%(D2,T2))^2
3300 IF M3%=1 THEN LET Z%=Z%+FNV%(D3,T3)
3305 IF M3%=1 THEN LET G=G+(FNV%(D3,T3))^2
3310 LET Q%=M1%+M2%+M3%
3311 IF Q%<>0 THEN 3320
3312 LET M%=0
3313 LET S%=0
3314 GO TO 3340
3320 LET M%=INT(Z%/Q%+.5)
3330 LET S%=INT(SQR(ABS((G-(Z%^2)/Q%)/(Q%-1)))+.5)
3340 REM SEND TO FILES
3345 IF T1<>0 THEN 3350
3346 LET L%(I%)=0
3347 GO TO 3355
3350 LET L%(I%)=FNV%(D1,T1)
3355 IF T2<>0 THEN 3360
3356 LET L%(I%+1)=0
3357 GO TO 3365
3360 LET L%(I%+1)=FNV%(D2,T2)
3365 IF T3<>0 THEN 3370
3366 LET L%(I%+2)=0
```

```
3367 GO TO 3380
3370 LET L%(I%+2)=FNV%(D3,T3)
3380 LET O%(J%,0)=M%
3390 LET O%(J%,1)=S%
3400 LET T%=T%+1 \ REM NEXT SITE
3410 IF T%<20 THEN 3150
3420 CLOSE #5,#6,#7,#8
3430 RETURN
```

MODDAT.BAS

```
10 REM -- MODDAT CHANGES THE DATA FOR SPECIFIED
20 REM -- SITES ON A GIVEN DATE.
30 REM -- I%=READING #-1; H$=DATE; D$=DO
40 COMMON A$,B$
45 COMMON I%,D$,H$
50 LET F%=0 \ REM FLAG
55 LET Z$=D$
58 LET C%=I%
60 PRINT
70 PRINT "DATA MAY BE CHANGED FOR THE FOLLOWING SITES:"
80 PRINT
90 PRINT "CODE";TAB(45);"CODE"
100 LET G%=1
110 RESTORE
120 READ G$
130 IF G$="" THEN 220
140 PRINT TAB(1);G%;TAB(7);"LEFT";TAB(14);G$;
150 PRINT TAB(37);"RIGHT";TAB(45);G%+10
160 LET G%=G%+1
170 GO TO 120
180 DATA "HUMERAL SHAFT","HUMERAL CONDYLE","TIBIAL SHAFT"
190 DATA "PROXIMAL TIBIAL SHAFT","DISTAL TIBIAL SHAFT"
200 DATA "TIBIAL METAPHYSIS","PATELLA","CALCANEOUS"
210 DATA "FIBULA","SECOND METATARSAL",""
220 PRINT
230 PRINT "SELECT SITES BY CODE NUMBER, OR CARRIAGE RETURN TO EXIT";
240 INPUT T$
250 IF T$="" THEN 990
260 LET F%=1 \ REM SET FLAG
270 LET T%=VAL(T$)-1 \ REM SITE COUNTER FROM 0-19
280 PRINT
290 IF T%<10 THEN PRINT "LEFT ";
300 IF T%>9 THEN PRINT "RIGHT ";
310 LET Z%=T%-10
320 IF T%<10 THEN LET Z%=T%
330 RESTORE
340 LET G%=0
350 READ G$
360 IF G%=Z% THEN 390
370 LET G%=G%+1
380 GO TO 350
390 PRINT G$;" -- ";H$;":"
400 LET M1%=0
410 LET M2%=0
420 LET M3%=0
430 LET D1=0
440 LET D2=0
450 LET D3=0
460 LET T1=0
470 LET T2=0
480 LET T3=0
490 DEF FNV%(D,T)=INT((((D-VAL(Z$))*25400)/T)+.5)
500 PRINT "1. ENTER DISTANCE, TIME";
510 INPUT D1,T1
520 IF D1=0 THEN 800
```

```
530 LET M1%=1
540 PRINT ,"VELOCITY =";FNV%(D1,T1)
550 PRINT "2. ENTER DISTANCE, TIME";
560 INPUT D2,T2
570 IF D2=0 THEN 650
580 LET M2%=1
590 PRINT ,"VELOCITY =";FNV%(D2,T2)
600 PRINT "3. ENTER DISTANCE, TIME";
610 INPUT D3,T3
620 IF D3=0 THEN 650
630 LET M3%=1
640 PRINT ,"VELOCITY =";FNV%(D3,T3)
650 GOSUB 1500
660 PRINT "MEAN =";M%,"SD =";S%
670 IF M1%+M2%+M3%<>3 THEN 800
680 PRINT "MASK READING 1,2,3, CARRIAGE RETURN IF OK, 0 TO UNMASK";
690 INPUT M$ \ REM MASK OPTION
700 IF M$="" THEN 800
710 LET M1%=1
720 LET M2%=1
730 LET M3%=1
740 IF VAL(M$)=1 THEN LET M1%=0
750 IF VAL(M$)=2 THEN LET M2%=0
760 IF VAL(M$)=3 THEN LET M3%=0
770 GOSUB 1500
780 PRINT "MEAN =";M%,"SD =";S%
790 GO TO 680
800 REM SEND DATA, MASK TO FILES
810 DIM #4,J(1200,1)
820 OPEN "DX1:HAR"+B$+".DAT" AS FILE #4
840 LET I%=C%*60+T%*3 \ REM LOCATION IN FILE
850 LET J(I%,0)=D1
860 LET J(I%,1)=T1
870 LET J(I%+1,0)=D2
880 LET J(I%+1,1)=T2
890 LET J(I%+2,0)=D3
900 LET J(I%+2,1)=T3
910 CLOSE #4
920 DIM #5,K%(1200)
930 OPEN "DX1:HAR"+B$+".MSK" AS FILE #5
940 LET K%(I%)=M1%
950 LET K%(I%+1)=M2%
960 LET K%(I%+2)=M3%
970 CLOSE #5
980 GO TO 60
990 IF F%=0 THEN CHAIN "MODHAR.BAS"
1000 REM CALCULATES VEL, M, AND SD, SEND TO FILE.
1010 REM RECALCULATES ALL DATA FOR A GIVEN DATE.
1020 PRINT
1030 PRINT "CALCULATING AND STORING VELOCITIES, MEANS, AND SD"
1040 OPEN "DX1:HAR"+B$+".DAT" AS FILE #4
1050 OPEN "DX1:HAR"+B$+".MSK" AS FILE #5
1060 DIM #6,L%(1200)
1070 OPEN "DX1:HAR"+B$+".VEL" AS FILE #6
1080 DIM #7,N%(400,1)
1090 OPEN "DX1:HAR"+B$+".STA" AS FILE #7
1100 LET T%=0
1110 LET I%=C%*60+T%*3 \ REM LOCATION IN FILE(1200)
1120 LET J%=C%*20+T% \ REM LOCATION IN FILE(400)
1130 LET D1=J(I%,0)
1140 LET T1=J(I%,1)
1150 LET D2=J(I%+1,0)
1160 LET T2=J(I%+1,1)
1170 LET D3=J(I%+2,0)
1180 LET T3=J(I%+2,1)
1190 LET M1%=K%(I%)
```

```
1200 LET M2%=K%(I%+1)
1210 LET M3%=K%(I%+2)
1220 GOSUB 1500 \ REM CALCULATE M, SD
1230 IF T1<>0 THEN 1260
1240 LET L%(I%)=0
1250 GO TO 1270
1260 LET L%(I%)=FNV%(D1,T1)
1270 IF T2<>0 THEN 1300
1280 LET L%(I%+1)=0
1290 GO TO 1310
1300 LET L%(I%+1)=FNV%(D2,T2)
1310 IF T3<>0 THEN 1340
1320 LET L%(I%+2)=0
1330 GO TO 1350
1340 LET L%(I%+2)=FNV%(D3,T3)
1350 LET N%(J%,0)=M%
1360 LET N%(J%,1)=S%
1370 LET T%=T%+1 \ REM NEXT SITE
1380 IF T%<20 THEN 1110
1390 CLOSE #4,#5,#6,#7
1400 CHAIN 'MODHAR.BAS'
1500 REM -- THIS SUBROUTINE CALCULATES AND ROUNDS THE MEAN M% AND
1510 REM -- STANDARD DEVIATION S% OF THE VELOCITIES,
1520 REM -- WITH RESPECT TO THE MASK.
1530 LET Z%=0 \ REM SUM OF VELOCITIES
1540 LET G=0 \ REM SUM OF SQUARED VELOCITIES
1550 IF M1%=1 THEN LET Z%=Z%+FNV%(D1,T1)
1560 IF M1%=1 THEN LET G=G+(FNV%(D1,T1))^2
1570 IF M2%=1 THEN LET Z%=Z%+FNV%(D2,T2)
1580 IF M2%=1 THEN LET G=G+(FNV%(D2,T2))^2
1590 IF M3%=1 THEN LET Z%=Z%+FNV%(D3,T3)
1600 IF M3%=1 THEN LET G=G+(FNV%(D3,T3))^2
1610 LET Q%=M1%+M2%+M3%
1620 IF Q%<>0 THEN 1660
1630 LET M%=0
1640 LET S%=0
1650 RETURN
1660 LET M%=INT(Z%/Q%+.5)
1670 LET S%=INT(SQR(ABS((G-(Z%^2)/Q%)/(Q%-1)))+.5)
1680 RETURN
```

ADDHAR.BAS

```
10 REM -- THIS PROGRAM ADDS INFO AND DATA TO SUBJECT'S FILES
20 COMMON A$,B$
30 PRINT
40 PRINT 'DATE SHOULD BE ENTERED IN THE FORMAT DD-MON-YY,'
45 PRINT 'FOR EXAMPLE: 03-DEC-82.'
50 PRINT 'ENTER DATE OF READING, OR CARRIAGE RETURN TO EXIT';
60 INPUT C$
70 IF C$='' THEN CHAIN 'MASHAR.BAS'
80 PRINT 'ENTER DO IN INCHES';
90 INPUT D$
100 PRINT
110 DIM #1,E$(20,1)=9
120 OPEN 'DX1:HAR'+B$+'.PAR' AS FILE #1
130 LET C%=0
135 LET R%=0 \ REM SET FOR NO RECALC
140 IF E$(C%,0)='EOF' THEN 230
150 IF E$(C%,0)=C$ THEN 180
160 LET C%=C%+1
170 GO TO 140
180 PRINT 'DATE ALREADY EXISTS WITH INFORMATION.'
185 IF E$(C%,1)<>D$ THEN LET R%=1 \ REM RECALC IF NEW DO
190 LET E$(C%,1)=D$ \ REM ENTER DO
200 CLOSE #1
210 PRINT 'DATA MAY BE ENTERED.'
220 GO TO 660
230 LET E$(C%,0)=C$
240 LET E$(C%,1)=D$
250 LET E$(C%+1,0)='EOF'
260 CLOSE #1
270 REM UPDATE INJURY SELECTION INFORMATION
280 DIM #2,H$(16)=3
290 OPEN 'DX1:HAR'+B$+'.INF' AS FILE #2
300 RESTORE
310 LET I%=8
320 DATA 'ANY INJURIES', 'A KNEE INJURY', 'SHIN SPLINTS'
330 DATA 'A STRESS FRACTURE','AN ACHILLES TENDON INJURY','A FOOT INJURY'
340 IF I%=14 THEN 420
350 READ G$
360 LET I%=I%+1
370 IF H$(I%)='Y' THEN 340
380 PRINT 'DOES ';A$;' HAVE ';G$;' (Y OR N)';
390 INPUT Z$
400 LET H$(I%)=SEG$(Z$,1,1)
410 IF I%<>9 THEN 340
415 IF SEG$(Z$,1,1)='N' THEN 420
416 GO TO 340
420 CLOSE #2
430 GOSUB 3000 \ REM READ .SEQ FILE
440 LET P%=0 \ REM F$()..POINTER
450 LET Z$='INJURIES'
460 GOSUB 3200 \ REM POINT TO INJURIES HEADING IN F$()
470 DIM T$(300)
480 LET T%=0 \ REM NUMBER OF LINES TRANSFERRED TO T$
490 LET I%=0 \ REM NEXT LINE OF F$()..TO BE TRANSFERRED
500 LET G$='INJURY STATUS'
```

```
510 GOSUB 3300
520 LET G$='TRAINING ROUTINE INFO'
530 GOSUB 3300
540 LET G$='COMMENTS'
550 GOSUB 3300
555 LET T$(T%)='END'
557 T%=T%+1
560 REM WRITE T$ INTO .SEQ FILE
570 OPEN 'DX1:HAR'+B$+'.SEQ' FOR OUTPUT AS FILE #3
580 PRINT #3,T%,',',
590 LET I%=0
600 IF I%=T%-1 THEN 640
610 PRINT #3,T$(I%),',',
620 LET I%=I%+1
630 GO TO 600
640 PRINT #3,T$(I%)
650 CLOSE #3
660 REM INPUT DATA
670 PRINT
680 PRINT 'DO YOU WANT TO ENTER DATA FOR ';A$;' ON ';C$;' (Y OR N)';
690 INPUT Z$
700 IF SEG$(Z$,1,1)='Y' THEN 710
703 IF R%=1 THEN 2350
705 CHAIN 'MASHAR.BAS'
710 PRINT
720 PRINT '   BELOW YOU WILL BE ASKED TO ENTER DISTANCE READINGS'
730 PRINT 'IN INCHES AND TIME READINGS IN MICROSECONDS FOR THE'
740 PRINT 'VARIOUS MEASUREMENT SITES.'
750 PRINT '   THE VELOCITY WILL BE CALCULATED AND DISPLAYED AFTER'
760 PRINT 'EACH SET OF DATA IS ENTERED.'
770 PRINT '   UP TO 3 READINGS MAY BE ENTERED FOR EACH SITE.'
780 PRINT '   WHEN THE DATA FOR THE SITE IS ENTERED, THE MEAN AND'
790 PRINT 'STANDARD DEVIATION OF THE VELOCITIES WILL BE DISPLAYED.'
800 PRINT '   IF 3 READINGS HAVE BEEN ENTERED FOR THE SITE, ONE OF'
810 PRINT 'THEM MAY BE MASKED TO IMPROVE THE STANDARD DEVIATION.'
820 PRINT '   IF A READING IS NOT AVAILABLE ENTER: 0,0'
830 LET T%=0 \ REM SITE COUNTER 0-19
840 DATA 'LEFT HUMERAL SHAFT','LEFT HUMERAL CONDYLE','LEFT TIBIAL SHAFT'
850 DATA 'LEFT PROXIMAL TIBIAL SHAFT','LEFT DISTAL TIBIAL SHAFT'
860 DATA 'LEFT TIBIAL METAPHYSIS','LEFT PATELLA','LEFT CALCANEOUS'
870 DATA 'LEFT FIBULA','LEFT SECOND METATARSAL','RIGHT HUMERAL SHAFT'
880 DATA 'RIGHT HUMERAL CONDYLE','RIGHT TIBIAL SHAFT'
890 DATA 'RIGHT PROXIMAL TIBIAL SHAFT','RIGHT DISTAL TIBIAL SHAFT'
900 DATA 'RIGHT TIBIAL METAPHYSIS','RIGHT PATELLA'
910 DATA 'RIGHT CALCANEOUS','RIGHT FIBULA','RIGHT SECOND METATARSAL'
920 DEF FNV%(D,T)=INT((((D-VAL(D$))*25400)/T)+.5) \ REM VELOCITY
921 RESTORE
922 LET G%=0
923 READ G$ \ REM READ PREVIOUS DATA LINES TO END
924 LET G%=G%+1
925 IF G%<6 THEN 923
930 READ G$
940 LET M1%=0
950 LET M2%=0
960 LET M3%=0
970 LET D1=0
980 LET D2=0
990 LET D3=0
1000 LET T1=0
1010 LET T2=0
1020 LET T3=0
1030 PRINT
1040 PRINT G$;':'
1050 PRINT '1. ENTER DISTANCE, TIME';
1060 INPUT D1,T1
1070 IF D1=0 THEN 2144
```

```
1080 LET M1%=1
1090 PRINT ,'VELOCITY =';FNV%(D1,T1)
1100 PRINT '2. ENTER DISTANCE, TIME';
1110 INPUT D2,T2
1120 IF D2=0 THEN 2010
1130 LET M2%=1
1140 PRINT ,'VELOCITY =';FNV%(D2,T2)
1160 PRINT '3. ENTER DISTANCE, TIME';
1170 INPUT D3,T3
1180 IF D3=0 THEN 2010
1190 LET M3%=1
2000 PRINT ,'VELOCITY =';FNV%(D3,T3)
2010 GOSUB 3600
2020 PRINT 'MEAN =';M%,'SD =';S%
2030 IF M1%+M2%+M3%<>3 THEN 2144
2040 PRINT 'MASK READING 1,2,3, CARRIAGE RETURN IF OK, 0 TO UNMASK';
2050 INPUT Z$ \ REM MASK OPTION
2060 IF Z$='' THEN 2144
2070 LET M1%=1
2080 LET M2%=1
2090 LET M3%=1
2100 IF VAL(Z$)=1 THEN LET M1%=0
2110 IF VAL(Z$)=2 THEN LET M2%=0
2120 IF VAL(Z$)=3 THEN LET M3%=0
2130 GOSUB 3600
2140 PRINT 'MEAN =';M%,'SD =';S%
2143 GO TO 2040
2144 REM STORE D,T,M IN ARRAYS FOR FUTURE CALCULATION
2145 REM AND STORAGE OF STATS
2146 DIM U%(20,2) \ REM MASK X 3
2147 DIM W(20,2) \ REM DISTANCE X 3
2148 DIM X(20,2) \ REM TIME X 3
2149 LET U%(T%,0)=M1%
2150 LET U%(T%,1)=M2%
2151 LET U%(T%,2)=M3%
2152 LET W(T%,0)=D1
2153 LET W(T%,1)=D2
2154 LET W(T%,2)=D3
2155 LET X(T%,0)=T1
2156 LET X(T%,1)=T2
2157 LET X(T%,2)=T3
2160 REM SEND DATA, MASK TO FILES
2170 DIM #4,J(1200,1)
2180 OPEN 'DX1:HAR'+B$+'.DAT' AS FILE #4
2190 LET I%=C%*60+T%*3 \ REM LOCATION IN FILE
2200 LET J(I%,0)=D1
2210 LET J(I%,1)=T1
2220 LET J(I%+1,0)=D2
2230 LET J(I%+1,1)=T2
2240 LET J(I%+2,0)=D3
2250 LET J(I%+2,1)=T3
2260 CLOSE #4
2270 DIM #5,K%(1200)
2280 OPEN 'DX1:HAR'+B$+'.MSK' AS FILE #5
2290 LET K%(I%)=M1%
2300 LET K%(I%+1)=M2%
2310 LET K%(I%+2)=M3%
2320 CLOSE #5
2330 LET T%=T%+1
2340 IF T%<20 THEN 930 \ REM NEXT SITE
2350 REM CALCULATE VEL, MEAN, AND SD, SEND TO FILE
2360 PRINT
2370 PRINT 'CALCULATING AND STORING VELOCITIES, MEANS, AND SD'
2400 DIM #6,L%(1200)
2410 OPEN 'DX1:HAR'+B$+'.VEL' AS FILE #6
2420 DIM #7,N%(400,1)
```

```
2430 OPEN 'DX1:HAR'+B$+'.STA' AS FILE #7
2440 LET T%=0
2450 LET I%=C%*60+T%*3 \ REM LOCATION IN FILE(1200)
2460 LET J%=C%*20+T% \ REM LOCATION IN FILE (400)
2465 REM RETRIEVE D,T,M FROM ARRAYS FOR CALCULATION
2466 REM AND STORAGE OF STATS
2470 LET M1%=U%(T%,0)
2480 LET M2%=U%(T%,1)
2490 LET M3%=U%(T%,2)
2500 LET D1=W(T%,0)
2510 LET D2=W(T%,1)
2520 LET D3=W(T%,2)
2530 LET T1=X(T%,0)
2540 LET T2=X(T%,1)
2550 LET T3=X(T%,2)
2560 GOSUB 3600 \ REM CALCULATE M,SD
2565 IF T1<>0 THEN 2570
2566 LET L%(I%)=0
2567 GO TO 2575
2570 LET L%(I%)=FNV%(D1,T1)
2575 IF T2<>0 THEN 2580
2576 LET L%(I%+1)=0
2577 GO TO 2585
2580 LET L%(I%+1)=FNV%(D2,T2)
2585 IF T3<>0 THEN 2590
2586 LET L%(I%+2)=0
2587 GO TO 2600
2590 LET L%(I%+2)=FNV%(D3,T3)
2600 LET N%(J%,0)=M%
2610 LET N%(J%,1)=S%
2620 LET T%=T%+1 \ REM NEXT SITE
2630 IF T%<20 THEN 2450
2640 CLOSE #6,#7
2650 CHAIN 'MASHAR.BAS'
3000 REM -- THIS SUBROUTINE READS THE .SEQ FILE.  INPUT B$ (NUMBER)
3010 REM -- OUTPUT F%=NUMBER OF LINES IN F$()..ARRAY OF FILE
3020 OPEN 'DX1:HAR'+B$+'.SEQ' FOR INPUT AS FILE #3
3030 INPUT #3,F%
3040 DIM F$(300)
3050 LET I%=0
3060 IF END #3 THEN 3100
3070 INPUT #3,F$(I%)
3080 LET I%=I%+1
3090 GO TO 3060
3100 CLOSE #3
3110 RETURN
3200 REM -- THIS SUBROUTINE SCANS THE ARRAY FORMED FROM THE .SEQ
3210 REM -- FILE AND ADVANCES P% TO POINT TO Z$ IN THE ARRAY F$()
3220 LET P%=P%+1
3230 IF F$(P%)=Z$ THEN RETURN
3240 GO TO 3220
3300 REM -- THIS SUBROUTINE TRANSFERS F$()..TO T$()..FROM I%=FIRST LINE
3310 REM -- NOT TRANSFERRED TO JUST BEFORE THE NEXT DELIMITER 'END'.
3320 REM -- IT THEN INSERTS INTO T$()..THE DATE,
3330 REM -- DESCRIPTIVE INFO, AND A DELIMITING BLANK.
3340 REM -- IT UPDATES T%.
3350 LET Z$='END'
3360 GOSUB 3200 \ REM P%=LINE OF DELIMITER
3370 IF I%=P% THEN 3420 \ REM TRANSFER TO JUST BEFORE 'END'
3380 LET T$(T%)=F$(I%)
3390 LET I%=I%+1
3400 LET T%=T%+1
3410 GO TO 3370
3420 LET T$(T%)=C$ \ REM INSERT DATE
3430 LET T%=T%+1
3440 PRINT
```

```
3450 PRINT 'ENTER ';G$;' (NO COMMAS), OR CARR RETURN TO STOP:'
3460 INPUT Z$
3470 IF Z$='' THEN 3520
3480 LET T$(T%)=Z$
3490 LET T%=T%+1
3500 PRINT 'MORE';
3510 GO TO 3460
3520 LET T$(T%)='' \ REM INSERT DATE DELIMITER
3530 LET T%=T%+1
3540 RETURN
3600 REM -- THIS SUBROUTINE CALCULATES AND ROUNDS THE MEAN M% AND
3610 REM -- STANDARD DEVIATION S% OF THE VELOCITIES,
3620 REM -- WITH RESPECT TO THE MASK.
3630 LET Z%=0
3635 LET G=0
3640 IF M1%=1 THEN LET Z%=Z%+FNV%(D1,T1)
3645 IF M1%=1 THEN LET G=G+(FNV%(D1,T1))^2
3650 IF M2%=1 THEN LET Z%=Z%+FNV%(D2,T2)
3655 IF M2%=1 THEN LET G=G+(FNV%(D2,T2))^2
3660 IF M3%=1 THEN LET Z%=Z%+FNV%(D3,T3)
3665 IF M3%=1 THEN LET G=G+(FNV%(D3,T3))^2
3670 LET Q%=M1%+M2%+M3%
3671 IF Q%<>0 THEN 3680
3672 LET M%=0
3673 LET S%=0
3674 RETURN
3680 LET M%=INT(Z%/Q%+.5)
3690 LET S%=INT(SQR(ABS((G-(Z%^2)/Q%)/(Q%-1)))+.5)
3700 RETURN
```

SELHAR.BAS

```
10 REM -- THIS SELECTION ROUTINE MAKES A SEQUENTIAL FILE
20 REM -- OF APPLICABLE NAMES, NUMBERS.  THIS FILE IS SELEC.HAR.
30 REM -- CONTROL IS THEN PASSED TO DISHAR.BAS.
35 COMMON A$,B$
40 COMMON F$ \ REM NAME OF DISPLAY FILE
50 PRINT
60 PRINT 'INFORMATION CAN BE DISPLAYED FOR A SELECTED GROUP:'
70 PRINT
80 PRINT 'CODE'
90 PRINT TAB(1);1;TAB(7);'ALL SUBJECTS'
100 PRINT TAB(1);2;TAB(7);'CHOOSE NAMES'
110 PRINT TAB(1);3;TAB(7);'CHOOSE SELECTION CRITERIA'
120 PRINT TAB(1);4;TAB(7);'EXIT TO TOP LEVEL MENU'
125 PRINT
130 PRINT 'SELECT OPTION BY CODE NUMBER';
140 INPUT A%
150 ON A% GO TO 200,310,600,160
160 CHAIN 'MASHAR.BAS'
200 REM -- CONVERT NAMNUM.HAR INTO SELEC.HAR
210 OPEN 'SELEC.HAR' FOR OUTPUT AS FILE #1
220 DIM #2,C$(40,1)=25
230 OPEN 'NAMNUM.HAR' FOR INPUT AS FILE #2
240 LET I%=0
250 IF C$(I%,0)='EOF' THEN 290
260 PRINT #1,C$(I%,0),',',C$(I%,1)
270 LET I%=I%+1
280 GO TO 250
290 CLOSE #1,#2
300 CHAIN 'DISHAR.BAS'
310 REM -- PUT NAMES IN SELEC.HAR
320 LET F%=0 \ REM RESET FLAG
330 OPEN 'SELEC.HAR' FOR OUTPUT AS FILE #1
340 PRINT
350 PRINT 'NAME, OR CARRIAGE RETURN TO STOP';
360 INPUT A$
370 IF A$<>'' THEN 420
380 CLOSE #1
390 IF F%=0 THEN 50
400 CHAIN 'DISHAR.BAS'
420 OPEN 'NAMNUM.HAR' FOR INPUT AS FILE #2
430 LET I%=0 \ REM LOOK FOR NAME IN NAMNUM
440 IF C$(I%,0)='EOF' THEN 480
450 IF C$(I%,0)=A$ THEN 520
460 LET I%=I%+1
470 GO TO 440
480 PRINT 'NAME NOT FOUND'
490 CLOSE #2
500 PRINT 'CHECK THE SPELLING'
510 GO TO 340
520 PRINT #1,C$(I%,0),',',C$(I%,1) \ REM NAME FOUND
525 CLOSE #2
530 LET F%=1
540 GO TO 340
600 REM -- CHOOSE SELECTION CRITERIA
610 REM -- THE ROUTINE FIRST COPIES THE WHOLE OF NAMNUM TO SELEC.HAR.
620 REM -- BASED ON CHOSEN CRITERIA, SELEC.HAR IS SCANNED AND THE
```

```
630 REM -- SELECTED NAMES ARE TRANSFERRED TO A TEMPORARY ARRAY N$.
640 REM -- N$ IS THE DUMPED BACK TO SELEC.HAR
645 REM -- FOR THE NEXT CRITERION.
650 \ REM FIRST COPY NAMNUM.HAR TO SELEC.HAR
660 OPEN 'SELEC.HAR' FOR OUTPUT AS FILE #1
670 OPEN 'NAMNUM.HAR' FOR INPUT AS FILE #2
680 LET I%=0
690 IF C$(I%,0)='EOF' THEN 730
700 PRINT #1,C$(I%,0),',',C$(I%,1)
710 LET I%=I%+1
720 GO TO 690
730 CLOSE #1,#2
740 REM SELECT CRITERIA
745 LET F1%=0 \ REM DISK FLAGS
746 LET F2%=0
747 LET F3%=0
750 PRINT
760 PRINT 'THE FOLLOWING CRITERIA MAY BE USED TO SELECT SUBJECTS:'
770 PRINT
780 PRINT 'CODE';TAB(25);'CODE'
790 PRINT TAB(1);1;TAB(6);'RACE';TAB(25);9;TAB(31);'TIME IN TRAINING'
800 PRINT TAB(1);2;TAB(6);'SEX';TAB(25);10;TAB(31);'ANY INJURY'
810 PRINT TAB(1);3;TAB(6);'AGE';TAB(25);11;TAB(31);'KNEE INJURY'
820 PRINT TAB(1);4;TAB(6);'HANDEDNESS';TAB(25);12;TAB(31);'SHIN SPLINTS'
830 PRINT TAB(1);5;TAB(6);'HEIGHT';TAB(25);13;TAB(31);'STRESS FRACTURE'
840 PRINT TAB(1);6;TAB(6);'WEIGHT';TAB(25);14;TAB(31);'ACHILLES INJURY'
850 PRINT TAB(1);7;TAB(6);'CYCLE';TAB(25);15;TAB(31);'FOOT INJURY'
860 PRINT TAB(1);8;TAB(6);'EVENT RANGE';TAB(25);16;TAB(31);'DELETE NAME'
870 PRINT
880 PRINT 'CHOOSE A CRITERION BY CODE, OR CARRIAGE RETURN TO STOP';
890 INPUT T$
900 IF T$=' ' THEN CHAIN 'DISHAR.BAS'
910 LET T%=VAL(T$)
920 DIM N$(40,1)
930 PRINT
940 IF T%<>16 THEN 1180
950 \ REM DELETE NAME
960 PRINT 'NAME TO BE DELETED FROM SELECTION LIST';
970 INPUT Z$
980 IF Z$=' ' THEN 740
990 OPEN 'SELEC.HAR' FOR INPUT AS FILE #1
1000 LET I%=0
1010 IF END #1 THEN 1080
1020 INPUT #1,A$,B$ \ REM SELEC.HAR TO N$ ARRAY
1030 IF A$=Z$ THEN 1010 \ REM CHECK FOR DELETED NAME
1040 LET N$(I%,0)=A$
1050 LET N$(I%,1)=B$
1060 LET I%=I%+1
1070 GO TO 1010
1080 CLOSE #1 \ REM CLOSE SELEC.HAR FOR INPUT
1090 LET N$(I%,0)='EOF' \ REM ADD EOF TO N$ ARRAY
1100 OPEN 'SELEC.HAR' FOR OUTPUT AS FILE #1
1110 LET I%=0 \ REM DUMP N$ TO SELEC.HAR
1120 IF N$(I%,0)='EOF' THEN 1160
1130 PRINT #1,N$(I%,0),',',N$(I%,1)
1140 LET I%=I%+1
1150 GO TO 1120
1160 CLOSE #1
1170 GO TO 740
1180 IF T%<10 THEN 1420
1190 \ REM INJURY CRITERION
1200 IF T%=10 THEN LET I$='ANY INJURY'
1210 IF T%=11 THEN LET I$='A KNEE INJURY'
1220 IF T%=12 THEN LET I$='SHIN SPLINTS'
1230 IF T%=13 THEN LET I$='A STRESS FRACTURE'
1240 IF T%=14 THEN LET I$='AN ACHILLES INJURY'
```

```
1250 IF T%=15 THEN LET I$='A FOOT INJURY'
1260 PRINT 'DO YOU WISH TO INCLUDE SUBJECTS WHO HAVE HAD'
1270 PRINT I$;' (TYPE 'Y'), OR THOSE WHO HAVEN'T (TYPE 'N')';
1280 INPUT Z$
1285 PRINT
1290 LET S$=SEG$(Z$,1,1)
1300 OPEN 'SELEC.HAR' FOR INPUT AS FILE #1
1310 LET I%=0
1320 IF END #1 THEN 1080 \ REM DUMP N$ TO SELEC.HAR
1330 INPUT #1,A$,B$
1335 GOSUB 2500
1340 DIM #3,E$(16)=3
1350 OPEN 'DX1:HAR'+B$+'.INF' AS FILE #3
1360 IF E$(T%-1)<>S$ THEN 1390
1370 LET N$(I%,0)=A$ \ REM TRANSFER TO N$ ARRAY
1380 LET N$(I%,1)=B$
1385 LET I%=I%+1
1390 CLOSE #3
1410 GO TO 1320
1420 ON T% GO TO 1430,1450,1470,1650,1670,1720,1770,1860,1940
1430 PRINT 'SELECT B OR W'; \ REM RACE
1440 GO TO 1280
1450 PRINT 'SELECT M OR F'; \ REM SEX
1460 GO TO 1280
1470 PRINT 'SELECT AGE LESS THAN'; \ REM AGE
1480 INPUT Z2%
1490 PRINT 'SELECT AGE GREATER THAN';
1500 INPUT Z1%
1505 \ REM SELECT WITH Z1% LOWER LIMIT AND Z2% UPPER LIMIT
1510 PRINT
1515 OPEN 'SELEC.HAR' FOR INPUT AS FILE #1
1520 LET I%=0
1530 IF END #1 THEN 1080
1540 INPUT #1,A$,B$
1545 GOSUB 2500
1550 OPEN 'DX1:HAR'+B$+'.INF' AS FILE #3
1560 IF VAL(E$(T%-1))<Z2% THEN 1600
1570 CLOSE #3
1590 GO TO 1530
1600 IF VAL(E$(T%-1))>Z1% THEN 1620
1610 GO TO 1570
1620 LET N$(I%,0)=A$
1630 LET N$(I%,1)=B$
1635 LET I%=I%+1
1640 GO TO 1570
1650 PRINT 'SELECT L OR R'; \ REM HANDEDNESS
1660 GO TO 1280
1670 PRINT 'SELECT HEIGHT(IN) LESS THAN';
1680 INPUT Z2%
1690 PRINT 'SELECT HEIGHT(IN) GREATER THAN';
1700 INPUT Z1%
1710 GO TO 1510
1720 PRINT 'SELECT WEIGHT(LBS) LESS THAN';
1730 INPUT Z2%
1740 PRINT 'SELECT WEIGHT(LBS) GREATER THAN';
1750 INPUT Z1%
1760 GO TO 1510
1770 PRINT 'CYCLE TYPES ARE:'
1780 PRINT 'REG -- REGULAR'
1790 PRINT 'IRR -- IRREGULAR'
1800 PRINT 'NON -- NONE'
1810 PRINT
1820 PRINT 'SELECT WHICH CYCLE TYPE';
1830 INPUT Z$
1840 LET S$=SEG$(Z$,1,3)
1850 GO TO 1300
```

```
1860 PRINT "EVENT TYPES ARE:"
1870 PRINT "SPR -- SPRINT"
1880 PRINT "MID -- MIDDLE DISTANCE"
1890 PRINT "DIS -- DISTANCE"
1900 PRINT "OTH -- OTHER"
1910 PRINT
1920 PRINT "SELECT WHICH EVENT TYPE";
1930 GO TO 1830
1940 PRINT "TIME IN TRAINING TYPES ARE:"
1950 PRINT "BEG -- JUST BEGINNING TRAINING AT START OF STUDY"
1960 PRINT "FAL -- TRAINING SINCE THE FALL SEASON"
1970 PRINT "LNG -- TRAINING LONG BEFORE"
1980 PRINT
1990 PRINT "SELECT WHICH TYPE";
2000 GO TO 1830
2500 REM -- THIS SUBROUTINE ANNOUNCES WHEN DATA DISKS SHOULD
2510 REM -- BE CHANGED DURING SELECTION SCAN.
2520 REM -- IT ASSUMES SUBJECTS IN NAMNUM.HAR ARE IN NUMERICAL ORDER.
2530 IF VAL(B$)>12 THEN 2620
2540 IF F1%=1 THEN RETURN
2560 PRINT "DATA DISK 1 SHOULD BE IN DX1."
2570 PRINT "HIT CARRIAGE RETURN TO PROCEED";
2580 INPUT R$
2590 PRINT
2600 LET F1%=1
2610 RETURN
2620 IF VAL(B$)>24 THEN 2710
2630 IF F2%=1 THEN RETURN
2650 PRINT "DATA DISK 2 SHOULD BE IN DX1."
2660 PRINT "HIT CARRIAGE RETURN TO PROCEED";
2670 INPUT R$
2680 PRINT
2690 LET F2%=1
2700 RETURN
2710 IF F3%=1 THEN RETURN
2730 PRINT "DATA DISK 3 SHOULD BE IN DX1."
2740 PRINT "HIT CARRIAGE RETURN TO PROCEED";
2750 INPUT R$
2760 PRINT
2770 LET F3%=1
2780 RETURN
```

DISHAR.BAS

```
10 REM -- THIS ROUTINE MAKES A SEQUENTIAL FILE OF DESIRED
20 REM -- INFORMATION FOR THE SUBJECTS IN SELEC.HAR.
30 REM -- AFTER CREATING THE FILE F$, CONTROL IS PASSED
40 REM -- TO MASHAR.BAS FOR DISPLAY.
50 COMMON A$,B$
60 COMMON F$
70 PRINT
80 PRINT 'THE FOLLOWING INFORMATION CAN BE DISPLAYED:'
90 PRINT
100 PRINT 'CODE'
110 PRINT TAB(1);1;TAB(7);'SUBJECTS SELECTED'
120 PRINT TAB(1);2;TAB(7);'FULL DISPLAY'
130 PRINT TAB(1);3;TAB(7);'HEADING INFO'
140 PRINT TAB(1);4;TAB(7);'INJURY RECORD'
150 PRINT TAB(1);5;TAB(7);'DATE-RELATED INFO:DO,INJ,TRNING,COMMENTS'
160 PRINT TAB(1);6;TAB(7);'DATA FOR SPECIFIED SITES'
170 PRINT TAB(1);7;TAB(7);'DATA FOR SPECIFIED DATES'
400 PRINT
410 PRINT 'SELECT DISPLAY INFORMATION BY CODE NUMBER';
420 INPUT Z%
430 IF Z%<>1 THEN 620
500 REM -- DISPLAY SELECTED SUBJECTS' NAMES AND NUMBERS
510 OPEN F$ FOR OUTPUT AS FILE #1
520 OPEN 'SELEC.HAR' FOR INPUT AS FILE #2
530 PRINT #1,'THE FOLLOWING SUBJECTS ARE IN ';F$
540 PRINT #1
550 PRINT #1,TAB(7);'NAME';TAB(20);'NUMBER'
560 IF END #2 THEN 600
570 INPUT #2,A$,B$
580 PRINT #1,A$;TAB(21);B$
590 GO TO 560
600 CLOSE #1,#2
610 CHAIN 'MASHAR.BAS' LINE 460
620 REM -- GET INFORMATION FROM FILES
630 OPEN F$ FOR OUTPUT AS FILE #1
640 OPEN 'SELEC.HAR' FOR INPUT AS FILE #2
650 IF END #2 THEN 700
660 INPUT #2,A$,B$
670 GOSUB 4000 \ REM ANNOUNCE DISK
675 \ REM DO NOT ALTER Z%
680 ON Z%-1 GO TO 740,720,960,1100,1300,1800 \ REM DO NOT ALTER Z%
700 CLOSE #1,#2
710 CHAIN 'MASHAR.BAS' LINE 460
720 GOSUB 4200 \ REM HEADER INFO
730 GO TO 650
740 \ REM FULL DISPLAY
745 PRINT 'THIS WILL TAKE A WHILE'
746 PRINT
750 GOSUB 4200 \ REM HEADER INFO
760 PRINT #1
770 DIM #9,P$(20,1)=9
780 OPEN 'DX1:HAR'+B$+'.PAR' FOR INPUT AS FILE #9
790 LET C%=0 \ REM READING COUNTER
800 IF P$(C%,0)='EOF' THEN 940
```

```
810 LET G$=P$(C%,0) \ REM DATE
820 LET H$=P$(C%,1) \ REM DO
830 PRINT #1
840 GOSUB 4700 \ REM DATE-RELATED INFO
850 PRINT #1
860 PRINT #1,'SITE';TAB(11);'MASK';TAB(17);'D(IN)';TAB(25);'T(US)';
865 PRINT #1,TAB(32);'V(M/S)';TAB(40);'MEAN&SD';TAB(51);'D-DOMEAN';
870 PRINT #1,TAB(62);'TMEAN';TAB(70);'TCORR';TAB(79);'VCORR'
880 LET T%=0 \ REM SITE COUNTER
885 PRINT 'SITE #';
890 GOSUB 4900 \ REM DATA FOR SITE T%, READING C%
895 PRINT T%;
900 LET T%=T%+1
910 IF T%<20 THEN 890 \ REM NEXT SITE
920 LET C%=C%+1 \ REM NEXT DATE
925 PRINT 'NEXT DATE'
926 PRINT
930 GO TO 800
940 CLOSE #9
950 GO TO 650
960 \ REM INJURY RECORD
970 PRINT #1
980 PRINT #1,A$,'INJURY RECORD'
990 PRINT #1
1000 OPEN 'DX1:HAR'+B$+'.SEQ' FOR INPUT AS FILE #4
1010 LET Z$='INJURIES'
1020 LET O$='END'
1030 LET I%=0
1040 GOSUB 4600
1050 CLOSE #4
1060 GO TO 650
1100 \ REM DATE-RELATED INFO
1110 PRINT #1
1115 PRINT #1
1120 PRINT #1,A$
1130 PRINT #1
1140 OPEN 'DX1:HAR'+B$+'.PAR' FOR INPUT AS FILE #9
1150 LET C%=0
1160 IF P$(C%,0)='EOF' THEN 1230
1170 LET G$=P$(C%,0) \ REM DATE
1180 LET H$=P$(C%,1) \ REM DO
1190 GOSUB 4700 \ REM DATE-RELATED INFO
1210 LET C%=C%+1
1220 GO TO 1160
1230 CLOSE #9
1240 GO TO 650
1300 \ REM DATA FOR SPECIFIED SITES
1310 DIM X%(20) \ REM ARRAY OF SITE FLAGS
1320 LET L%=0
1330 LET X%(L%)=0 \ REM INITIALIZE TO ZERO
1340 LET L%=L%+1
1350 IF L%<=20 THEN 1330
1355 PRINT
1360 PRINT 'DATA FOR THE FOLLOWING SITES MAY BE DISPLAYED:'
1370 PRINT
1380 RESTORE
1390 PRINT 'CODE';TAB(12);'SITE'
1400 LET I%=1
1410 READ S$
1420 PRINT TAB(1);I%;TAB(7);S$
1430 LET I%=I%+1
1440 IF I%<=20 THEN 1410
1450 PRINT
1460 PRINT 'SELECT SITE BY CODE FOR ';A$;
1470 INPUT L%
1480 LET X%(L%)=1 \ REM SET SITE FLAG
```

```
1490 PRINT "DO YOU WISH TO SELECT AN ADDITIONAL SITE (Y OR N)";
1500 INPUT Z$
1510 IF SEG$(Z$,1,1)="Y" THEN 1360
1520 \ REM SITES SELECTED ARE FLAGGED "1" IN X% ARRAY 1-20
1530 PRINT #1
1540 PRINT #1,A$
1550 PRINT #1
1555 PRINT #1,"SITE";TAB(11);"MASK";TAB(17);"D(IN)";TAB(25);"T(US)";
1556 PRINT #1,TAB(32);"V(M/S)";TAB(40);"MEAN&SD";TAB(51);"D-DOMEAN";
1557 PRINT #1,TAB(62);"TMEAN";TAB(70);"TCORR";TAB(79);"VCORR"
1560 OPEN "DX1:HAR"+B$+".PAR" FOR INPUT AS FILE #9
1570 LET C%=0 \ REM READING COUNTER
1580 IF P$(C%,0)="EOF" THEN 1760
1590 LET G$=P$(C%,0) \ REM DATE
1600 LET H$=P$(C%,1) \ REM DO
1610 PRINT #1
1620 PRINT #1,"DATE: ";G$
1630 PRINT #1,"DO: ";H$
1670 LET L%=1
1680 IF X%(L%)=0 THEN 1720
1690 PRINT #1
1700 LET T%=L%-1 \ REM SITE FLAGGED
1710 GOSUB 4900 \ REM DATA
1720 LET L%=L%+1
1730 IF L%<=20 THEN 1680
1740 LET C%=C%+1
1743 PRINT "NEXT DATE"
1745 PRINT
1750 GO TO 1580
1760 CLOSE #9
1770 GO TO 650
1800 \ REM DATA FOR A SPECIFIED DATE
1810 PRINT #1
1820 PRINT #1
1830 PRINT #1,A$
1840 PRINT
1850 PRINT "DATE MUST BE ENTERED IN THE FORMAT DD-MON-YY,"
1860 PRINT "FOR EXAMPLE: 03-DEC-82"
1870 PRINT
1880 PRINT "ENTER DATE OF READINGS FOR ";A$;","
1890 PRINT "     OR CARRIAGE RETURN TO STOP";
1900 INPUT G$
1910 PRINT
1920 IF G$="" THEN 650
1930 OPEN "DX1:HAR"+B$+".PAR" FOR INPUT AS FILE #9
1940 LET C%=0
1950 IF P$(C%,0)<>"EOF" THEN 1990
1960 CLOSE #9
1970 PRINT "DATE NOT FOUND"
1980 GO TO 1870
1990 IF P$(C%,0)=G$ THEN 2020
2000 LET C%=C%+1
2010 GO TO 1950
2020 LET H$=P$(C%,1)
2030 CLOSE #9
2040 GOSUB 4700 \ REM DATE-RELATED INFO
2050 PRINT #1
2060 PRINT #1,"SITE";TAB(11);"MASK";TAB(17);"D(IN)";TAB(25);"T(US)";
2070 PRINT #1,TAB(32);"V(M/S)";TAB(40);"MEAN&SD";TAB(51);"D-DOMEAN";
2080 PRINT #1,TAB(62);"TMEAN";TAB(70);"TCORR";TAB(79);"VCORR"
2090 LET T%=0 \ REM SITE COUNTER
2100 PRINT "SITE #";
2110 GOSUB 4900 \ REM DATA FOR SITE T%, READING C%
2120 PRINT T%;
2130 LET T%=T%+1
2140 IF T%<20 THEN 2110
```

```
2150 GO TO 1870
4000 REM -- THIS SUBROUTINE ANNOUNCES WHICH DATA DISK
4010 REM -- SHOULD BE USED FOR SUBJECT NUMBER B$.
4020 LET F%=1
4030 IF VAL(B$)>12 THEN LET F%=2
4040 IF VAL(B$)>24 THEN LET F%=3
4050 PRINT
4060 PRINT 'DATA DISK';F%;'SHOULD BE IN DX1.'
4070 PRINT 'HIT CARRIAGE RETURN WHEN READY TO PROCEED';
4080 INPUT Z$
4090 PRINT
4100 RETURN
4200 REM -- THIS SUBROUTINE TRANSFERS HEADING INFO FOR
4210 REM -- NAME A$, NUMBER B$ TO F$ AS FILE #1
4220 DIM #3,C$(16)=3
4230 OPEN 'DX1:HAR'+B$+'.INF' FOR INPUT AS FILE #3
4240 OPEN 'DX1:HAR'+B$+'.SEQ' FOR INPUT AS FILE #4
4250 PRINT #1
4260 PRINT #1,'NAME: ';A$,,'NUMBER: ';B$,,'RACE: ';C$(0)
4270 PRINT #1,'SEX: ';C$(1),'AGE: ';C$(2),'HANDED: ';C$(3),
4280 PRINT #1,'HT(IN): ';C$(4),'WT(LBS): ';C$(5)
4290 IF C$(1)='M' THEN  GO TO 4390 \ REM SKIP CYCLE
4300 PRINT #1,'CYCLE: ';
4310 IF C$(6)='REG' THEN PRINT #1,'REGULAR'
4320 IF C$(6)='IRR' THEN PRINT #1,'IRREGULAR'
4330 IF C$(6)='NON' THEN PRINT #1,'NONE'
4340 IF C$(6)='' THEN PRINT #1,''
4350 LET Z$='CYCLE'
4360 LET O$='END'
4370 LET I%=5
4380 GOSUB 4600
4390 PRINT #1,'EVENT: ';
4400 IF C$(7)='SPR' THEN PRINT #1,'SPRINT'
4410 IF C$(7)='MID' THEN PRINT #1,'MIDDLE DISTANCE'
4420 IF C$(7)='DIS' THEN PRINT #1,'DISTANCE'
4430 IF C$(7)='OTH' THEN PRINT #1,'NOT STANDARD TRACK RANGE'
4440 IF C$(7)='' THEN PRINT #1,''
4450 LET Z$='EVENT'
4460 LET O$='END'
4470 LET I%=5
4480 GOSUB 4600
4490 PRINT #1,'TIME IN TRAINING: ';
4500 IF C$(8)='BEG' THEN PRINT #1,'BEGINNING TRAINING AT START OF STUDY'
4510 IF C$(8)='FAL' THEN PRINT #1,'TRAINING SINCE THE FALL SEASON'
4520 IF C$(8)='LNG' THEN PRINT #1,'TRAINING LONG BEFORE FALL SEASON'
4530 IF C$(8)='' THEN PRINT #1,''
4540 LET Z$='TIME IN TRAINING'
4550 LET O$='END'
4560 LET I%=5
4570 GOSUB 4600
4580 CLOSE #3,#4
4590 RETURN
4600 REM -- THIS SUBROUTINE IS USED TO PRINT HEADER INFO
4610 REM -- FROM .SEQ, FILE #4, TO .DIS, FILE #1.
4620 REM -- IT PRINTS BETWEEN THE NEXT OCCURENCE OF Z$
4625 REM -- AND O$, INDENTED BY I%
4630 INPUT #4,D$
4640 IF D$<>Z$ THEN 4630
4650 INPUT #4,D$
4652 IF D$<>O$ THEN 4670
4654 PRINT #1
4656 RETURN
4658 INPUT #4,D$
4660 IF D$=O$ THEN RETURN
4670 PRINT #1,TAB(I%);D$
4680 GO TO 4658
```

```
4700 REM -- THIS SUBROUTINE TRANSFERS DATE-RELATED INFO
4710 REM -- FOR NAME A$, NUMBER B$, ON DATE G$, WITH DO H$
4720 REM -- TO F$ AS FILE #1
4730 OPEN 'DX1:HAR'+B$+'.SEQ' FOR INPUT AS FILE #4
4740 PRINT #1
4750 PRINT #1,'DATE: ';G$
4760 PRINT #1,'DO: ';H$
4770 INPUT #4,D$
4780 IF D$<>'INJURIES' THEN 4770
4790 PRINT #1,'INJURIES: ';
4800 LET Z$=G$
4810 LET O$=''
4820 LET I%=5
4830 GOSUB 4600 \ REM PRINT FROM DATE TO ''
4840 PRINT #1,'TRAINING ROUTINE: ';
4850 GOSUB 4600 \ REM Z$,O$,I% UNALTERED
4860 PRINT #1,'COMMENTS: ';
4870 GOSUB 4600
4880 CLOSE #4
4890 RETURN
4900 REM -- THIS SUBROUTINE TRANSFERS DATA AND STATS
4910 REM -- FOR NAME A$, NUMBER B$ ON READING
4920 REM -- NUMBER C% (..FROM 0), AT SITE T% (0-19)
4930 REM -- INTO F$ AS FILE #1.  DO = H$
4940 LET I%=C%*60+T%*3 \ REM LOCATION IN FILE(1200)
4950 LET J%=C%*20+T% \ REM LOCATION IN FILE(400)
4960 DIM #5,J(1200,1)
4970 OPEN 'DX1:HAR'+B$+'.DAT' FOR INPUT AS FILE #5
4980 IF J(I%,0)<>0 THEN 5010 \ REM CHECK IF NO MEASUREMENT
4990 CLOSE #5
5000 RETURN
5010 LET D1=J(I%,0)
5020 LET T1=J(I%,1)
5030 LET D2=J(I%+1,0)
5040 LET T2=J(I%+1,1)
5050 LET D3=J(I%+2,0)
5060 LET T3=J(I%+2,1)
5070 DIM #6,K%(1200)
5080 OPEN 'DX1:HAR'+B$+'.MSK' FOR INPUT AS FILE #6
5090 LET M1%=K%(I%)
5100 LET M2%=K%(I%+1)
5110 LET M3%=K%(I%+2)
5120 DIM #7,L%(1200)
5130 OPEN 'DX1:HAR'+B$+'.VEL' FOR INPUT AS FILE #7
5140 LET V1%=L%(I%)
5150 LET V2%=L%(I%+1)
5160 LET V3%=L%(I%+2)
5170 DIM #8,N%(400,1)
5180 OPEN 'DX1:HAR'+B$+'.STA' FOR INPUT AS FILE #8
5190 LET M%=N%(J%,0)
5200 LET S%=N%(J%,1)
5210 CLOSE #5,#6,#7,#8
5220 LET C1=D1-VAL(H$) \ REM CORRECT FOR DO
5230 LET C2=D2-VAL(H$)
5240 LET C3=D3-VAL(H$)
5250 \ REM CALCULATE MEAN OF D-DO (..P) AND OF T(Q)
5255 \ REM WITH RESPECT TO THE MASK.
5260 LET Z=0
5270 LET G=0
5280 IF M1%=1 THEN LET Z=Z+C1
5290 IF M1%=1 THEN LET G=G+T1
5300 IF M2%=1 THEN LET Z=Z+C2
5310 IF M2%=1 THEN LET G=G+T2
5320 IF M3%=1 THEN LET Z=Z+C3
5330 IF M3%=1 THEN LET G=G+T3
5340 LET R%=M1%+M2%+M3%
```

```
5350 LET P=Z/R%
5360 LET Q=G/R%
5361 \ REM VELOCITY CORRECTION
5362 DIM #10,S(20)
5363 OPEN 'DX1:HAR'+B$+'.STD' FOR INPUT AS FILE #10
5364 C=(S(T%)-P)*25400/1540 \ REM CORRECTION FACTOR IN US
5365 V=S(T%)*25400/(Q+C) \ REM CORRECTED VELOCITY
5366 CLOSE #10
5370 \ REM MEASUREMENT SITES
5380 DATA 'LEFT HUMERAL SHAFT','LEFT HUMERAL CONDYLE'
5390 DATA 'LEFT TIBIAL SHAFT','L_PROXIMAL TIBIAL SHAFT'
5400 DATA 'L_DISTAL TIBIAL SHAFT','LEFT TIBIAL METAPHYSIS'
5410 DATA 'LEFT PATELLA .','LEFT CALCANEOUS .','LEFT FIBULA .'
5420 DATA 'LEFT SECOND METATARSAL','RIGHT HUMERAL SHAFT'
5430 DATA 'RIGHT HUMERAL CONDYLE','RIGHT TIBIAL SHAFT'
5440 DATA 'R_PROXIMAL TIBIAL SHAFT','R_DISTAL TIBIAL SHAFT'
5450 DATA 'RIGHT TIBIAL METAPHYSIS','RIGHT PATELLA .'
5460 DATA 'RIGHT CALCANEOUS .','RIGHT FIBULA .'
5465 DATA 'RIGHT SECOND METATARSAL',''
5470 RESTORE
5480 LET Z%=0
5490 READ S$
5500 IF Z%=T% THEN  GO TO 5530
5510 LET Z%=Z%+1
5520 GO TO 5490
5530 \ REM INSERT DATA INTO FILE #1
5540 PRINT #1
5545 LET P1%=POS(S$,' ',1)
5550 PRINT #1,SEG$(S$,1,P1%); \ REM FIRST WORD OF SITE
5555 PRINT #1,TAB(12);M1%;TAB(17);
5560 PRINT #1,USING '#.###',D1;
5570 PRINT #1,TAB(25);
5580 PRINT #1,USING '##.##',T1;
5590 PRINT #1,TAB(32);V1%;TAB(40);M%
5595 LET P2%=POS(S$,' ',P1%+1)
5600 PRINT #1,SEG$(S$,P1%+1,P2%); \ REM SECOND WORD OF SITE
5610 IF D2<>0 THEN 5635
5620 PRINT #1
5630 GO TO 5690
5635 PRINT #1,TAB(12);M2%;TAB(17);
5640 PRINT #1,USING '#.###',D2;
5645 PRINT #1,TAB(25);
5650 PRINT #1,USING '##.##',T2;
5655 PRINT #1,TAB(32);V2%;TAB(41);
5660 PRINT #1,USING '###',S%;
5670 PRINT #1,TAB(52);
5672 PRINT #1,USING '#.###',P; \ REM D-DOMEAN
5674 PRINT #1,TAB(62);
5676 PRINT #1,USING '##.##',Q; \ REM TMEAN
5678 PRINT #1,TAB(70);
5680 PRINT #1,USING '##.##',Q+C; \ REM TCORR
5682 PRINT #1,TAB(80);
5684 PRINT #1,USING '####',V \ REM VCORR
5690 PRINT #1,SEG$(S$,P2%+1,LEN(S$)); \ REM THIRD WORD OF SITE
5700 IF D3=0 THEN  GO TO 5730
5705 PRINT #1,TAB(12);M3%;TAB(17);
5710 PRINT #1,USING '#.###',D3;
5715 PRINT #1,TAB(25);
5720 PRINT #1,USING '##.##',T3;
5725 PRINT #1,TAB(32);V3%
5730 PRINT #1
5740 RETURN
```

TRTEFF.BAS

```
10 REM -- THIS PROGRAM ANALYZES THE DIFFERENCES IN SITE MEASUREMENTS.
20 REM -- IT CALCULATES S AND N OF D.
30 DATA "1","2","3","4","5","6","7","8","9","10","11","12",
31 DATA "13","14","15","16","17","18","20","21","22","23",
32 DATA "24","26","27","28","29","30","31","32","33"
40 PRINT
50 PRINT "THE CALCULATION OF DIFFERENCE CAN BE DONE WITH VARIOUS DATA:"
60 PRINT
70 PRINT 1;TAB(5);"WORST CASE"
80 PRINT 2;TAB(5);"FIRST TWO READINGS"
90 PRINT "OPTION";
100 INPUT A% \ REM OPTION
110 PRINT
120 PRINT 1;TAB(5);"WITH RESPECT TO MASK"
130 PRINT 2;TAB(5);"IGNORING MASK"
140 PRINT "MASK OPTION";
150 INPUT B% \ REM MASK OPTION
160 PRINT
170 PRINT 1;TAB(5);"SIGNED DIFFERENCES"
180 PRINT 2;TAB(5);"ABSOLUTE VALUES"
190 PRINT "SIGN OPTION";
195 INPUT C% \ REM SIGN OPTION
196 PRINT
197 PRINT 1;TAB(5);"ALL SITES"
198 PRINT 2;TAB(5);"ONE SITE"
199 PRINT "SITE OPTION";
200 INPUT S7%
201 IF S7%=1 THEN 207
202 PRINT
203 PRINT "ENTER SITE NUMBER";
204 INPUT S8%
207 LET R=0 \ REM SUM OF D
208 LET S=0 \ REM SUM OF D-SQUARED
209 LET N%=0 \ REM N
210 PRINT
220 READ N$ \ REM NEXT SUBJECT NUMBER
230 \ REM WATCH FOR CORRECT DISK
240 IF N$<>"1" THEN 280
250 PRINT "DATA DISK 1 SHOULD BE IN DX1."
260 PRINT "HIT CARRIAGE RETURN TO PROCEED";
270 INPUT Z$
280 IF N$<>"13" THEN 320
290 PRINT "DATA DISK 2 SHOULD BE IN DX1."
300 PRINT "HIT CARRIAGE RETURN TO PROCEED";
310 INPUT Z$
320 IF N$<>"26" THEN 360
330 PRINT "DATA DISK 3 SHOULD BE IN DX1."
340 PRINT "HIT CARRIAGE RETURN TO PROCEED";
350 INPUT Z$
360 \ REM FIND OUT HOW MANY DATES
370 DIM #1,D$(20,1)=9
380 OPEN "DX1:HAR"+N$+".PAR" FOR INPUT AS FILE #1
390 LET D%=0
400 IF D$(D%,0)="EOF" THEN 430
410 LET D%=D%+1
```

```
420 GO TO 400
430 CLOSE #1 \ REM D%=# OF DATES READ FOR SUBJECT N$
440 DIM #2,F%(1200)
450 OPEN 'DX1:HAR'+N$+'.MSK' FOR INPUT AS FILE #2
460 DIM #3,G%(1200)
470 OPEN 'DX1:HAR'+N$+'.VEL' FOR INPUT AS FILE #3
480 LET E%=0 \ REM DATE COUNTER
485 IF E%=D% THEN 1000
490 LET T%=0 \ REM SITE COUNTER
495 IF S7%=1 THEN 500
496 LET T%=S8%-1 \ REM T% IS 0-19 BUT SITE CODES ARE 1-20
500 LET I%=E%*60+T%*3
510 \ REM ASSIGN MASK VARIABLES
520 ON B% GO TO 530,570
530 LET M1%=F%(I%)
540 LET M2%=F%(I%+1)
550 LET M3%=F%(I%+2)
560 GO TO 600
570 LET M1%=1
580 LET M2%=1
590 LET M3%=1
600 \ REM GET VELOCITIES USING ALTERED MASK
610 LET V1%=0
620 LET V2%=0
630 LET V3%=0
640 IF M1%=1 THEN LET V1%=G%(I%)
650 IF M2%=1 THEN LET V2%=G%(I%+1)
660 IF M3%=1 THEN LET V3%=G%(I%+2)
670 IF V1%+V2%+V3%=0 THEN 960 \ REM NEXT
680 \ REM GET SIGNED DIFFERENCE
690 IF V3%<>0 THEN 720
700 LET X%=V2%-V1%
710 GO TO 890
720 IF V2%<>0 THEN 750
730 LET X%=V3%-V1%
740 GO TO 890
750 IF V1%<>0 THEN 780
760 LET X%=V3%-V2%
770 GO TO 890
780 \ REM THERE ARE THREE READINGS
790 ON A% GO TO 820,800
800 LET X%=V2%-V1% \ REM FIRST 2 READINGS
810 GO TO 890
820 \ REM CHOOSE LARGEST DIFFERENCE
830 LET W1%=ABS(V3%-V2%)
840 LET W2%=ABS(V3%-V1%)
850 LET W3%=ABS(V2%-V1%)
860 IF W1%>=W2% THEN IF W1%>=W3% THEN LET X%=V3%-V2%
870 IF W2%>=W1% THEN IF W2%>=W3% THEN LET X%=V3%-V1%
880 IF W3%>=W1% THEN IF W3%>=W2% THEN LET X%=V2%-V1%
890 \ REM X% IS SIGNED DIFFERENCE
900 IF C%=2 THEN LET X%=ABS(X%) \ REM ABSOLUTE VALUE
910 REM - UPDATE STATS
920 LET R=R+X%
930 LET S=S+X%^2
940 LET N%=N%+1
950 PRINT X%
960 IF S7%<>1 THEN 980
965 LET T%=T%+1 \ REM NEXT SITE
970 IF T%<20 GO TO 500
980 LET E%=E%+1 \ REM NEXT DATE
990 GO TO 485
1000 \ REM NEXT PERSON
1010 CLOSE
1020 IF N$="33" THEN 1040
1030 GO TO 220
```

```
1040 \ REM CALCULATE
1050 LET Y=SQR((S-(R^2)/N%)/(N%-1))
1060 PRINT
1070 PRINT
1080 PRINT "MEAN OF DIFFERENCE =";R/N%
1090 PRINT "S =";Y
1100 PRINT "N =";N%
1110 PRINT
1120 END
```

MEDIAN.BAS

```
10 REM -- THIS PROGRAM TAKES ONE TYPICAL VALUE FOR EACH SITE
20 REM -- FOR EACH SUBJECT - THE MEDIAN VALUE - AND STORES IT
25 REM -- IN AN ARRAY.
30 REM -- MEDIAN VALUES CAN BE DISPLAYED FOR A SUBJECT, AND
35 REM -- IN ORDER FOR A POPULATION.  THE PROGRAM ALSO CALCULATES
36 REM -- STATISTICS AND HISTOGRAMS FOR A POPULATION.
40 DATA 'LEFT HUMERAL SHAFT','LEFT HUMERAL CONDYLE'
50 DATA 'LEFT TIBIAL SHAFT','L_PROXIMAL TIBIAL SHAFT'
60 DATA 'L_DISTAL TIBIAL SHAFT','LEFT TIBIAL METAPHYSIS'
70 DATA 'LEFT PATELLA','LEFT CALCANEOUS'
80 DATA 'LEFT FIBULA','LEFT SECOND METATARSAL'
90 DATA 'RIGHT HUMERAL SHAFT','RIGHT HUMERAL CONDYLE'
100 DATA 'RIGHT TIBIAL SHAFT','R_PROXIMAL TIBIAL SHAFT'
110 DATA 'R_DISTAL TIBIAL SHAFT','RIGHT TIBIAL METAPHYSIS'
120 DATA 'RIGHT PATELLA','RIGHT CALCANEOUS'
130 DATA 'RIGHT FIBULA','RIGHT SECOND METATARSAL'
140 DIM #1,M(33,20)
150 OPEN 'MEDIAN.HAR' AS FILE #1
160 PRINT
170 PRINT 1;TAB(5);'ENTER MEDIAN VALUES'
180 PRINT 2;TAB(5);'DISPLAY MEDIAN VALUES FOR ONE SUBJECT'
185 PRINT 3;TAB(5);'DISPLAY AND FILE MEDIAN VALUES FOR ONE SITE'
190 PRINT 4;TAB(5);'CALCULATE STATS AND HISTOGRAM GROUPINGS'
200 PRINT 5;TAB(5);'END'
210 PRINT 'OPERATION';
220 INPUT Z%
230 PRINT
240 ON Z% GO TO 250,560,2200,670,3500
250 \ REM ENTER MEDIAN VALUES
260 PRINT 'SUBJECT NUMBER';
270 INPUT A%
280 PRINT
290 PRINT 1;TAB(5);'RUN THROUGH LIST OF SITES'
300 PRINT 2;TAB(5);'CHOOSE SITES'
310 PRINT 'OPTION';
320 INPUT Z%
330 PRINT
340 ON Z% GO TO 350,440
350 RESTORE  \ REM RUN THROUGH LIST OF SITES
360 LET T%=1 \ REM SITE NUMBER
365 PRINT 'ENTER MEDIANS -- 0 IF NO ENTRY.'
370 READ S$
380 PRINT 'MEDIAN OF ';S$;
390 INPUT C \ REM MEDIAN
400 LET M(A%,T%)=C
410 LET T%=T%+1
420 IF T%<=20 THEN 370
430 GO TO 160
440 RESTORE  \ REM CHOOSE SITES
445 PRINT 'ENTER MEDIANS -- 0 IF NO ENTRY.'
450 GOSUB 1600
460 PRINT TAB(1);0;TAB(7);'STOP'
470 PRINT
480 PRINT 'SELECT SITE BY CODE';
```

```
490 INPUT T%
500 IF T%=0 THEN 160
510 PRINT 'MEDIAN';
520 INPUT C
530 PRINT
540 LET M(A%,T%)=C
550 GO TO 440
560 \ REM DISPLAY MEDIAN VALUES
570 PRINT 'SUBJECT NUMBER';
580 INPUT A%
590 PRINT
600 RESTORE
610 LET T%=1
620 READ S$
630 PRINT S$;TAB(25);M(A%,T%)
640 LET T%=T%+1
650 IF T%<=20 THEN 620
655 PRINT
656 PRINT 'HIT CR TO CONTINUE';
657 INPUT S$
660 GO TO 160
670 \ REM CALCULATE STATS
680 GOSUB 1700 \ REM GET SUBJECTS
860 PRINT
870 PRINT 1;TAB(5);'CALCULATE STATS FOR MEDIANS'
880 PRINT 2;TAB(5);'CALCULATE STATS FOR DIFFERENCE OF MEDIANS'
885 PRINT 3;TAB(5);'RETURN TO TOP MENU'
890 PRINT 'OPTION';
900 INPUT Z%
910 PRINT
920 ON Z% GO TO 930,1250,160
930 REM -- CALCULATE STATS FOR MEDIANS OF SITES
940 GOSUB 1600
950 PRINT
960 PRINT 'SELECT SITE TO BE USED IN CALCULATION';
970 INPUT T%
980 PRINT
990 GOSUB 1900 \ REM GATHER HISTOGRAM PARAMETERS
1020 \ REM COMPILE DATA
1030 LET A%=1
1050 LET N%=0 \ REM N
1060 LET P=0 \ REM SUM OF M
1070 LET Q=0 \ REM SUM OF M-SQUARED
1080 IF G%(A%)=0 THEN 1150
1090 IF M(A%,T%)=0 THEN 1150 \ REM IGNORE IF NO ENTRY
1100 LET N%=N%+1
1110 LET P=P+M(A%,T%)
1120 LET Q=Q+M(A%,T%)^2
1130 LET L=M(A%,T%)
1140 GOSUB 2100 \ REM HISTOGRAM
1150 LET A%=A%+1 \ REM NEXT SUBJECT
1160 IF A%<=33 THEN 1080
1170 \ REM DO CALCULATION
1180 PRINT
1190 PRINT
1200 PRINT 'MEAN =';P/N%
1210 PRINT 'S =';SQR((Q-(P^2)/N%)/(N%-1))
1220 PRINT 'N =';N%
1230 PRINT
1231 \ REM PRINT HISTOGRAM FREQUENCIES
1232 LET I%=0
1233 LET Z%=X%+W%*I% \ REM CENTER VELOCITY OF I%TH DIVISION
1234 IF Z%>Y% THEN 1240
1235 PRINT Z%;'--';H%(I%)
1236 LET I%=I%+1
1237 GO TO 1233
```

```
1240 PRINT
1241 PRINT 'SAME POPULATION'
1242 PRINT
1243 GO TO 870
1250 REM -- CALCULATE STATS FOR DIFFERENCE OF 2 SITES
1260 PRINT 'STATS WILL BE CALCULATED FOR THE DIFFERENCE OF 2 MEDIANS.'
1270 PRINT '    THIS DIFFERENCE WILL BE FOR SITE A - SITE B.'
1280 PRINT
1290 GOSUB 1600
1300 PRINT
1310 PRINT 'SELECT SITE A';
1320 INPUT T%
1330 PRINT 'SELECT SITE B';
1340 INPUT U%
1350 PRINT
1355 GOSUB 1900 \ REM GATHER HISTOGRAM PARAMETERS
1360 \ REM COMPILE DATA
1370 LET A%=1
1380 LET N%=0 \ REM N
1390 LET P=0 \ REM SUM OF M
1400 LET Q=0 \ REM SUM OF M-SQUARED
1410 IF G%(A%)=0 THEN 1470
1420 IF M(A%,T%)=0 THEN 1470
1430 IF M(A%,U%)=0 THEN 1470
1440 LET N%=N%+1
1450 LET P=P+M(A%,T%)-M(A%,U%)
1460 LET Q=Q+(M(A%,T%)-M(A%,U%))^2
1465 LET L=M(A%,T%)-M(A%,U%)
1466 GOSUB 2100 \ REM HISTOGRAM
1470 LET A%=A%+1 \ REM NEXT SUBJECT
1480 IF A%<=33 THEN 1410
1490 GO TO 1170
1600 REM -- THIS SUBROUTINE PRINTS THE LIST OF SITES AND CODES
1610 RESTORE
1620 PRINT 'CODE';TAB(12);'SITE'
1630 LET T%=1
1640 READ S$
1650 PRINT TAB(1);T%;TAB(7);S$
1660 LET T%=T%+1
1670 IF T%<=20 THEN 1640
1680 RETURN
1700 REM -- THIS SUBROUTINE SETS A LIST OF SUBJECTS
1710 REM -- TO BE INCLUDED IN CALCULATIONS.
1720 DIM G%(33) \ REM SUBJECT MASK
1730 LET I%=0
1740 LET G%(I%)=0 \ REM INITIALIZE MASK
1750 LET I%=I%+1
1760 IF I%<=33 THEN 1740
1770 PRINT 'ENTER SUBJECTS' NUMBERS TO INCLUDE.'
1780 PRINT 'ENTER 0 IF FINISHED.' \ REM NO SUBJECT NUMBER 0
1790 PRINT
1800 PRINT 'SUBJECT NUMBER';
1810 INPUT A%
1820 IF A%=0 THEN RETURN
1830 LET G%(A%)=1
1840 GO TO 1800
1900 REM -- THIS SUBROUTINE GATHERS HISTOGRAM PARAMETERS.
1910 PRINT 'ENTER APPROPRIATE INFO FOR HISTOGRAM CALCULATION:'
1920 PRINT 'SIZE OF ONE VELOCITY DIVISION';
1930 INPUT W%
1940 PRINT 'CENTER OF LOWEST DIVISION (MULTIPLE OF SIZE)';
1950 INPUT X%
1960 PRINT 'CENTER OF HIGHEST DIVISION (MULTIPLE OF SIZE)';
1970 INPUT Y%
1980 PRINT
1990 DIM H%(20) \ REM HISTOGRAM FREQUENCIES
```

```
2000 LET I%=0
2010 LET H%(I%)=0 \ REM INITIALIZE H%
2020 LET I%=I%+1
2030 IF I%<=20 THEN 2010
2040 RETURN
2100 REM -- THIS SUBROUTINE CALCULATES HISTOGRAM FREQUENCIES
2110 LET I%=0
2120 LET R1=X%+(I%*W%)-(W%/2) \ REM LOWER BOUND OF I%TH DIVISION
2130 LET R2=X%+(I%*W%)+(W%/2) \ REM UPPER BOUND OF I%TH DIVISION
2133 IF L>=R1 THEN 2140 \ REM CHECK FOR LOW RANGE
2134 PRINT
2135 PRINT 'NOT ENOUGH LOW RANGE'
2136 PRINT 'DO YOU WISH TO RESET HISTOGRAM (R) OR CONTINUE (C)';
2137 INPUT C$
2138 IF C$='R' THEN ON Z% GO TO 980,1350
2139 RETURN \ REM IGNORE RANGE ERROR
2140 IF R1<=Y% THEN 2150 \ REM CHECK FOR HIGH RANGE
2141 PRINT
2142 PRINT 'NOT ENOUGH HIGH RANGE'
2143 PRINT 'DO YOU WISH TO RESET HISTOGRAM (R) OR CONTINUE (C)';
2144 INPUT C$
2145 IF C$='R' THEN ON Z% GO TO 980,1350
2146 RETURN \ REM IGNORE RANGE ERROR
2150 IF L<R2 THEN 2180 \ REM IS THIS THE CORRECT DIVISION
2160 LET I%=I%+1 \ REM NOT IN CURRENT DIVISION - TRY NEXT
2170 GO TO 2120
2180 LET H%(I%)=H%(I%)+1 \ REM INCREMENT HISTOGRAM FREQUENCY
2190 RETURN
2200 REM -- DISPLAY AND FILE MEDIAN VALUES FOR ONE SITE
2210 GOSUB 1700 \ REM GET SUBJECTS
2220 PRINT
2230 PRINT 1;TAB(5);'LIST IN SUBJECT ORDER'
2240 PRINT 2;TAB(5);'LIST IN NUMERICAL ORDER'
2250 PRINT 3;TAB(5);'RETURN TO TOP MENU'
2260 PRINT 'OPTION';
2270 INPUT Z%
2280 PRINT
2290 IF Z%=3 THEN 160
2300 GOSUB 1600 \ REM LIST SITES
2310 PRINT 'SELECT SITE BY CODE';
2320 INPUT T%
2330 PRINT
2340 PRINT 'ENTER A FILENAME (EXTENSION WILL BE .MED)';
2350 INPUT F$
2360 PRINT
2370 OPEN F$+'.MED' FOR OUTPUT AS FILE #2
2380 PRINT 'ENTER A LINE OF INFO FOR FILE HEADING'
2390 INPUT S$
2400 PRINT
2410 PRINT #2,S$
2420 PRINT #2
2430 ON Z% GO TO 2440,2600
2440 \ REM LIST IN SUBJECT ORDER
2450 PRINT 'NUMBER','MEDIAN'
2460 PRINT
2470 PRINT #2,'NUMBER','MEDIAN'
2480 PRINT #2
2490 LET A%=0
2500 IF G%(A%)<>1 THEN 2530
2505 IF M(A%,T%)=0 THEN 2530
2510 PRINT TAB(4);A%,M(A%,T%)
2515 GOSUB 3100 \ REM INITIALS
2520 PRINT #2,TAB(4);A%,M(A%,T%)
2530 LET A%=A%+1
2540 IF A%<=33 THEN 2500
2550 CLOSE #2
```

```
2560 PRINT
2570 PRINT 'SAME POPULATION'
2580 GO TO 2220 \ REM NEW FILE, SAME POPULATION
2600 \ REM LIST IN NUMERICAL ORDER
2610 DIM E(33,1) \ REM FOR SORT - 0 IS MEDIAN, 1 IS SUBJECT NUMBER
2620 LET I%=0
2630 LET E(I%,0)=0 \ REM INITIALIZE SORT ARRAY
2640 LET E(I%,1)=0
2650 LET I%=I%+1
2660 IF I%<=33 THEN 2630
2670 LET A%=0
2680 IF G%(A%)=1 THEN 2720
2690 LET A%=A%+1 \ REM NEXT SUBJECT
2700 IF A%<=33 THEN 2680
2710 GO TO 2970
2720 REM M IS VALID, SORT
2725 IF M(A%,T%)=0 THEN 2690
2730 LET I%=0
2740 IF E(I%,0)<>0 THEN 2790
2750 \ REM PLACE AT END OF LIST
2760 LET E(I%,0)=M(A%,T%)
2770 LET E(I%,1)=A%
2780 GO TO 2690
2790 \ REM SORT
2800 IF E(I%,0)>M(A%,T%) THEN 2830 \ REM DOES NEW VALUE GO HERE
2810 LET I%=I%+1
2820 GO TO 2740
2830 \ REM INSERT NEW VALUE
2840 LET B1=E(I%,0)
2850 LET B2=E(I%,1)
2860 LET E(I%,0)=M(A%,T%)
2870 LET E(I%,1)=A%
2880 LET D1=E(I%+1,0)
2890 LET D2=E(I%+1,1)
2900 LET I%=I%+1
2910 LET E(I%,0)=B1
2920 LET E(I%,1)=B2
2930 IF D1=0 THEN 2690
2940 LET B1=D1
2950 LET B2=D2
2960 GO TO 2880
2970 REM PRINT
2980 PRINT 'MEDIAN','SUBJECT NUMBER'
2990 PRINT
3000 PRINT #2,'MEDIAN','SUBJECT NUMBER'
3010 PRINT #2
3020 LET I%=0
3030 IF E(I%,0)=0 THEN 2550 \ REM FINISHED
3040 PRINT E(I%,0),'          ';E(I%,1)
3050 PRINT #2,E(I%,0),'          ';E(I%,1);'   ';
3055 LET A%=E(I%,1)
3056 GOSUB 3100 \ REM INITIALS
3057 PRINT #2 \ REM FINISH LINE
3060 LET I%=I%+1
3070 GO TO 3030
3100 REM -- THIS SUBROUTINE PRINTS INITIALS OF SUBJECT TO FILE
3110 IF A%=1 THEN PRINT #2,'EB';
3120 IF A%=2 THEN PRINT #2,'YB';
3130 IF A%=3 THEN PRINT #2,'KB';
3140 IF A%=4 THEN PRINT #2,'TC';
3150 IF A%=5 THEN PRINT #2,'GD';
3160 IF A%=6 THEN PRINT #2,'SE';
3170 IF A%=7 THEN PRINT #2,'CF';
3180 IF A%=8 THEN PRINT #2,'KG';
3190 IF A%=9 THEN PRINT #2,'BE';
3200 IF A%=10 THEN PRINT #2,'SH';
```

```
3210 IF A%=11 THEN PRINT #2,"BH";
3220 IF A%=12 THEN PRINT #2,"CL";
3230 IF A%=13 THEN PRINT #2,"KM";
3240 IF A%=14 THEN PRINT #2,"TM";
3250 IF A%=15 THEN PRINT #2,"AN";
3260 IF A%=16 THEN PRINT #2,"DO";
3270 IF A%=17 THEN PRINT #2,"MP";
3280 IF A%=18 THEN PRINT #2,"AS";
3290 IF A%=20 THEN PRINT #2,"BS";
3300 IF A%=21 THEN PRINT #2,"JV";
3310 IF A%=22 THEN PRINT #2,"LB";
3320 IF A%=23 THEN PRINT #2,"JP";
3330 IF A%=24 THEN PRINT #2,"SG";
3340 IF A%=26 THEN PRINT #2,"CS";
3350 IF A%=27 THEN PRINT #2,"PC";
3360 IF A%=28 THEN PRINT #2,"JS";
3370 IF A%=29 THEN PRINT #2,"JJ";
3380 IF A%=30 THEN PRINT #2,"BB";
3390 IF A%=31 THEN PRINT #2,"GU";
3400 IF A%=32 THEN PRINT #2,"DS";
3410 IF A%=33 THEN PRINT #2,"KW";
3420 RETURN
3500 CLOSE
3510 END
```

CHANGE.BAS

```
10 REM -- THIS PROGRAM ENABLES THE CHANGE IN CORRECTED VELOCITIES
20 REM -- TO BE DISPLAYED FOR ANALYSIS.  IT CONTROLS INPUT
30 REM -- TO A FILE VCORR.HAR, AND SETS UP DISPLAY FILES IN.CHG
40 DATA 'LHUS','RHUS','LHUC','RHUC','LTIS','RTIS'
50 DATA 'LPTI','RPTI','LDTI','RDTI','LTIM','RTIM'
60 DATA 'LPAT','RPAT','LCAL','RCAL','LFIB','RFIB','LMET','RMET'
70 DIM #1,V%(33,220) \ REM 20 SITES X MAX 11 READINGS
80 OPEN 'VCORR.HAR' AS FILE #1
90 PRINT
100 PRINT 1;TAB(5);'ENTER CORRECTED VELOCITIES'
110 PRINT 2;TAB(5);'SET UP .CHG FILE'
120 PRINT 3;TAB(5);'ZERO VELOCITIES'
125 PRINT 4;TAB(5);'EXIT'
130 PRINT 'OPTION';
140 INPUT Z%
150 PRINT
160 ON Z% GO TO 170,390,161,1400
161 REM -- ZERO VELOCITIES FOR ONE SUBJECT
162 PRINT 'SUBJECT NUMBER';
163 INPUT A%
164 LET I%=0
165 LET V%(A%,I%)=0
166 LET I%=I%+1
167 IF I%<=220 GO TO 165
168 GO TO 90
170 REM -- ENTER CORRECTED VELOCITIES
180 PRINT 'SUBJECT NUMBER';
190 INPUT A%
200 PRINT
210 PRINT 'ENTER CORRECTED VELOCITIES IN ORDER.'
220 PRINT 'ENTER 0 IF NO READING WAS TAKEN.'
230 PRINT 'ENTER 9999 TO GO TO NEXT SITE.'
240 RESTORE
250 LET T%=1 \ REM SITE COUNTER 1-20
260 LET I%=T%
270 READ S$ \ REM SITE
280 PRINT
290 PRINT S$;':'
300 PRINT 'ENTER VCORR';
310 INPUT Z%
320 IF Z%=9999 THEN 360
330 LET V%(A%,I%)=Z% \ REM PUT VCORR IN FILE
340 LET I%=I%+20
350 GO TO 300
360 LET T%=T%+1 \ REM NEXT SITE
370 IF T%<=20 THEN 260
380 GO TO 90
390 REM -- SET UP .CHG FILE
400 PRINT 'SUBJECT NUMBER';
410 INPUT A%
420 PRINT 'SUBJECT'S INITIALS';
430 INPUT B$
440 PRINT
450 PRINT 'CHECK FOR PROPER DATA DISK IN DX1 -- HIT CR WHEN READY';
460 INPUT S$
```

```
470 PRINT
480 OPEN B$+'.CHG' FOR OUTPUT AS FILE #2
490 DIM #3,P$(20,1)=9
500 OPEN 'DX1:HAR'+STR$(A%)+'.PAR' FOR INPUT AS FILE #3
510 LET C%=0 \ REM READING COUNTER
520 IF P$(C%,0)='EOF' THEN 910
525 PRINT #2
526 PRINT #2,B$
530 GOSUB 1000
540 PRINT #2
550 RESTORE
560 LET I%=0
570 READ S$
580 PRINT #2,TAB(I%);S$;
590 IF S$='RMET' THEN 620 \ REM CHECK FOR LAST SITE
600 LET I%=I%+6
610 GO TO 570
620 PRINT #2 \ REM FINISH LINE
630 LET I%=1 \ REM INITIALIZE PREVIOUS VELOCITY
640 LET V%(0,I%)=V%(A%,I%)
650 LET I%=I%+1
660 IF I%<=20 THEN 640
670 LET C%=C%+1
680 IF P$(C%,0)='EOF' THEN 910
690 GOSUB 1000
700 PRINT #2
710 LET I%=0
720 LET T%=1
730 PRINT #2,TAB(I%);
740 IF V%(A%,C%*20+T%)<>0 THEN 770
750 PRINT #2,' -- ';
755 LET I%=I%+1
760 GO TO 860
770 IF V%(0,T%)<>0 THEN 800 .
780 PRINT #2,' -- ';
783 LET V%(0,T%)=V%(A%,C%*20+T%) \ REM REPLACE PREVIOUS VELOCITY
785 LET I%=I%+1
790 GO TO 860
800 LET N%=V%(A%,C%*20+T%)-V%(0,T%)
810 LET V%(0,T%)=V%(A%,C%*20+T%) \ REM REPLACE PREVIOUS VELOCITY
820 IF N%<0 THEN PRINT #2,'-';
830 LET I%=I%+1 \ REM TAB COUNTER
840 PRINT #2,TAB(I%);
850 PRINT #2,USING '###',ABS(N%);
860 LET I%=I%+5
870 LET T%=T%+1
880 IF T%<=20 THEN 730
890 PRINT #2 \ REM FINISH LINE
900 GO TO 670
910 CLOSE #2,#3
920 PRINT
930 GO TO 90
1000 REM -- THIS SUBROUTINE TRANSFERS INJURY AND TRAINING INFO.
1010 REM -- ADAPTED FROM DISHAR.BAS
1020 OPEN 'DX1:HAR'+STR$(A%)+'.SEQ' FOR INPUT AS FILE #4
1030 PRINT #2
1040 PRINT #2,'DATE: ';P$(C%,0)
1050 INPUT #4,D$
1060 IF D$<>'INJURIES' THEN 1050
1070 PRINT #2,'INJURIES: ';
1080 LET Z$=P$(C%,0)
1090 LET O$=''
1100 LET I%=5
1110 GOSUB 1200
1120 PRINT #2,'TRAINING ROUTINE: ';
1130 GOSUB 1200
```

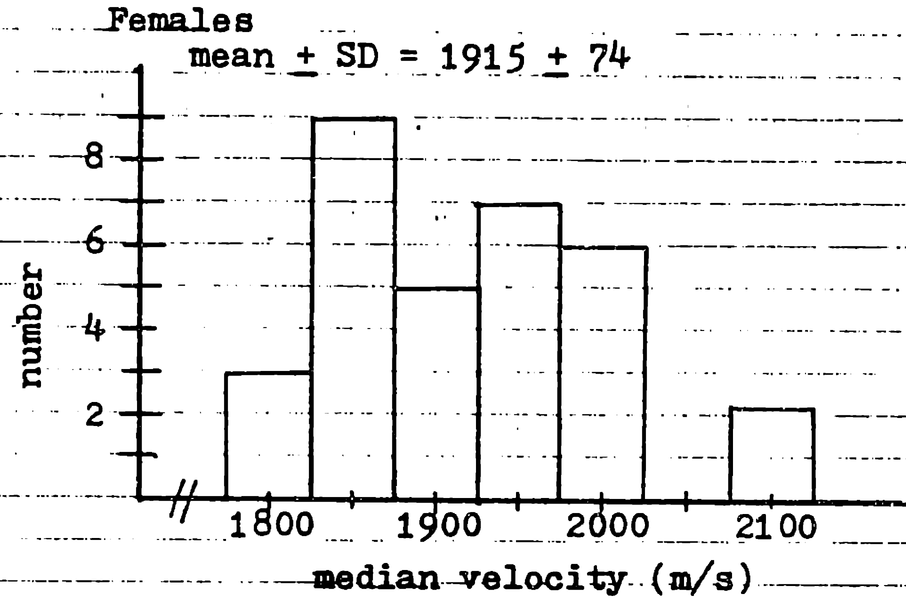
```
1140 CLOSE #4
1150 RETURN
1200 REM -- THIS SUB-SUBROUTINE PRINT BETWEEN THE NEXT
1210 REM -- OCCURENCE OF Z$ AND O$ FROM THE .SEQ FILE,
1220 REM -- INDENTED BY I%.
1230 REM -- ADAPTED FROM DISHAR.BAS
1240 INPUT #4,D$
1250 IF D$<>Z$ THEN 1240
1260 INPUT #4,D$
1270 IF D$<>O$ THEN 1320
1280 PRINT #2
1290 RETURN
1300 INPUT #4,D$
1310 IF D$=O$ THEN RETURN
1320 PRINT #2,TAB(I%);D$
1330 GO TO 1300
1400 CLOSE
1410 END
```

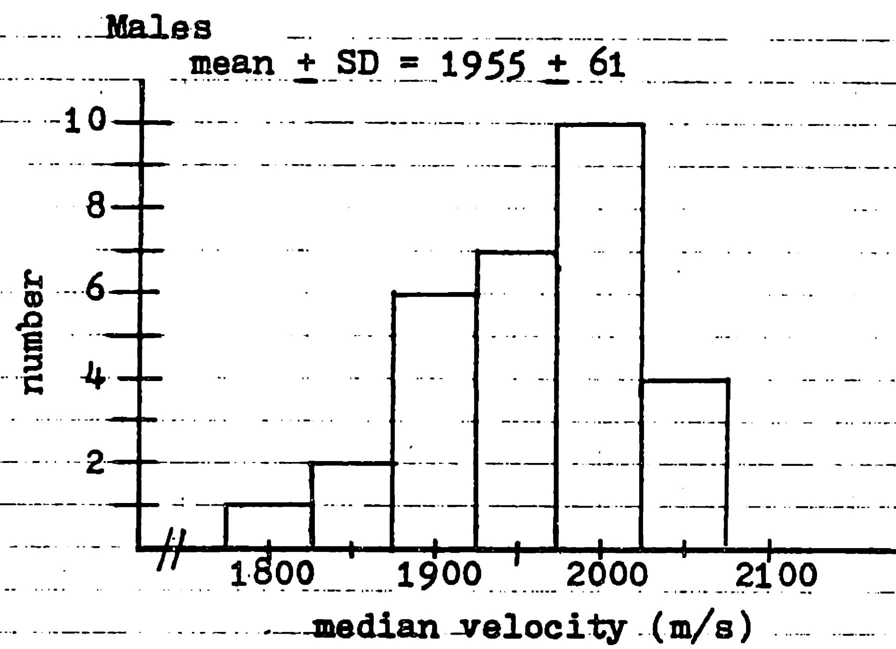
APPENDIX C

DISTRIBUTIONS OF MEDIAN VELOCITIES

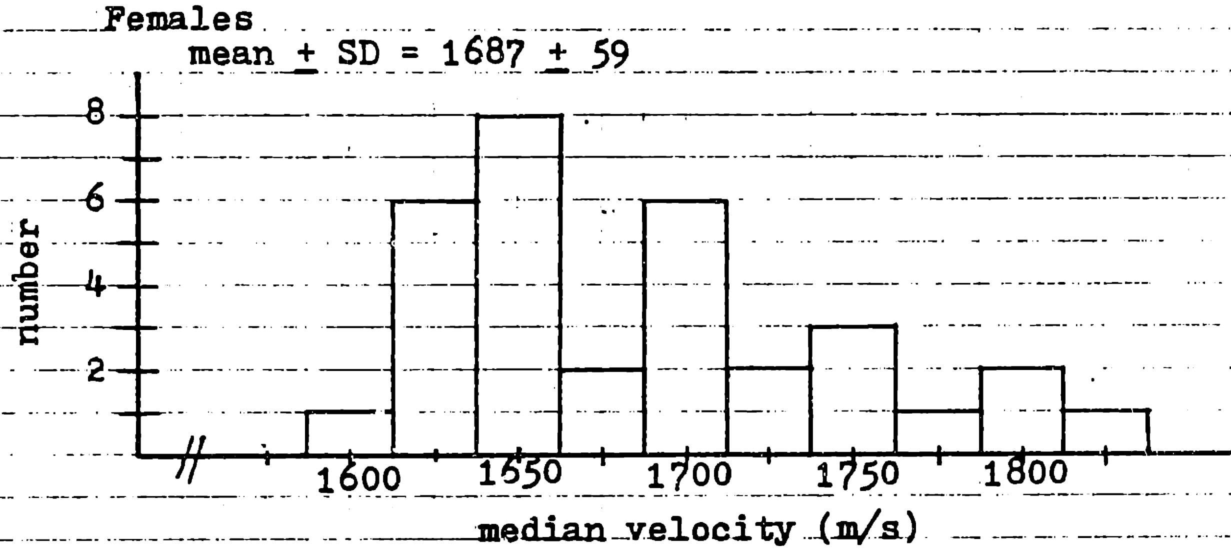
MALE AND FEMALE SUB-GROUPINGS

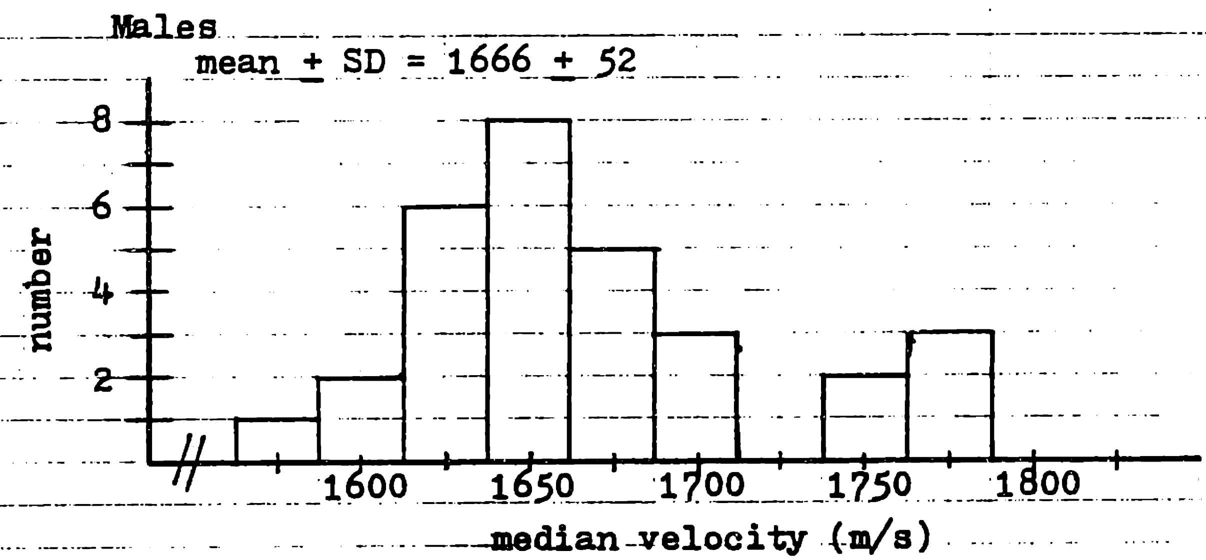
HUMERAL SHAFT



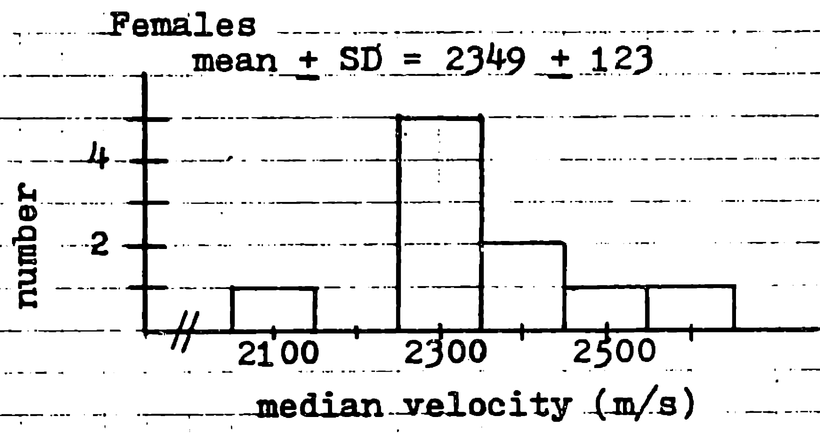


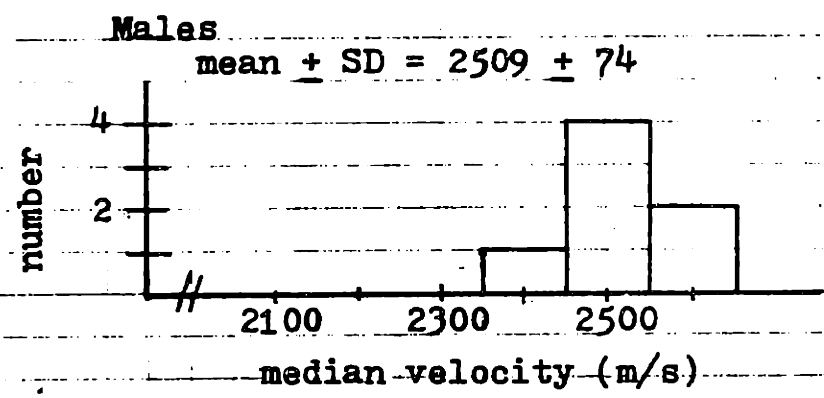
HUMERAL CONDYLE



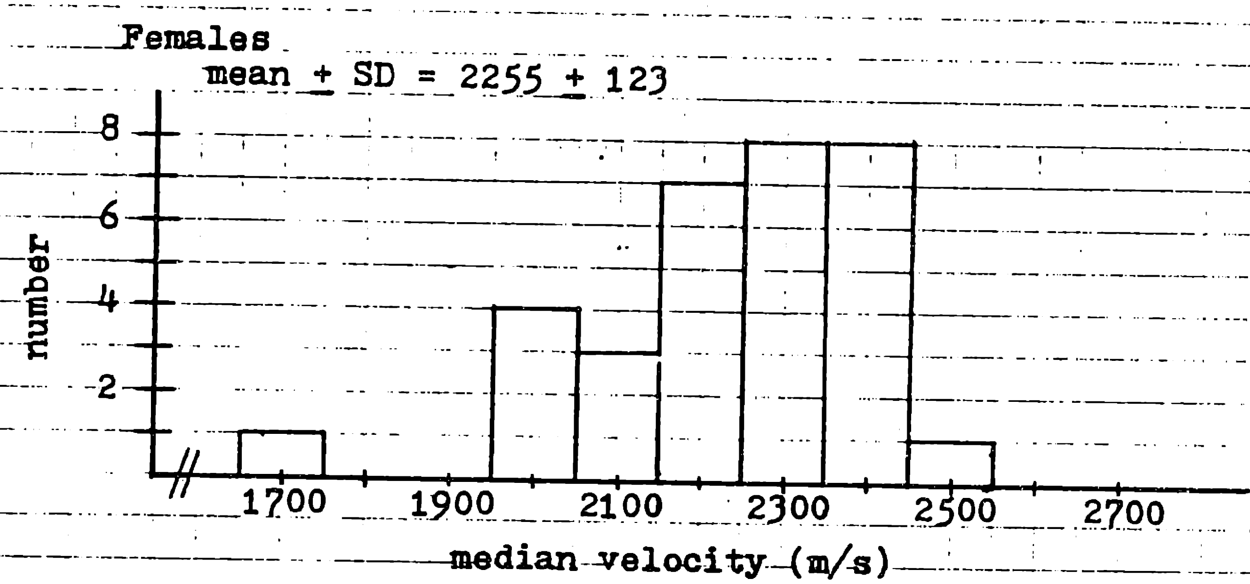


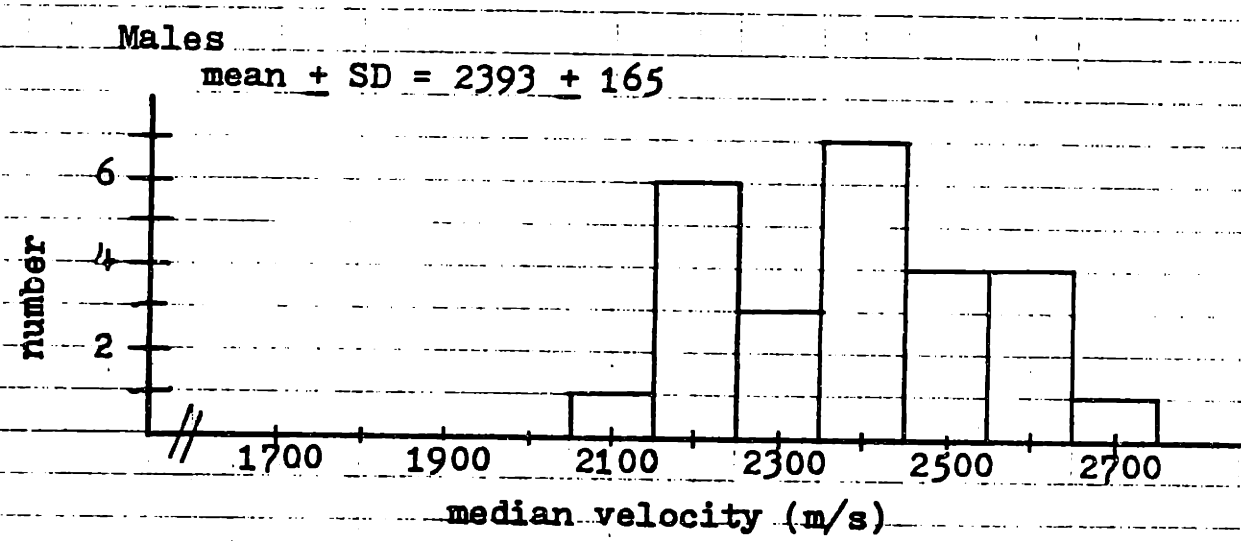
PROXIMAL TIBIAL SHAFT



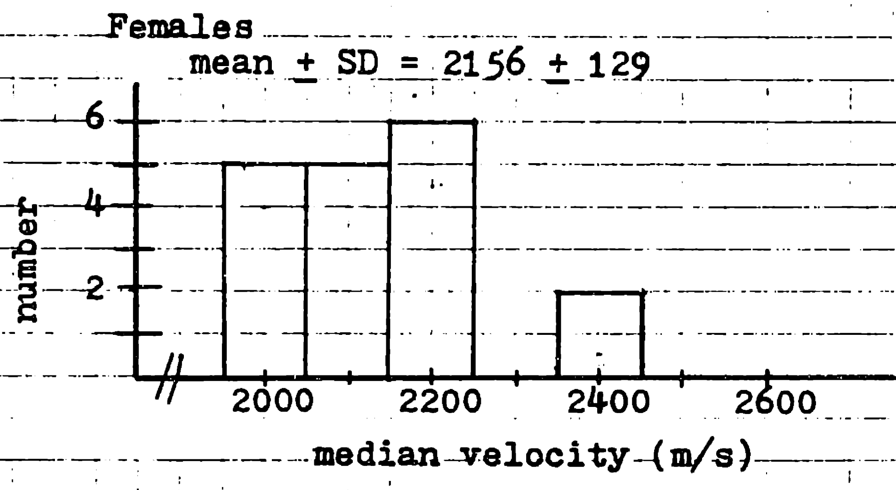


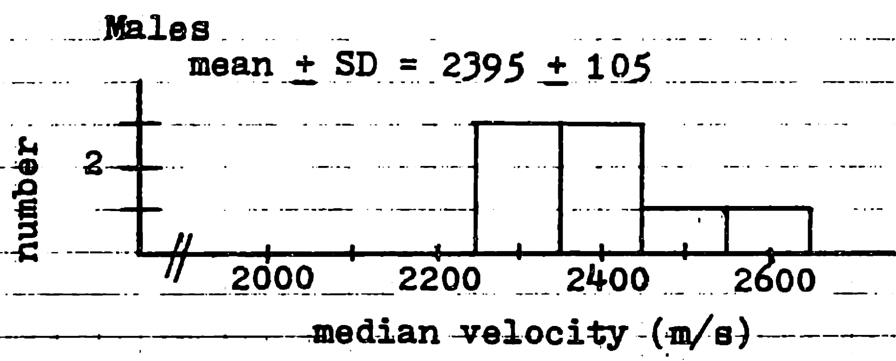
TIBIAL MIDSHAFT



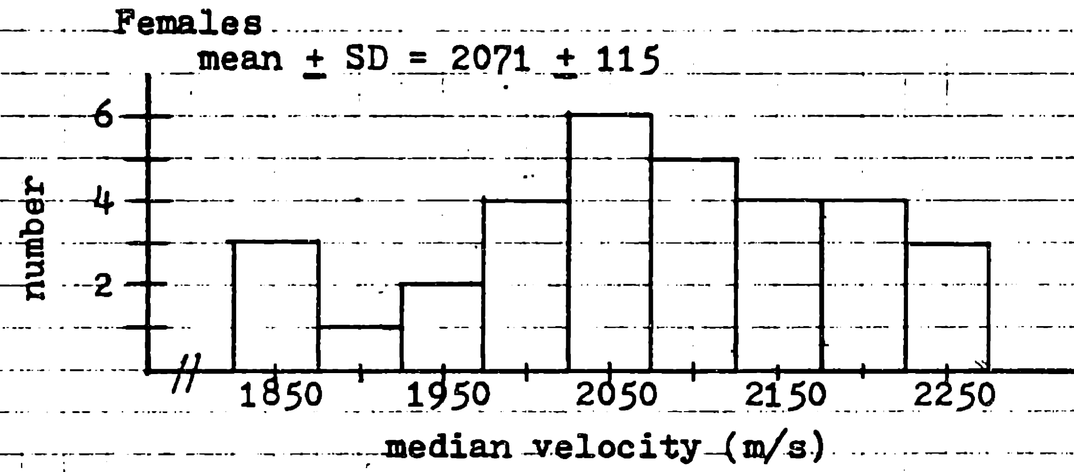


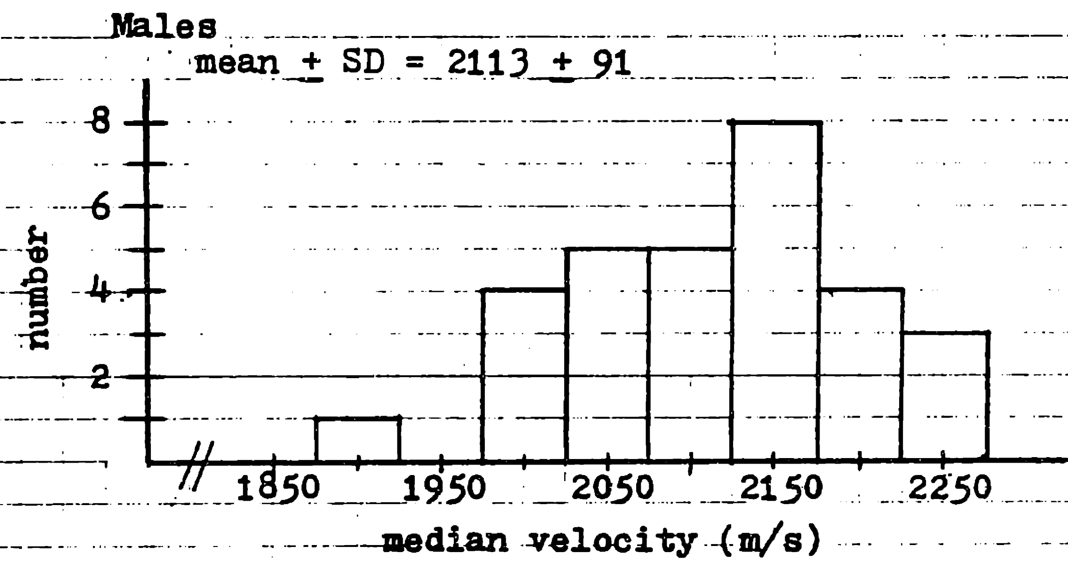
DISTAL TIBIAL SHAFT





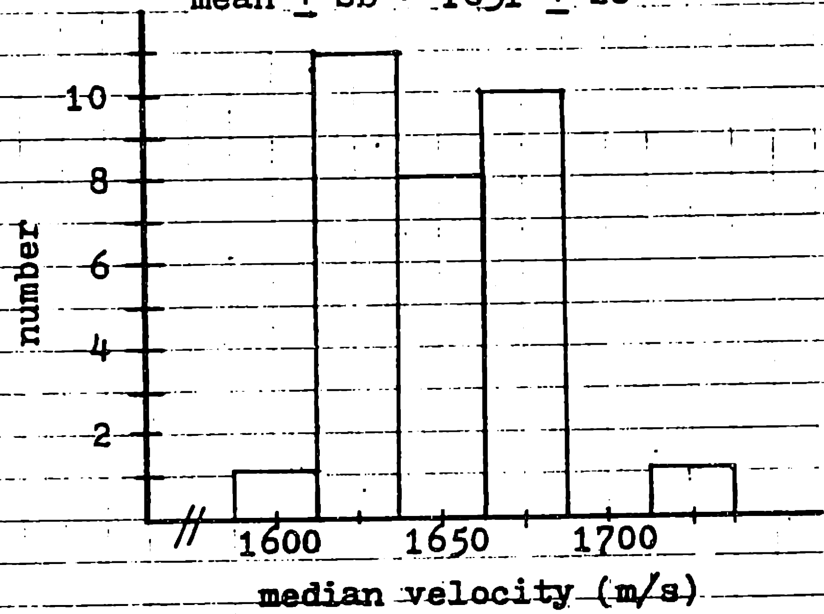
PATELLA


Females
mean ± SD = 2071 ± 115
number
6
4
2
1850
1950
2050
2150
2250
median velocity (m/s)

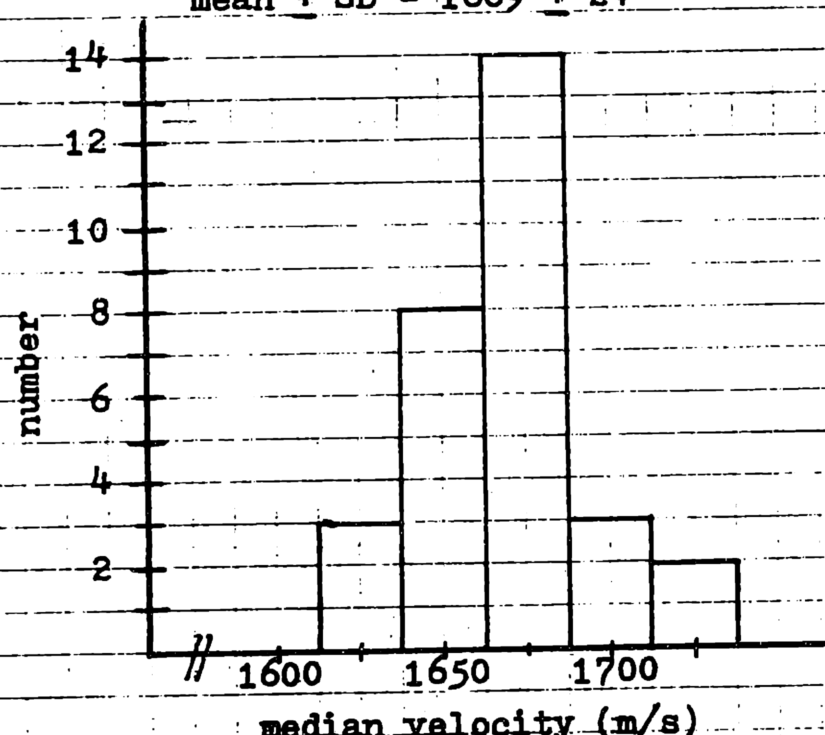

Males
mean ± SD = 2113 ± 91
number
8
6
4
2
1850
1950
2050
2150
2250
median velocity (m/s)

TIBIAL METAPHYSIS

Females
mean ± SD = 1651 ± 26



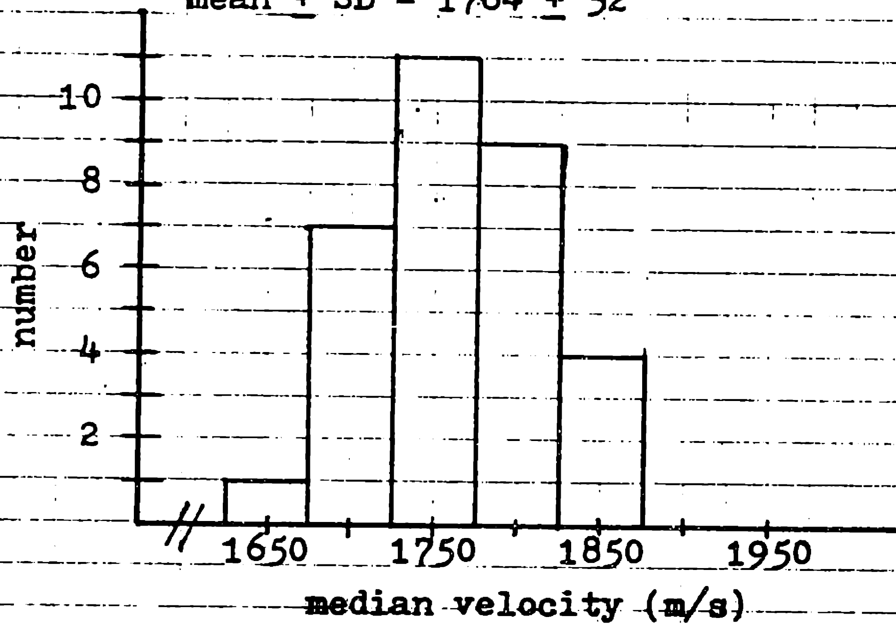
Males
mean ± SD = 1669 ± 24



CALCANEUS

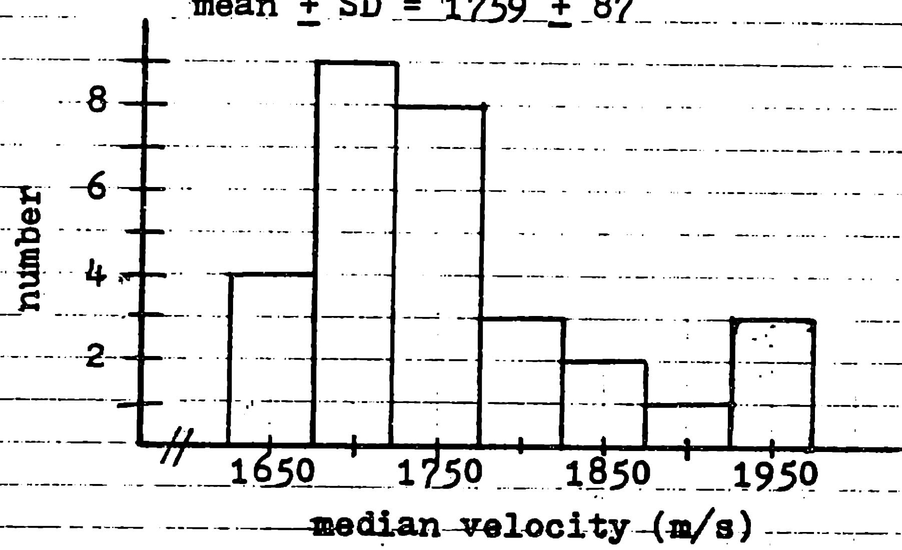
Females

mean ± SD = 1764 ± 52



Males

mean ± SD = 1759 ± 87



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