Final Report
Contract No. NAS9-1246

"Responses of Healthy Subjects to Stresses of Selected Athletic Events"

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[redacted]

ABSTRACT

Electrocardiographic measurements were obta[redacted]d by telemetry from 49 participants during athletic events. Physiological measures plus timed blood and urine samples were also collected at specified intervals prior to and subsequent to the events. The physiological data and biochemical analyses of the blood and urine samples provide normative data which are descriptive of the stress response of expert and novice athletes.

Athletic events monitored were: (1) auto racing, (2) sky diving, (3) polo, (4) bullfighting, (5) hockey, (6) skiing, (7) crew, and (8) track. The selection of sports includes team versus individual competition, life endangering versus low injury events, and tests of strength and stamina versus agility and skill. For most of the sports, both expert and relative novice participants were monitored.

The electrocardiographic measures and other physical parameters are described in this report. The biochemical data will be reported elsewhere.

author

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I. Introduction

A. Contractual Scope of Work

This is the final report prepared for Contract No. NAS 9-1246 entitled "Responses of Healthy Subjects to Stresses of Selected Athletic Events". The data for this study were gathered during the period from January 1963 through July 1964.

The objectives for this study were to provide normative data related to the following areas of interest:

1. Definition of major parameters which are sensitive to stresses imposed by athletic events.
2. Study of individual differences in response to stress in the attempt to isolate characteristic stress patterns of response.
3. Study of post-event recovery as a "cost of performance" measure.
4. Development of predictive measures for determining impending or present disability.
5. Study of previous training as a means for reducing stress development during events, and to relate the degree of training to the physiological cost of a given level of performance.
6. Study of "holds" in regard to their effect on stress development.

7. Analysis of decision-making responsibility effects on stress development.

B. Background

Within the confines of clinical medicine, a substantial amount of data exists pertaining to the effects of physical effort (standardized tests) on physiological processes of diseased persons. Also, data exist on normal individuals subject to rigorous stress under laboratory conditions. Until recently, the majority of stress data obtained in the field was limited to measurement before and after an event,due to the unavailability of suitable telemetry equipment which would provide a means for the continuous examination of pre-, during, and post-event physiological response. The impetus provided by the space program, however, has accelerated the development of refined telemetry and transducer hardware. Further, this hardware can be utilized with reasonable economic outlay. Procedural refinements have also alleviated a secondary problem in active physiological monitoring-myographic noise. The equipment now exists for physiological monitoring--the remaining problems pertain to acquisition of field data and interpretation of results.

Data obtained during the X-15 and Mercury programs had shown increases in cardiac responses beyond a level which could then be considered normal. While there was no evidence to indicate that these "excessive" physiological response patterns had been harmful or detrimental to mission function, there existed a paucity of data to use for comparative purposes.

The purpose of this program, then, was to answer a requirement for physiological response data obtained during athletic and sporting events which, in part, could be related to similar stress responses elicited by crews and personnel associated with the space program.

Certain sporting events appeared to offer situations which could be related to excessive physical or psychological stress. An attempt was made to select events which could be interpreted as being primarily physical stress, psychological stress, or a combination of the two. A last criterion was, whenever possible, to utilize those events which involved a life hazard.

Using the above as standards, the following events were selected:

Auto Racing (Sports Car)

Parachute Jumping (Sky Diving)

Bullfighting

Polo

Hockey

Skiing (Down-Hill Racing)

Crew

Track

To differentiate the aspects of experience, experts and novices were to be considered in each event. Additionally, as stipulated in the work statement, a number of individuals were monitored who were not participating during the monitoring period, yet were psychologically involved.

As previously mentioned, the parameters to be measured were those which either duplicated or approximated the physiological monitoring protocol for the astronauts including pre-, during, and post-flight analysis.

Explanation of the physiological parameters measured and the methodology employed is given in the following section. The biochemical analysis, interpretation, and correlation with the monitored data contained herein is to be published by the various NASA contractors associated with this portion of the study.

This report, as a consequence, represents only a partial summary of the data obtained during the program.

II. Instrumentation

A. Introduction

The wide variety of sports contemplated for use in the program imposed severe restrictions on the selection of equipment necessary to continuously monitor EKG and respiration rate.

The equipment actually carried by the subject was to be as small and light as practicable and self-contained. Since, in many of the anticipated events to be monitored, the subject would be very active and in danger of serious injury, the equipment could not impose any restrictions on the subject's normal movements.

Environmental considerations were also important as temperatures ran from $0^{o}F$ (skiing) to over $100^{o}F$ (normal summer weather, augmented by special conditions, such as location inside a racing car).

There were two practical data acquisition systems--one which would record data on a portable recorder (the data to be reduced at a later time), and the other to telemeter the data to a fixed station.

B. Portable Recorders

The advantage of these systems were that they allowed continuous recording of the subject regardless of where he was or what he was doing. The frequency range of the desired signals was 0 - 100 cps, with emphasis on the lower frequencies. Since this range of frequencies cannot be directly recorded, an FM or pulse technique would have to be employed. A recording duration of 4 hours was required as a minimum.

A survey of available equipment showed nothing to meet these requirements, especially the size and weight requirement. The linearity and speed accuracies required of an FM system are on the order of 0.1 to 0.05% for full waveform recovery. These requirements are more easily met at higher tape speeds, but the required 4-hour monitoring period without changing tapes dictated a slower speed. The tape-drive mechanism would have to be controlled to a speed accuracy of 0.1%. All of these factors combine to require a fairly large package and one which would weigh well over the one pound which was set as a maximum, to insure minimal interference with the subject activities. In addition, there was no tape-drive mechanism available which was insensitive to G-forces in all axes. The characteristics of all tape-drive systems are such that at least one plane is sensitive to G-forces, causing tape speed variations. Since the subjects would be participating in stressful events, it would be certain that this problem would be encountered and that overcoming it required an additional clock channel to serve as a time base.

C. Telemetry Systems

The size, weight, and duration requirements could be met with present telemetry systems. However, the problem of range was present. In practice, size and weight and duration of a self-contained system dictate the maximum usable range.

Sports events within an enclosed space or restricted area, such as hockey and track, presented no range problem. However, events such as auto racing, skiing, and sky diving required ranges of up to 5 miles, and, in many instances, under highly adverse transmission conditions. Additionally, since two systems were required to operate simultaneously, two frequencies would have to be selected compatible with FCC requirements.

Practical considerations require a fairly high frequency to be used, which means essentially line-of-sight transmission. Since auto racing and skiing would both impose severe restrictions on line-of-sight distances, it was decided to limit range requirements to one mile.

D. Requirements of Telemetry System

With the above considerations in mind, Bio-Dynamics requested bids on the following equipment:

1. Two each two-channel telemetry systems, with signal-conditioning amplifiers and electrodes to telemeter a two-lead EKG and respiration rate.
2. Useful range of one mile, line-of-sight.
3. Must perform reliably while subject undergoes exercise.
4. Receiver station(s) must be readily portable for field use.
5. Transmitter weight and size must not encumber subject so as to compromise his performance during athletic events of the type contemplated.
6. Conformation to all applicable FCC regulations.

7. Components should be off-the-shelf items (to minimize delivery time).

8. Expected environment temperatures to range from $0^{o}F$ to $100^{o}F$.

Bids were received from five companies. Two proposed systems utilized low-powered transmitters in the commercial FM band (88 - 108 Mc). These were unacceptable for several reasons--the units were single-channel, and they could not increase their range (power output) under FCC regulations; and their general use was essentially restricted to hospital conditions.

Another proposed system was to utilize an existing EKG transmission system which had successfully transmitted full-wave EKG for distances approaching one mile. The company submitting this proposal planned to develop a multiplier to provide a second channel. This plan was rejected because it was felt that the package would require development and proving time, with no assurance of complete success.

Two firms submitted bids which guaranteed meeting our requirements, using essentially off-the-shelf equipment. Of these, the proposal of Biometrics Inc. (Texas) was accepted.

E. Description of System

As delivered, the system included:

Receiving Station, comprising:

1. A hi-gain antenna, 13-element yagi configuration, with built-on balun and 50 feet

coaxial lead-in, 30-foot telescoping mast, guy wires, anchors, etc..

2. Receiving console, containing:
   a. Two receivers, tunable, in 220 Mc range.
   b. Four sub-carrier discriminators.
   c. Power Supply for above.

The receiving console has provision for adding four more discriminators as plug-in units.

Transmitter Pack - two transmitter packs each weighing 11 ounces, containing:

1. Transmitter - specially designed for operation in 220 Mc range, with an output power of approximately 500 milliwatts.
2. Two sub-carrier oscillators.
3. Bridge Amplifier, for use with respiration rate strain gage.
4. EKG Amplifier.
5. Rechargeable 12-volt battery with spare.
6. Chest band sensor.
7. EKG Electrodes.
8. Transmitter pack case - a leather case to contain all the above (except the spare battery). It is attached

to the subject using two leather straps, and the electrodes and chest band connect to the pack via a single-fire terminal miniature Cannon connector. Additionally, a battery charger was supplied for the four rechargeable batteries.

Recorder - An Offner Type 542 Dynograph Recorder was used to record all telemetered signals. This recorder has two channels, with the addition of two externally-powered event pens. The two data channels contain an internal amplifier, and electric-writing styli. Input impedance was on the order of 500,000 ohms, with a maximum sensitivity of 0.5 mv/cm available, which was greater than required. Frequency response is 0 - 200 cps, with flat response to 100 cps. Paper drive could be varied from 1 to 100 mm/sec. Most EKG recordings were made at the standard 25 mm/sec. with occasional 50 mm/sec. segments for closer examination of the waveform.

Initially, it was planned to record one channel of EKG and one of respiration rate, if only one subject were being monitored. When two subjects were to be monitored simultaneously, both channels would record EKG, and the two event pens were to be used for respiration rate. Accordingly, a two-channel, self-contained, zero-crossing device was designed and built which would accept the respiration signal and throw a relay as the signal reversed direction. This, in turn, operated the event pens.

Other miscellaneous equipment needed were two Kupfrian, solid-state inverters and two, heavy-duty, 12-volt, lead-acid batteries. These inverters supplied 115 volts AC 60 cycle for operating the receiving console and recorder in the field where no power was available.

A second antenna was furnished at a later date, consisting of two folded dipoles at right angles. This turnstyle arrangement allowed a more omni-directional reception field and was far less cumbersome than the large array. This antenna was used for most of the sports, as detailed later.

F. Problems Encountered

In general, two types of problems were encountered; those generated by the particular sport or event, and those which were a function of the equipment and/or methodology, and generally applied to all events.

Of the latter, the most difficult problem was in the method used to acquire respiration rate. The chest band sensor, as initially supplied, was mounted on a plastic band. It worked well in laboratory tests, but, in actual use, had three deficiencies; first, the plastic band would slip from its position because the subject would not allow it to be tightened too greatly, and chest expansion of the subject when active caused slippage. Second, the plastic band itself stretched fairly readily as a consequence of temperature changes. This caused a base-line excursion which quickly drove the bridge off-scale. Third, the range of expansions and contractions were such that, at the gain necessary to determine resting or normal respiration, the signal was driven off-scale for violent respiration.

Biometrics then fabricated a harness-type device of woven cotton straps, which included a chest band and two shoulder straps. This device greatly reduced the first two problems, but the third remained.

Additionally, there was an over-all problem of subject dislike for any kind of chest strap. This was understandable, since most of the subjects were engaging in a strenuous and sometimes dangerous activity, and a chest strap would be a natural inhibitor to their performance, and therefore might possibly jeopardize their safety. For this reason, the respiration device was not used for many of the events. In the events where it was used, the information was often distorted due to violent arm movements required--polo, for example.

The transmitter package caused two small problems. First, as supplied, the electrode connectors were miniaturized Cannon, push-together types. These were good from a quick-release viewpoint, but had no locking feature. During several of the early events, signal loss resulted from connection separation. These connectors were replaced by Winchester miniature locking connectors secured by two thumb-screws.

Secondly, the original transmitters were encased in a soft, leather case with two leather straps which went around the subject's body. The transmitter placement was usually on the lower back of the subject. These straps were subject to breakage and slipping, and were somewhat uncomfortable. The straps were replaced with an elastic band, four inches wide, sewn to the leather case, with two straps and buckles to secure it. This proved far more convenient to use and more comfortable.

The only other notable problem was in actually detecting the transmitted signal. This was partially a problem of methodology. The highly directive aspects of the array antenna meant that, for instance, in auto-racing, the subject (car) must be tracked by manually rotating the antenna mast. This was accomplished without too much difficulty. However, in sky diving, a slant direction also had to be considered. Also, the jump point was usually out of range. For this reason, the equipment was placed in the jump plane, and using the small turnstyle antenna, data were recorded full time, even after the jump, by having the plane fly a tight spiral and track the subject. Wherever possible, this method was used. In the restricted sports (polo, hockey, bullfighting, indoor track), the small antenna covered the field of interest. In sky diving, crew, and marathon running, the equipment was placed in the plane, chase boat, and chase car, respectively, to accomplish the same purpose. In skiing and auto racing, a fixed ground station was maintained using the directive array and manually turning it.

The antenna on the transmitter was supplied as a fixed 27 inch metal rod, similar to an automobile radio antenna. This was used for all events except hockey, in which physical placement of this antenna was impossible. For this event, a shielded wire of proper length was substituted, and wrapped horizontally around the body. This method was successful and, subsequently was used for bullfighting also.

In all events studied, a vertical 2-lead sternal electrode placement was used to avoid myographic interference.

G. Instrumentation Recommendations

Within the limitations previously described for telemetry systems in general, this equipment performed well. It was placed in airplanes, automobiles, boats, snow-cats, and various galleries, arenas, and fields. It was used in hot, humid conditions, rain, snow, and $0^{o}F$.

Tape data acquisition has not yet reached the state of development where the instrument package is of reasonable size and weight for many of these events. It is possible, for instance, to get a tape acquisition system suitable for use in racing cars, but such a system could not be used on an individual in a track meet.

The most obvious change needed with either system is another method of obtaining respiration rate data.

It should be pointed out that the Biometrics system, as purchased, can be expanded to a four-channel system by the addition of plug-in units to the basic equipment.

III. Biochemical Sampling

A. Objectives

Both physical and emotional stress are reflected by changes in levels of compounds circulating in the blood and by changes in urinary content and volume. Since response to stress is a highly individualistic thing, depending on the person's past experience, physical condition, etc., the measurement of blood and urine changes is a necessary technique for assessing individual response patterns. A biochemical sampling regimen was adopted for this study which would provide blood and urine data comparable to that derived from samples collected during project Mercury. The collection schedule was devised to provide samples at selected intervals during the 24 hours both preceding and following the event, and diurnal control data, when possible, during a nonevent period. Sampling techniques and preservation of samples were rigorously performed. Preserved samples were then shipped to Houston for dissemination to laboratories already performing analyses for the NASA program.

No single measurement of hormone(s) or other compound has been found to describe adequately the complex adaptations to physical or psychological stress. Secretions from the pituitary gland and adrenals (medulla and cortex) play an important integrated role. However, measurements of these hormones in the blood are difficult and do not, in themselves, describe all of the important stress response factors. Eosinophil counts are easy to perform and have been used as a reflection of adrenal activation, but direct urinary measurements of adrenal hormones are more useful if differential plasma analyses are not possible. Both free and conjugated 17-hydroxycorticosteroids, corticosterone-like hormones, catecholamines (epinephrine, norepinephrine, and dopamine), catecholamine metabolites (VMA, metanephrine, normetanephrine, dihydroxymandelic acid, and DOPAC) can be measured in the urine. For this study, both blood and urine samples were collected to permit a wide range of analyses (the actual selection of analyses performed was made by the NASA and are not reported here).

In addition to measurements of adrenal secretions or their metabolites, other plasma measures of interest would include potassium, sodium, chloride, pH, glucose, proteins, uric acid, lactic acid, and lipids (especially free fatty acids). Urine measurements should include creatinine as a crude index of completeness of urine sample collection. Other urine measurements of interest in stress assessment include uropepsin, sodium, potassium, albumin, specific gravity, and excretion rate.

B. Collection Schedule

Urine samples were obtained 24 hours, 4 hours, and immediately before the event, immediately after, 4 hours, and 24 hours after the event. In addition, subjects collected all other urine voided during a 48 - 72 hour period, depending on the event, recorded the time of voiding, and refrigeration of the sample until it could be delivered to Bio-Dynamics, Inc., for further processing. Peripheral venous blood samples were also collected at 24 hours, 4 hours, immediately before, immediately after, 4 hours, and 24 hours after the event. Both blood and urine samples were collected every

4 hours over a 24-hour period, commencing at 8:00 a.m. and ending at 8:00 a.m., on an uneventful day, in order to establish diurnal variations (no 4:00 a.m. samples were collected). However, not all subjects were available for diurnal measurements since these had to be collected a number of days before, or preferably, after the event. Some variations of the collection schedule were inevitable for certain events. These variations are described in the sections of this report dealing with the particular events.

C. Sample Preservation

Blood samples were collected from the medial cubital or cephalic vein at the elbow. A heparin lavage was used to prepare the syringe prior to drawing 10 cc from the subject. Samples were immediately centrifuged, the plasma volume was then measured, drawn off, and frozen in a dry ice chest.

Urine volume and specific gravity were measured, after which the sample was divided into three separate containers and frozen. One of the three samples was acidified by addition of 10 N sulfuric acid prior to freezing (1 ml/100 cc urine).

All samples were labeled as to date and time of collection, volume, specific gravity (urine), whether acidified or not (urine), name of subject, and code number. Sample data and code numbers were also recorded in the study records. Samples were packed in styrofoam containers with dry ice and shipped by Air Express to Houston. All samples remained frozen from shortly after collection until thawed for analysis.

IV. PROCEDURES AND RESULTS

A. Sports Car Racing

1. General

Sports car racing was selected because of the high risks, skilled, competitive, individual effort, and close man-machine relationship characteristic of this sport.

In addition to the constant death or injury hazard, drivers are subjected to pronounced physical strains as well. There are high transverse accelerations encountered during turns and spins. Temperature is also a stress; all drivers wear a neck-to-ankle, flame-resistant suit which does not dissipate body heat particularly well. Second, most of the cars, open or closed, generate considerable heat so that the cockpit is often uncomfortably warm. Third, ambient temperatures were very high--a range of 80^{o}F to 120^{o}F. Finally, the noise and vibration level is exceptionally high.

Sports car racing is conducted on a closed-circuit course which has turns, hills, and other obstacles to test the drivers' skill. On this basis, it can be differentiated from "Indianapolis"-type events: Typical races are held over a week-end period and involve as few as two or as many as 10 separate events. These events vary in length according to the status of the driver, the significance of the race (in terms of importance based on a national rating system) and the engine displacement of the vehicles.

Three week-end races were attended at three different courses to obtain the required data. A total of 10 separate events were involved and two events, each 500 kilometers in length over a 4.5 mile course. Attainable speeds were in excess of 180 miles per hour. The length of these events was sufficient to require pit stops for fuel, tires, and, in some instances, the exchange of drivers.

3. Procedure for Sports Car Racing

Typically, the drivers arrive a day or two before the event to practice and to participate in time trials. Immediately following the events, the drivers usually quickly disperse to other parts of the country. As a consequence, we were generally able to initiate blood, urine, and the physical data collection 24 hours preceding the event, but were limited to only the one "immediate" post-event sample.

4. Telemetering Arrangements

The geographical layout of most of these tracks precludes line-of-sight transmission except for relatively small sections of the track. In general, attempts were made to locate the receiving systems at a known hazard point. This location was identified by discussion of the course with the track officials. Because transmission was limited to a short range, monitoring times varied from 2 to 16 seconds per individual per lap. This means that the drivers were monitored for from 1% to 20% of the time throughout the race.

Problems were also encountered in installing the telemetry transmitter within the confines of the car. In some instances, the cars were completely enclosed and external installation of the transmitting antenna was

16 individual drivers studied.

2. Events

National Races - Lime Rock Park, Lime Rock, Connecticut, June 13, 14, and 15, 1963

This racing session involved several separate races over a 1.5 mile irregular course for various types of cars. By definition, this event was limited to expert drivers competing for points for the national rating of drivers. The length of the individual races were 50 laps (or 75 miles) and involved speeds from 15 miles an hour to a maximum of 100 miles an hour.

Road Races, Watkins Glen, New York, June 28, 29, and 30, 1963

This racing event included a practice session on June 28; five regional races, open to novices, on June 29 and two national races, experts only, on June 30th. The course length is 2.3 miles with speeds varying from 15 to 180 miles per hour.

The regional* races were of 20 laps duration, 46 miles, with the national being 80 laps or 184 miles in length.

Double 500 Kilometer Auto Race, Bridgehampton, New York, September 14 and 15, 1963

It was the most significant auto event covered during the course of the contract as it pertained and offered points to the international standing of drivers and auto manufacturers. It was limited to experts and involved

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*Regional races are events which pertain to individual driver standing in a particular geographical area; for example, New England.

prohibited. In other cases, mounting of the antenna externally was possible.

5. Subjects

Both experts and novices were monitored for these events. For this study, a novice was defined as an individual who had completed a prerequisite training program (drivers school) and had participated in no more than four regional races. The experts selected for study had raced in 50 or more events, and all were known among their contemporaries.

6. Events and Measurements

Lime Rock National Races, Lime Rock, Connecticut

Three expert drivers were selected for participation in this event through prior arrangement with the race course medical team. An attempt was made to select drivers who would not be participating in the same event in order to avoid scheduling problems for immediate pre- and post-event samples. Although delivery of the telemetry gear had been promised by mid-May, it did not arrive until June 13, the first day scheduled for monitoring. A series of attempts were made to gather telemetry data during both the practice sessions and the actual races, but without success due to the unsatisfactory performance of the telemetry system.*

Blood samples were taken on three subjects at minus 24 hours, immediately prior, and immediately after the race. Some urine samples were

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*The equipment was returned to the manufacturer for additional work.

obtained but complete 24-hour collection was not possible. These samples were forwarded to MSC for analysis. Because of the telemetry equipment failure, this event was used primarily to test out the logistics program. While coverage of this event was only partially successful, it provided a great deal of information regarding the logistics problems involved.

Watkins Glen Sports Car Grand Prix

The national road races at Watkins Glen included a practice session on June 28, five novice races on June 29, and two expert races on June 30th. Five candidates, three novices and two experts, had been pre-selected through the assistance of the race committee.

Biochemical samples consisted of timed urine samples and blood samples drawn at minus 24 hours, immediately prior, and immediately after, and plus 24 hours for the three novices. The two experts were not available for the plus 24 hour samples, but did contribute samples from minus 24 hours up to and including immediately after the event.

One of the telemetry receivers had been damaged in transit from the manufacturer and was inoperative over the duration of this race. As a consequence, only four of the available five candidates for the study could be monitored by telemetry. The telemetry data consisted of EKG recordings obtained by a M-X (manubrium-xiphoid) sternal lead position using NASA electrodes. Data from four drivers, two novice and two expert, are presented in Figures 1 and 2. The pulse rate data computed over the period monitored for each lap is presented as a function of race lap number.

Pulse Rate Vs. Lap Number
for Two Automobile Drivers
Telemetered Data
Watkins Glen Sports Car Grand Prix
June 28, 29, 30, 1963

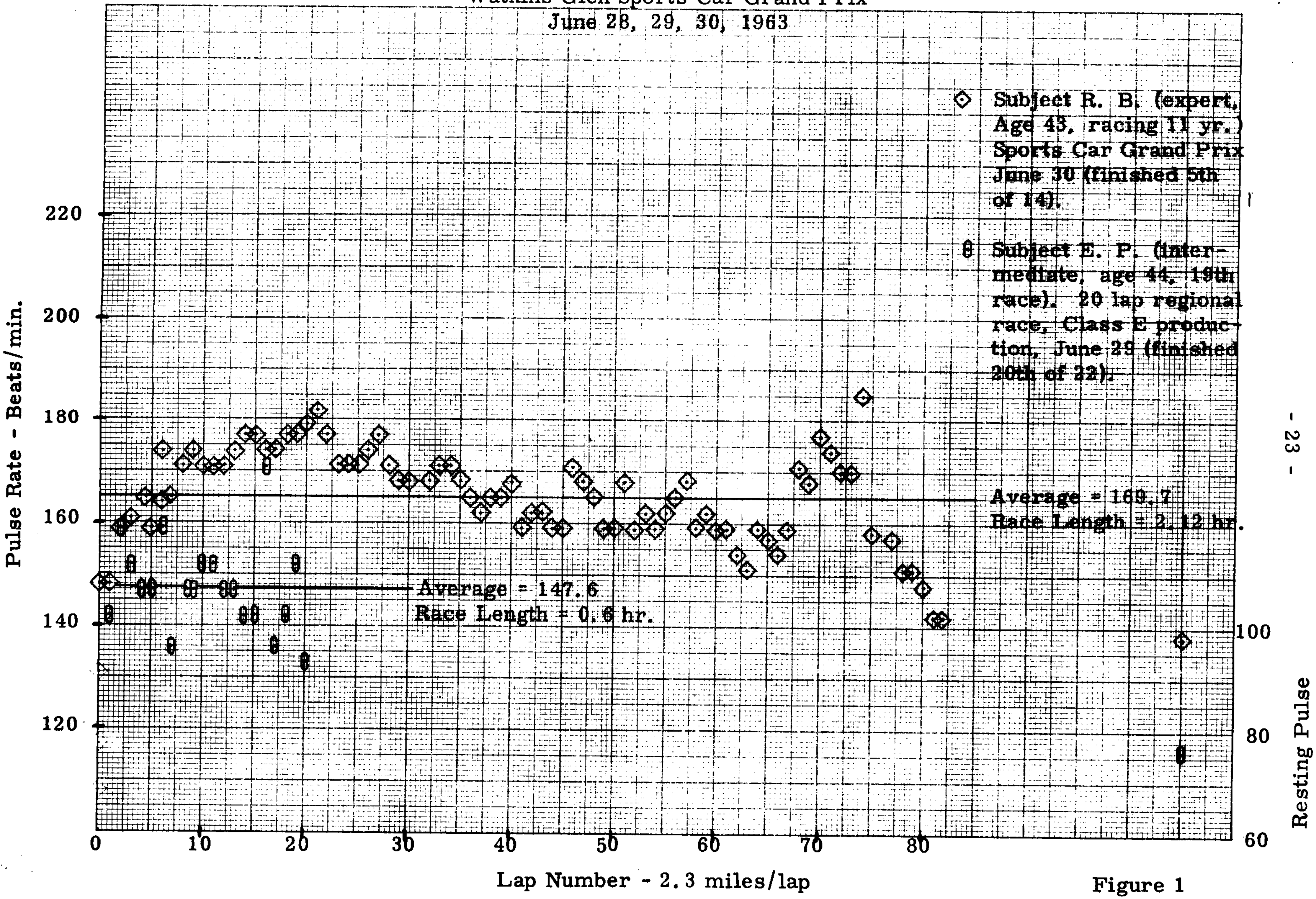

Figure 1

bio-dynamics, inc.

Pulse Rate Vs. Lap Number
for Two Automobile Drivers
Telemetered Data
Watkins Glen Sports Car Grand Prix
June 28, 29, 30, 1963

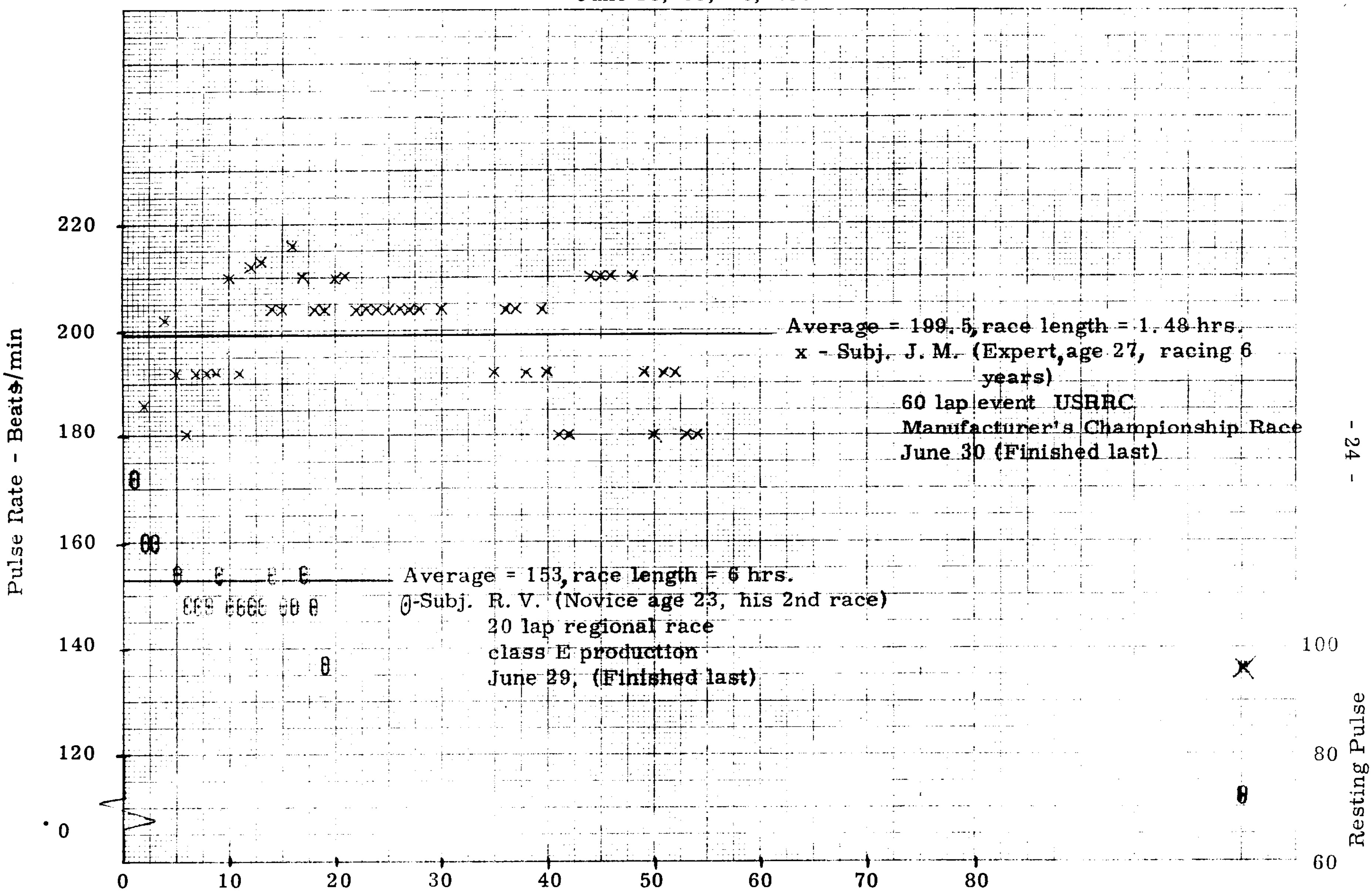

Figure 2

Lap Number-2.3 miles/lap

<u>bio-dynamics, inc.</u>

The age and relative racing experience of each driver are shown on the figures, and pre-event resting pulse rates are indicated at the zero lap mark.

All of the drivers monitored were required to undergo a rather detailed medical examination prior to each race. However, drivers were not required to meet exacting physical fitness requirements; they only had to be free of certain medical "abnormalities". Unless waived by a medical examining board, the medical defects which can preclude participation are:

1. Epilepsy
2. High blood pressure greater than 150/100
3. Past history of heart disease
4. Diabetes
5. Dizzy spells
6. Less than 20-40 vision when corrected
7. Loss of extremities
8. Alcoholism
9. Evidence of psychological disorders

Of the four drivers whose pulse rates are shown in Figures 1 and 2, only one individual, R. V., engaged in a regular physical conditioning program--running.

The pulse rates gathered from the two novices (Figures 1 and 2, lower curves) were consistently smaller than those obtained from the experts. However, in every other sport studied, the novices generally had higher pulse rates than the experts. One speculative explanation for the lower rates among novice auto drivers may be the generally lower speed levels (hence reduced stress) of the novice races.

During the races from which data were gathered at Watkins Glen, the ambient temperature was 102^{o}F. Subject J. M. (Figure 2) drove in a completely enclosed car and was subjected to temperatures in the vicinity of 120^{o}F plus. This, in part, would account for his elevated pulse rate. This same driver was monitored a second time at Bridgehampton (see Figure 3) where his average pulse rate was approximately 20 beats per minute lower. This was partially due to a reduction in ambient temperature from the 102^{o}F, encountered at Watkins Glen, to 60^{o}F, at Bridgehampton.

Bridgehampton "500"

All drivers monitored at Bridgehampton were experts. Measurements included telemetry data on four drivers and biochemical data on eight drivers, including the four in the telemetry group. Most of the drivers from whom only the biochemical data were obtained raced both days of the two-day event.

Data were obtained, whenever possible, for both races and consisted of blood samples, blood pressure, body temperature, and resting pulse at minus 24 hours, just before the race, and immediately after the race. Body weight was taken immediately before and immediately after. Table 1 shows the summary of these measurements for eight drivers. Urine collection was initiated at minus 24 hours and was continued over both race days for all eight drivers.

Telemetry data using the MX sternal lead were obtained from two drivers during the first race on September 14 (Figure 3). Both of these drivers drove the entire 500 kilometer race (110 laps) without relief drivers. Good EKG data were obtained on W. H. throughout the race. One of the electrodes became detached from J. M. after 12 laps, although the signal was good up until that time. Their pulse rate data for each lap are summarized in Figure 3.

During the Sunday races (September 15), telemetry data were obtained on A. W. and W. W. (Figure 4). The transmitter extension cable separated

Pulse Rate Vs. Lap Number
for Two Automobile Drivers
Telemetered Data
Bridgehampton "500"
Sept. 14 & 15, 1963

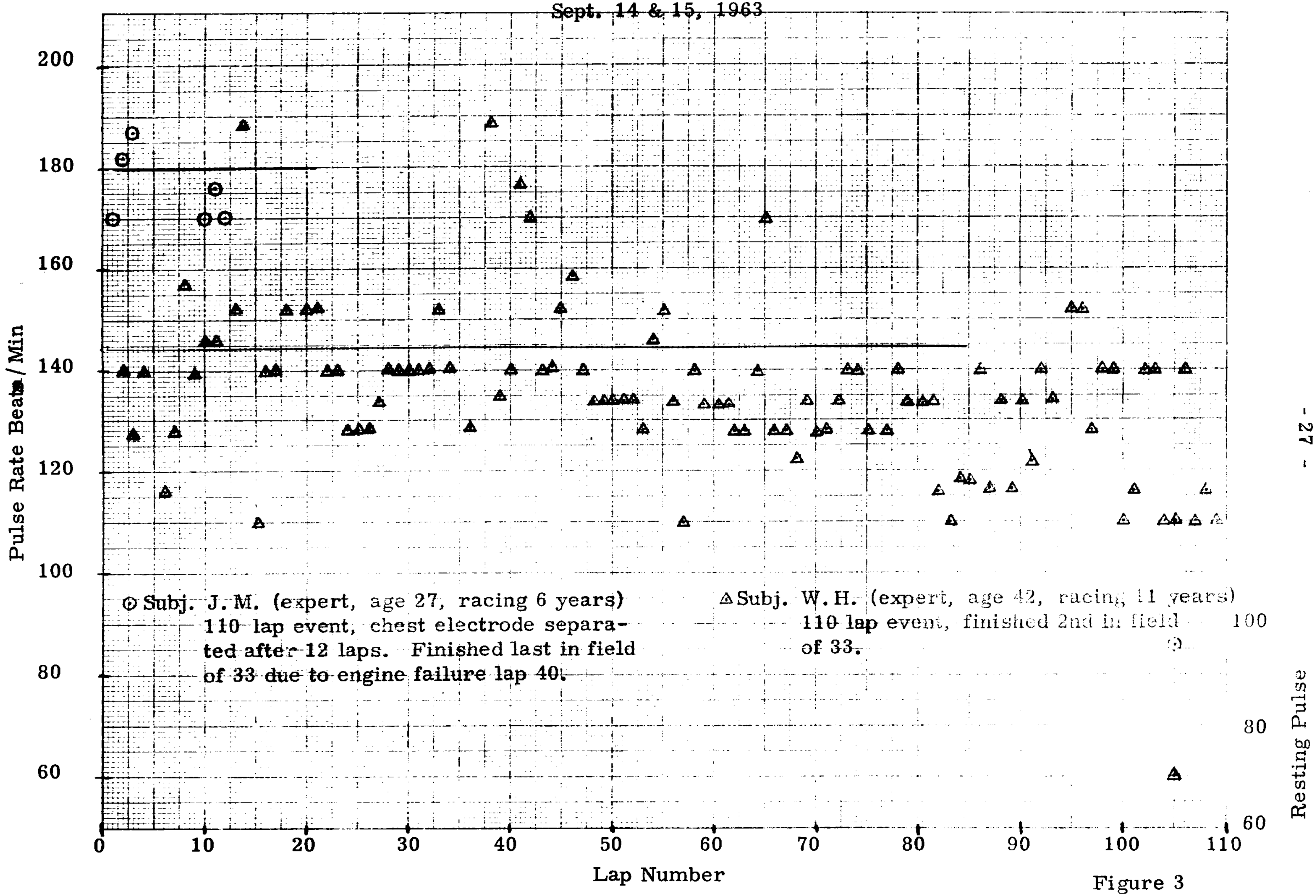

Figure 3

Table 1 - Sports Car Racing, Bridgehampton, New York

							Remarks
Subject: Newton Davis Age:	9/13/64 -24 hrs.	9/14/64 Just before	9/14/64 Race	9/15/64 -2 hrs.	Race	9/15/64 Just after	*Did not race 9/14/64; car malfunction. **Was not monitored during this race, 9/15/64.
Ambient temperature							
Blood pressure	130/60	130/75		130/80		135/75	
Resting pulse	76	80		72		72	
Body temperature	99.2	97.6	*	98.2	**		
Weight		151.5		155		154	
Subject: Arthur Riley Age:	9/13/64 -24 hrs.	9/14/64 Just before	9/14/64 Race	9/15/64 -45 min.	Race	9/15/64 +50 min	*Was not monitored during either race. Driver did not show up after race on 9/14/64.
Ambient temperature							
Blood pressure	120/80	135/90		130/40		120/80	
Resting pulse	78	72		84		96	
Body temperature	97.8	98.7	*	99	*	98.7	
Weight		184		183		181.5	
Subject: Pedro Rodriguez Age:	9/13/64 -48 hrs.			9/15/64 -2 hrs.	Race	9/15/64 Just after	*Was not monitored during the race on 9/15/64.
Ambient temperature							
Blood pressure	120/80			120/65		120/55	
Resting pulse	60			70	*	120	
Body temperature	97.8			98.2		98.7	
Weight				147.5		144.5	

(continued on next page)

Table 1

Table 1 - Sports Car Racing, Bridgehampton, New York (Cont'd.)

								Remarks
Subject: Alan Wylie	9/13/64	9/14/64	9/14/64	9/14/64	9/15/64	9/15/64	9/15/64	*Was not monitored during race on 9/14/64
Age: 42	-24 hrs.	-90 min.	Race	+2 hrs.	-45 min.	Race	+20 min.	**Was monitored 9/15/64. Data in Figure 4; placed fifty; did well.
Ambient temperature								
Blood pressure	120/70	160/100		138/80	150/80		130/75	
Resting pulse	80	100	*	92	90	**	102	
Body temperature	97	97.6		98.8	97.0		99.2	
Weight		179		179	177.5		176.0	
Subject: William Wonder					9/15/64	9/15/64	9/15/64	
Age: 39					-2 hrs.	Race	Just after	
Ambient temperature								*Did not race on 9/14/64.
Blood pressure					145/70		135/75	
Resting pulse			*		114	**	114	**Placed fourth; did very well.
Body temperature					97.7		98.4	
Weight					154.0		150.5	
Subject: Gary Georgi	9/13/64	9/14/64	9/14/64	9/14/64	9/15/64	9/15/64	9/15/64	
Age:	-24 hrs.	-90 min.	Race	+20 min.	-25 min.	Race	Just after	
Ambient temperature								*Was not monitored during the race on 9/14/64 or 9/15/64.
Blood pressure	120/60	120/70		140/75	130/70		150/65	
Resting pulse	78	72	*	88	96	*	92	
Body temperature	98.7	98.5		98.6	98.6		--	
Weight		174		170.5	176.5		174	

Table 1 (Cont'd.)

Table 1 - Sports Car Racing, Bridgehampton, New York (Cont'd.)

					Remarks
Subject: Walter Hansgen Age: 42	9/13/64 -24 hrs.	9/14/64 Just before	9/14/64 Race	9/14/64 Just after	
Ambient temperature					*Monitored data in Figure 3. Placed 2nd; drove very hard.
Blood pressure	135/70	150/90		150/90	
Resting pulse	70	72		96	
Body temperature	98.4	98	*	97	
Weight		186.0		184.5	
Subject: Jack Moore Age: 27	9/13/64 -24 hrs.	9/14/64 -45 min.	9/14/64 Race	9/14/64 +5 min.	
Ambient temperature					*Monitored data in Figure 3. Placed fifth.
Blood pressure	135/70	125/80		120/80	
Resting pulse	96	96	*	120	
Body temperature	98.8	97.6		99.1	
Weight		145.5		144.4	

Table 1 (Cont'd.)

Pulse Rate Vs. Lap Number
for Two Automobile Drivers
Telemetered Data
Bridgehampton "500"
Sept. 14 & 15, 1963

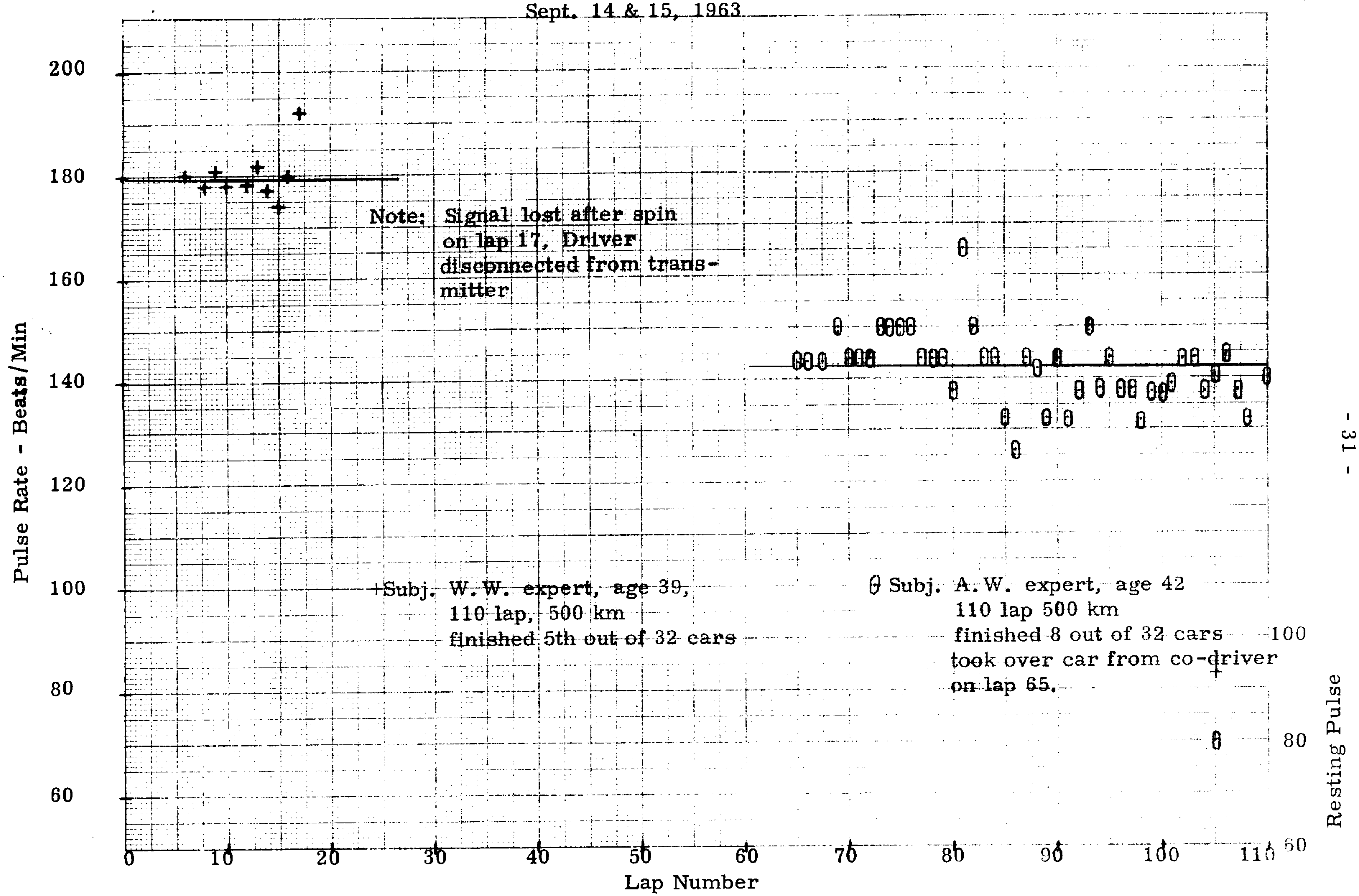

Figure 4

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from W. W. after a violent spin during lap 17 and remained separated for the remainder of the race. A. W. relieved his co-driver at lap 65 and good data were obtained throughout the race.

7. Discussion

The telemetry data gathered on all drivers shows a relatively constant elevated rate throughout the race. Two of the drivers at the Watkins Glen event, J. M. (Figure 2) and R. B. (Figure 1) had an additional stress situation during their respective events. J. M. spun out on the first lap, and R. B. had a collision with another car on lap 55 after skidding over an oil slick and losing control of his car. The time between these incidents and receipt of a telemetry signal was approximately one minute for J. M. and 30 seconds with R. B.. It is interesting to note that these additional stresses had no apparent prolonged effect on the pulse rate since no significant changes were measured shortly after these incidents.

There were occasions when an unusual slide, spin, or bumping of cars occurred during the period when telemetry was received. It was not possible to pick out any unusual response in heart rate on these few occasions.

Diurnal cycle biochemical data were not obtained on race drivers due to geographical dispersion of these individuals immediately following the events.

B. Sky Diving

Sky diving has recently gained interest in the United States and was selected as a sport that provides a strong psychological stress, particularly for the novice. In sky diving, experts usually jump from altitudes above 6 or 7,000 feet and have a long free fall period prior to parachuse deployment. However, the higher altitude jumps and long free falls are restricted to experts who have considerable skill and experience. The typical training program for sky diving involves approximately 25 minutes of ground instruction followed by a static line jump at 2,800 feet. This is performed as follows: (a) the subject climbs out on a small step attached to the strut of the aircraft, (b) the instructor monitoring the jump attaches the parachute static line to the aircraft, (c) upon command from the instructor, the novice separates himself from the aircraft, and (d) the static line deploys the parachute. Typically, four or five jumps are performed by this static line technique at which time the student progresses to a second category called a jump and pull. The same altitude is used--the student separates from the aircraft and immediately pulls his ripcord.

1. Procedures

Because the novices selected for this event had no experience whatsoever, they all used the static line technique. The experts, on the other hand, used the jump and pull exercise previously mentioned. The novice subject would initiate the jump by climbing out on the platform, holding the wing strut with his hand, and facing in the direction of flight. On command, the subject pushes off from that position and falls in spread eagle fashion until parachute deployment.

Due to range and environmental considerations, a fixed ground station to receive telemetered data proved impractical. A high gain receiving antenna array with extreme front-to-back ratio was tried as a means to increase the range. Due to the sharpness of the lobes, the antenna had to be rotated to follow the airplane and diver's path. In addition, adjustment of the elevation of the array was required. Simultaneous adjustment of the antenna in two planes proved cumbersome. The situation was ultimately solved by mounting the telemetry receiving station in the aircraft and having the aircraft circle the parachutist during descent at a distance of about 500 feet. Data were taken throughout the entire flight and jump period. Two of the experts delayed pull excessively and outdistanced the plane, causing loss of the telemetry signal.

The telemetry transmitter was located on the retaining straps of the reserve parachute and the electrodes were placed in the M-X sternal position.

2. <u>Subject Selection</u>

Seven individuals participated in the sky diving program, four novices and three experts. The four novices had never jumped before while the experts had an experience level ranging from 150 to 600 jumps.

All four novices were given brief ground training covering aircraft separation, landing, and maneuvering instructions. All novice jumps were static line with parachute deployment initiated by a static line attached to the interior of the aircraft.

This event also involved the use of a "hold" subject (novice) who, at the last minute prior to jumping, was informed that his actual jump would occur the following day.

3. Measurements

Biochemical samples included timed urine samples initiated at approximately 72 hours prior to the events and continued until 8 hours after the jump. Blood samples were obtained 72 hours (or more) before, immediately before, and immediately after the event.

Biochemical samples for diurnal cycle data were obtained on all participants approximately three weeks after the event.

Telemetry data was obtained for representative time intervals during the events up to the time the participant left the aircraft cabin and assumed his jump position. Thereafter, continuous data were obtained to the time when the jumper landed. An additional EKG sample was obtained 3 to 5 minutes after landing.

The telemetry data are presented in Figures 5 through 8 and show pulse rate as a function of discreet events (take-off, climb, etc.) and as a function of real time after aircraft separation.

Pulse rate data from a novice,used unknowingly as a "hold" subject, appears in Figure 5 together with data obtained during his actual jump a week later. During the hold run, the subject performed all phases of the

Pulse Rate Vs. Time and Events
for Hold Versus Jump
Parachute Jumping, Mansfield, Mass.
July 18-20, 1963

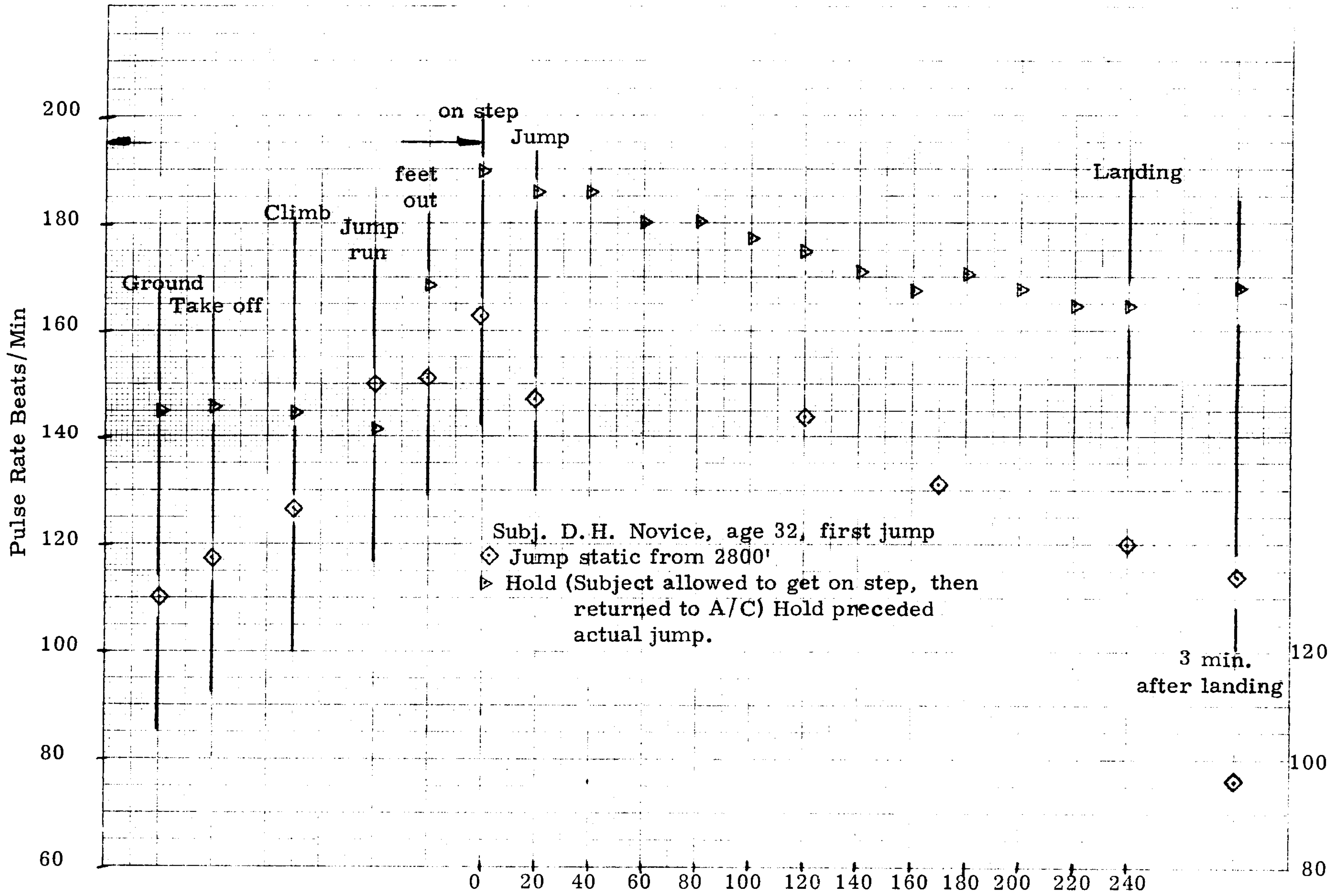

Figure 5

jump run, including positioning for the jump on the wing strut, at which time he was returned by command of the jump master. It is interesting to note that the physiological response elicited during the actual jump was appreciably lower. The subjective comments of the participant regarding his emotional response to the hold run vs. the actual jump were the reverse of the physiological evidence. This individual, unlike the other novices, had no overt desire to participate in a parachute jump.

Figure 6 presents data on two other novices. Note that their peak pulse rate and recovery curve are substantially below that exhibited by the novice in Figure 5.

Figure 7 contrasts data gathered on the fourth novice, upper curve, and the response of an expert, lower curve.

Figure 8 includes data obtained on the other experts. The telemetry signal in both cases failed after aircraft departure. However, it is evident that their responses to all events leading up to the jump are at levels lower than those attained by the novices.

4. Discussion

Monitoring of this event provided large differences in pulse rate patterns for the individuals studied. On the average, the rates were markedly lower for the experts during the pre-jump activities. The response pattern for the one expert monitored during descent was markedly different from the novices. Heart rate for the novices fell as they neared the ground, but rose for the expert. Auto racing, bullfighting and the other

Pulse Rate Vs. Time and Event
for Two Subjects
Parachute Jumping, Mansfield, Mass.
July 18-20, 1963

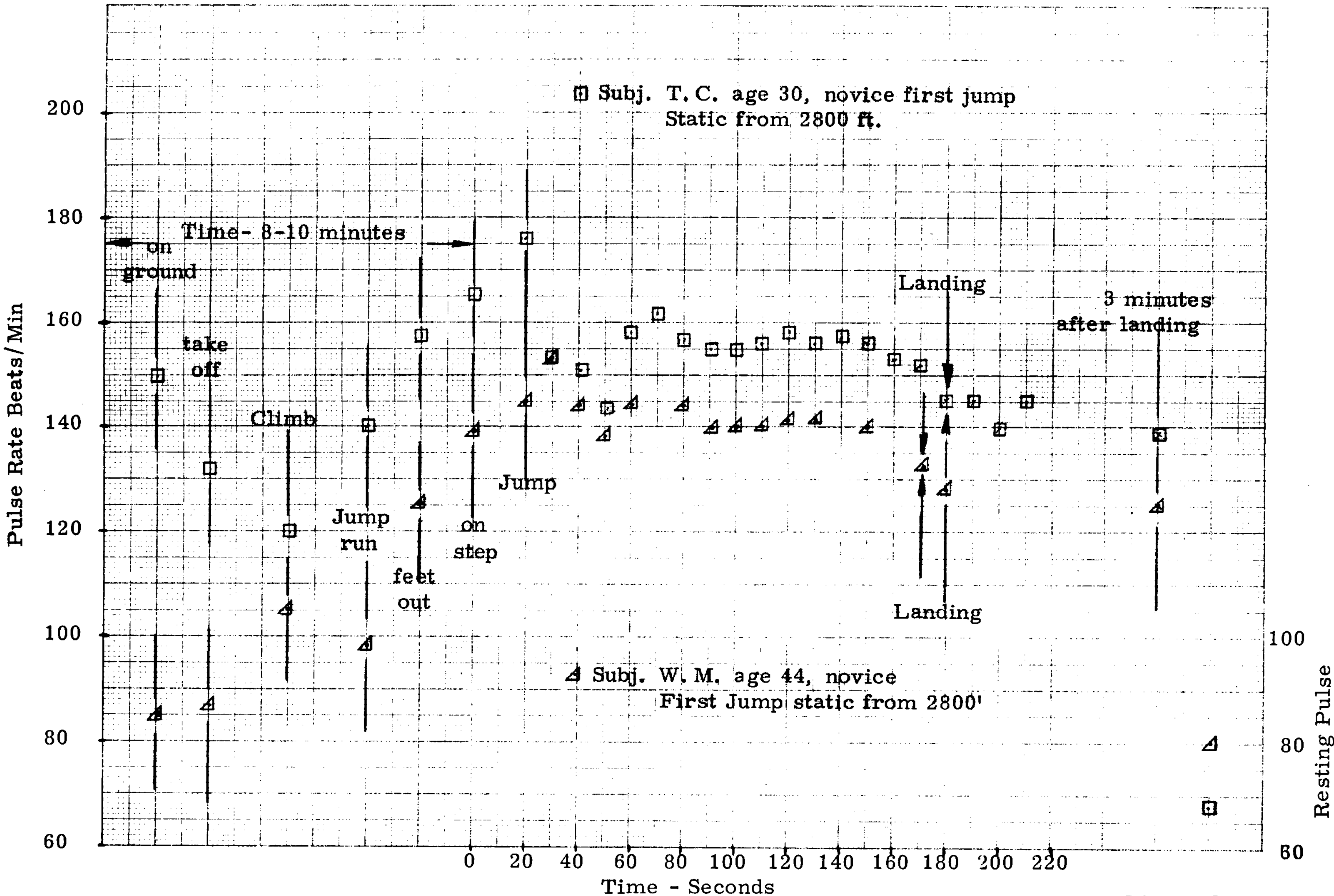

Figure 6

Pulse Rate Vs. Time and Events
for Two Subjects
Parachute Jumping, Mansfield, Mass.
July 18-20, 1963

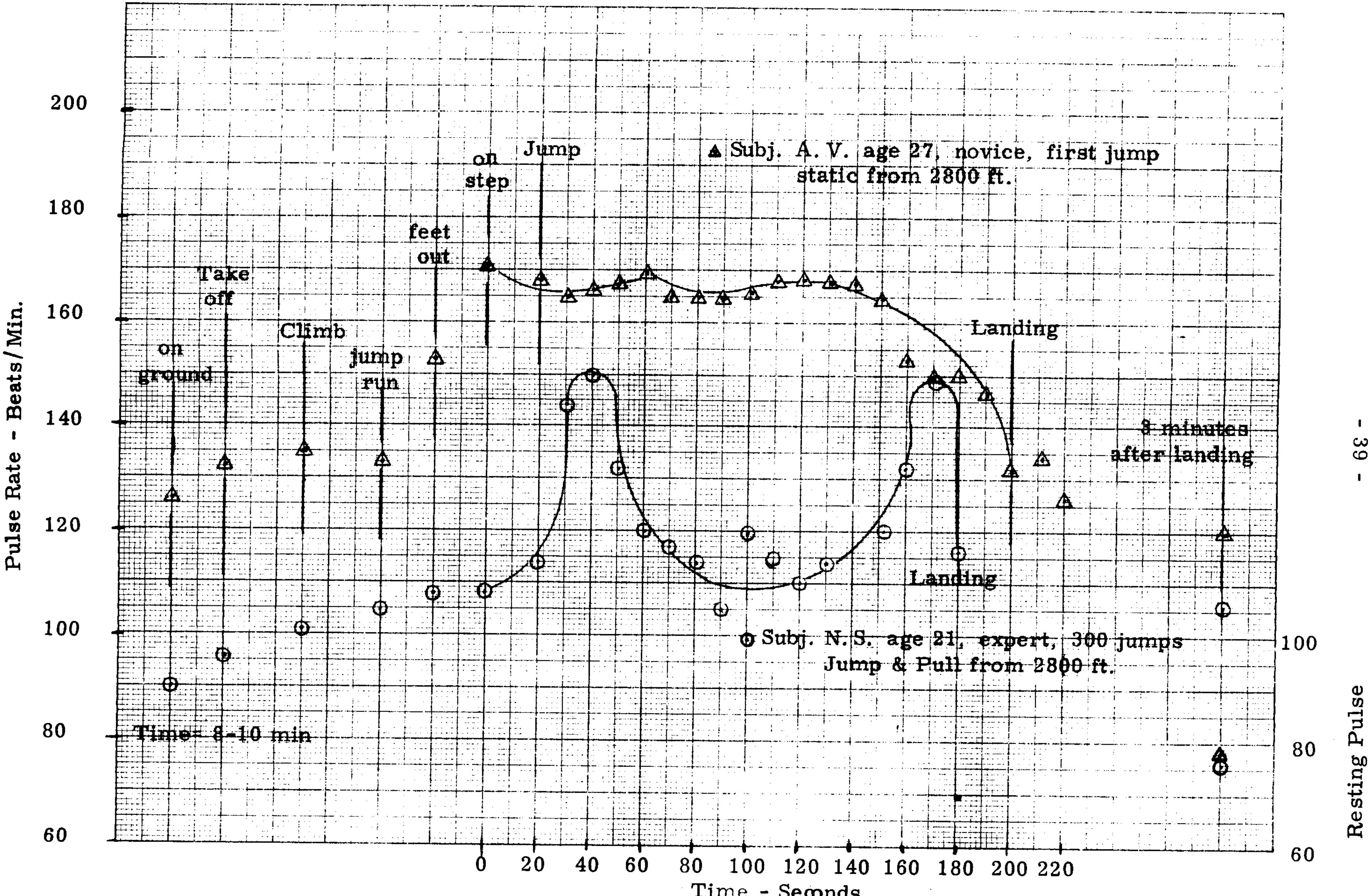

Figure 7

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Pulse Rate Vs. Events
for Two Subjects
Parachute Jumping, Mansfield, Mass.
July 18-20, 1963

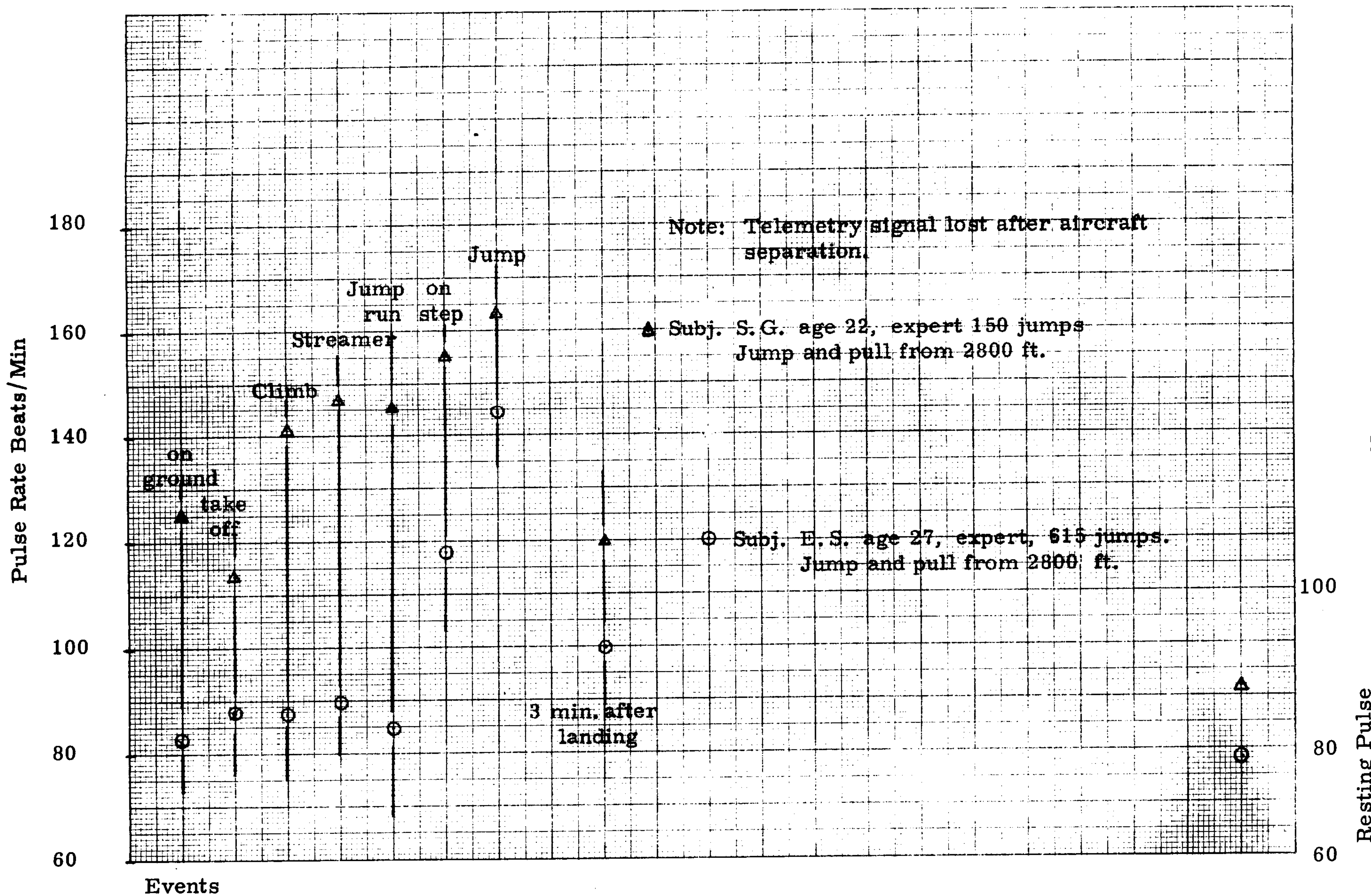

Figure 8

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events studied can be grossly categorized as producing combinations of psychological and physical stress. The stress of sky diving, on the other hand, is predominantly psychological in nature and provides an opportunity for examining adaptation to such a stress.

Characteristically, the stress of sky diving for experts is evidenced in a gradual increase in pulse rate initiated after aircraft takeoff followed by a rapid decrease in pulse rate after parachute deployment. Although complete data were gathered on only one expert (Figure 7, lower curve), the general trend of cardiac response was similar for the other experts up to the time of aircraft separation. It is noted that the expert in Figure 7 had an additional elevated response just prior to landing. This can be partially explained by the frequency of ankle and leg injuries during landing. Subject N. S., for example, admitted apprehension concerning landing because of a past history of knee cap damage as a consequence of an automobile accident.

C. Bullfighting

This section summarizes the data gathered on bullfighters in Mexico City on June 21 and 28, 1964.

A bullfight generally involves three matadors, each of whom fights two bulls during the course of an afternoon. Typically, the first matador will obtain bull No. 1 and No. 4, the second matador has bull No. 2 and No. 5, etc.. Each individual fight lasts between 15 and 20 minutes, depending on the proficiency of the fighter and the stamina of the bull. Each fight is broken down into three phases of approximately 5 minutes each. Each succeeding phase is more dangerous to the fighter because the bull is generally worked closer to the body with a smaller cape and, by then, has begun to distinguish between the fighter and the cape.

Some difficulty was encountered in clearing the equipment through Mexican Customs, and, although the equipment arrived in the city four days preceding the first scheduled event, it was not available for use until the day preceding the fight. A defective amplifier in one of the transmitters was discovered at that time. Maximum transmission range was in the vicinity of 100 feet with the signal intermittent. However, an attempt was made to utilize the equipment on the first scheduled event the following day.

1. Procedures

Five bullfighters were selected for monitoring through cooperative efforts with the Bullfighters' Union in Mexico City.

During a pre-session conference, we were requested to minimize the contact and handling of the bullfighters immediately prior to participation. Consequently, with one exception, the only contact made with the matadors on the day of the event prior to the event was the installation of the transmitter about one hour before their fight.

Blood pressure, temperature and resting pulse were handled in a similar manner.

2. First Fight - June 22, 1964

Three subjects were scheduled for blood, urine, and physical data during the first fight, and two of the participants were scheduled for EKG monitoring. The following describes their status as recognized fighters.

Subject No. 1 - Victor Pastor, age 22, fighting as a promising novice for 10 years - not scheduled for monitoring.

Subject No. 2 - Manuel Duron, age 27, fighting as a novice for 15 years, further classified as "old timer", but lack of proficiency precluded eminence - scheduled for EKG monitoring.

Subject No. 3 - Felipe Tellez, age 22, fighting as a novice for 3 years, first appearance in Mexico City - scheduled for EKG monitoring.

The two fighters scheduled for EKG monitoring were subject No. 2, Manuel Duron, and subject No. 3, Felipe Tellez, who were scheduled for bull No. 2 and No. 5, and No. 3 and No. 6, respectively. The signal from subject No. 2 was well received during the fight and also while he observed the preceding fighter. Immediately after completing his own first fight, he removed the telemetry system, complaining that it hampered his movements.

No telemetry data were obtained on subject No. 3 as his transmitter contained the defective amplifier. He, for the same reason as subject No. 2, removed the transmitter after his first fight.

3. Second Fight - June 28, 1964

Two fighters were scheduled for Sunday, June 28.

Subject No. 4 - Fermin Rivera, age 42, fighting 22 years, recognized as one of the top bullfighters in the world, retired in 1957 after a heart attack in the ring.

Subject No. 5 - Mario de la Borbolla, age 24, fighting 12 years, recognized as one of the most promising novices in Mexico.

Subject No. 4, Fermin Rivera, is currently head of the Bullfighting Union in Mexico and came out of retirement to fight one bull for a benefit program. He had no qualms about wearing the transmitter and participated in the normal blood and urine collection, including the sample just prior to the event.

Subject No. 5, based on the experience of his associates the preceding week,was reluctant to perform while wearing the transmitter.

Urine and blood collection schedules for subject No. 5 were those previously employed for the fight the preceding week, with the exception of the blood sample taken immediately prior to the fight.

4. Results and Discussion

The two telemetry records for subject No. 2 and subject No. 4

are presented in Figures 9 and 10. Pulse rate is plotted as a function of sample number. Each fight lasted for approximately 15 minutes,but data were also collected prior to and after each fight.

The telemetered data show increases in pulse rate as the fights progress through the three phases. The telemetry data gathered on both fighters prior to their individual events were gathered while they were observing another matador in the act of fighting. A sympathetic pulse rate reaction to the experiences of the other fighters are evidenced.

Each of the two fighters for which telemetry data were obtained were classed as superb performances. Subject No. 4 was sufficiently outstanding that he was awarded two ears, a symbol of excellence and skill. As was previously indicated, subject No. 4 had suffered a heart attack in 1957. Samples of his clinical EKG records since that time are shown in Figure 10(a).

All five fighters participated in the collection of biochemical and physical data according to a modified schedule as illustrated in Table 2. Except for subject No. 4, no biochemical nor physical data were obtained immediately prior to the event.

Pulse Rate Vs. Sample Number
Expert Matador
Mexico City, D. F. Mexico
June 21, 1964

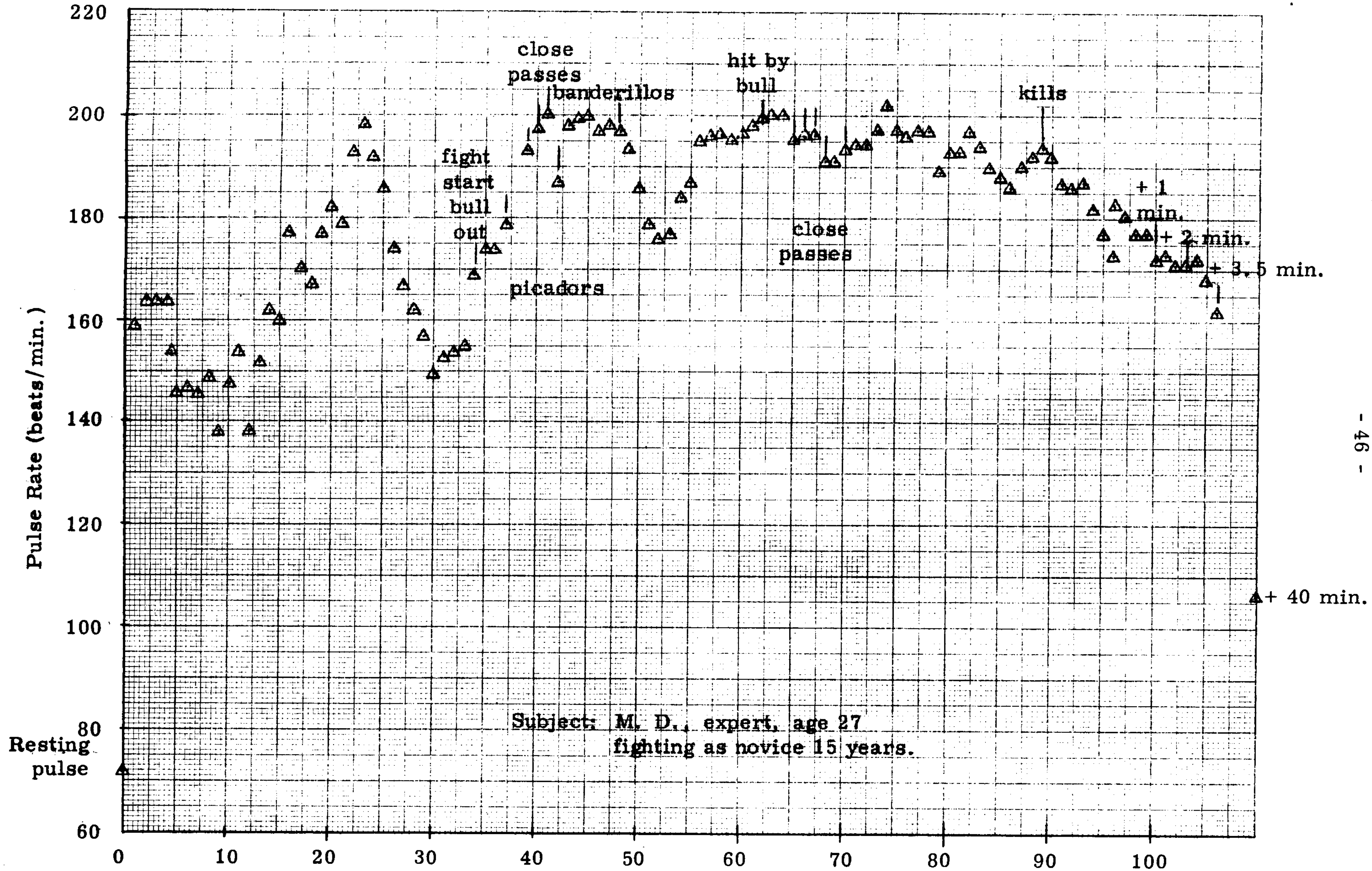

Figure 9

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Pulse Rate Vs. Sample Number
Expert Matador
Mexico City, D. F. Mexico
June 28, 1964

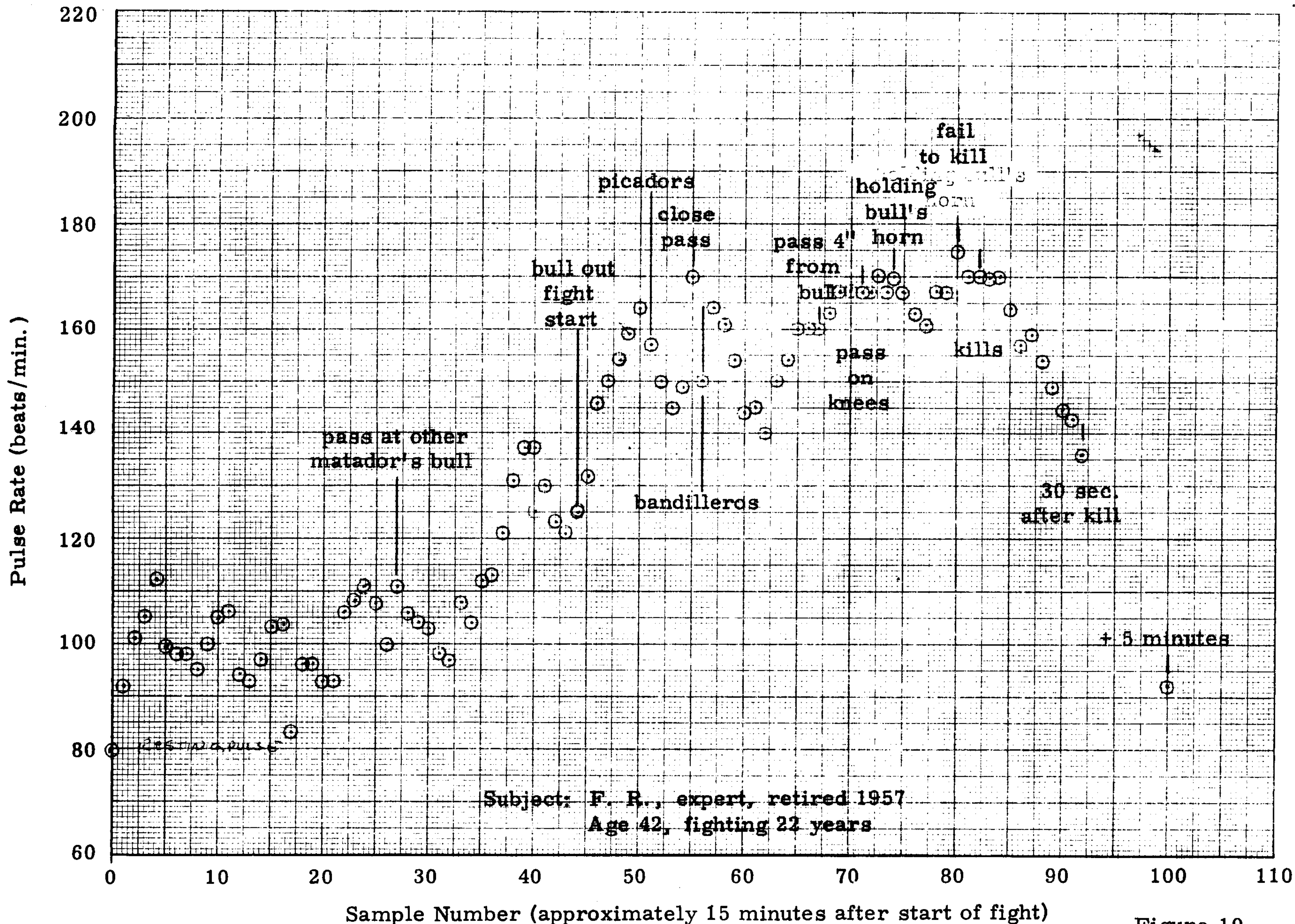

Figure 10

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Figure 10(a) - Typical Clinical EKG Records Obtained on Subject #4, Fermin Rivera. Subject had heart attack in 1957.

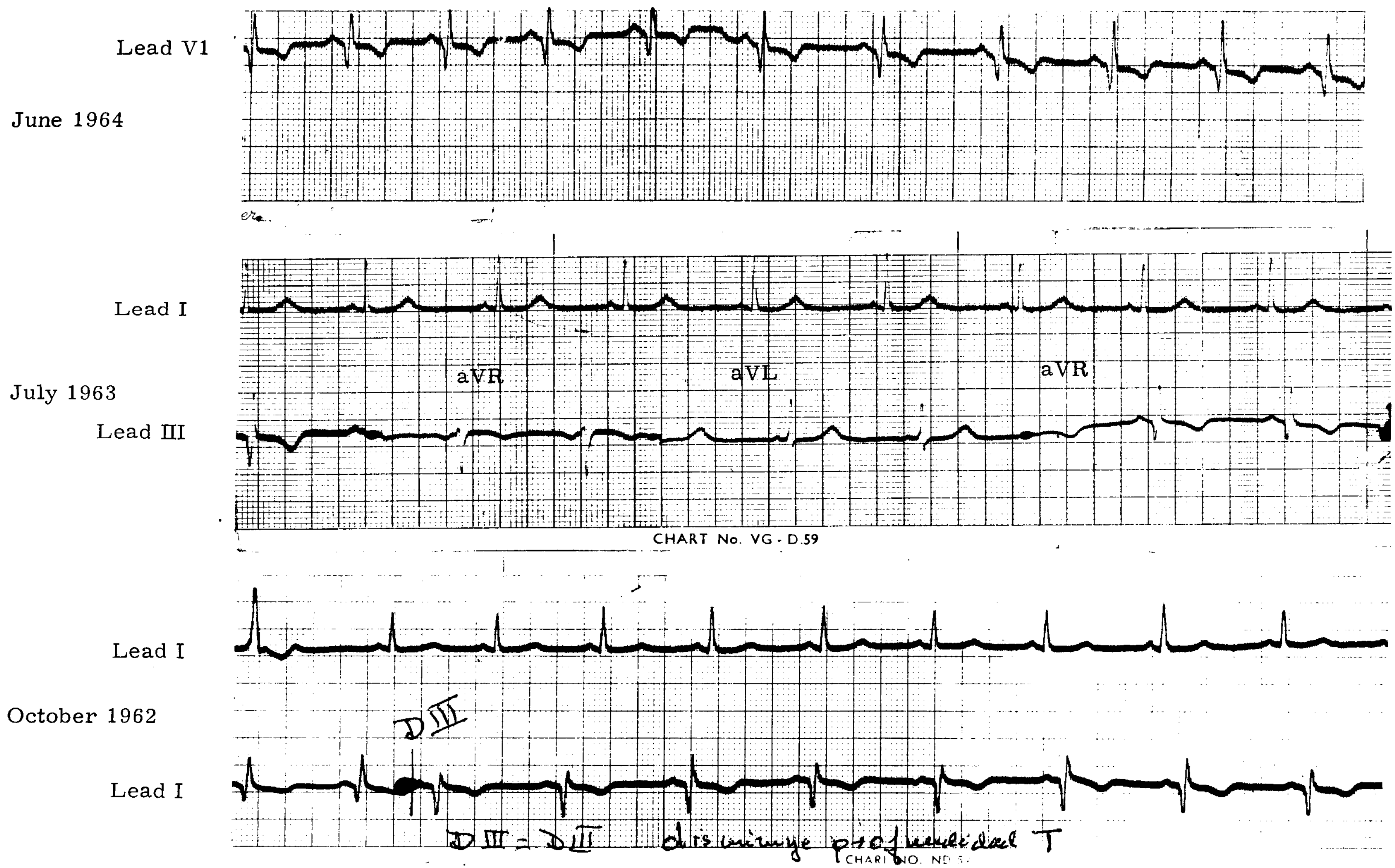

Table 2 - Bullfighting Data, Mexico City, D. F., Mexico

	Time				Remarks
Subject: Victor Pastor	6/20/64		6/21/64	6/22/64	
Age: 22	-24 hrs.		+1 hr., 45 min.	+24 hrs.	
Ambient temperature	80		80	78	Poor performance, partially due to bad bulls.
Blood pressure	135/80		130/70	110/80	
Resting pulse	88		92	92	
Body temperature	98.6		98	97.7	
Weight					
Subject: Manuel Duron	6/20/64		6/21/64	6/22/64	
Age: 27	-24 hrs.		+40 min.	+24 hrs.	
Ambient temperature	80		78	78	Hit once by bull during fight; poor performance partially due to bad bulls.
Blood pressure	150/85		145/90	110/70	
Resting pulse	100		106	72	
Body temperature	98.9		101	98.5	
Weight					
Subject: Felipe Tellez	6/20/64		6/21/64	6/22/64	
Age: 22	-24 hrs.		+5 min.	+24 hrs.	
Ambient temperature	80		78	78	Hit and knocked down 5 times during fight; poor performance partially due to bad bulls.
Blood pressure	125/85		135/70	100/60	
Resting pulse	68		104	60	
Body temperature	98.2		100	98.1	
Weight					
Subject: Fermin Rivera	6/27/64	6/28/64	6/28/64	6/29/64	
Age: 42	-24 hrs.	-20 min.	+5 min.	+24 hrs.	
Ambient temperature	70	65	65	72	Excellent performance; awarded 2 ears.
Blood pressure	126/84	150/95	140/90	128/96	
Resting pulse	88	86	92	80	
Body temperature	97.9	96.8	97.7	98	
Weight					

(continued on next page)

Table 2 - Bullfighting Data, Mexico City, D. F., Mexico (Cont'd.)

	Time			Remarks
Subject: Mario de la Borbolla Age: 24	6/27/64 -24 hrs.	6/28/64 +1 hr., 40 min. (after shower)	6/29/64 +24 hrs.	
Ambient temperature	70	90+	72	Excellent performance.
Blood pressure	100/60	(not obtained)	100/60	
Resting pulse	64	64	74	
Body temperature	98.4	100.2	99.5	
Weight				

D. Skiing

Skiers during a downhill race require a high degree of kinesthetic-visual-motor coordination, expend substantial physical effort, and run the risk of severe injury should they make a mistake. Speeds in excess of 60 mph are not unusual. Length of the course, number of turns, variety of grades, etc., may vary from one ski area to another. Skiers race one at a time against the clock, but experts are generally quite accurate in assessing their run and can give their time within a few seconds.

The Gunstock Ski Area in Laconia, New Hampshire was selected for this study. With the assistance of the Penny Pitou Ski School, a downhill race was set up over a challenging one and a quarter mile course.

1. Subjects

Three expert skiers, all professional instructors and including one former Olympic skier, and two novice skiers were studied. The experts were selected from the ski school staff and had had extensive practice on the course used for this race. The two novices had never participated in ski racing and lacked the proficiency associated with "expert" skiers.

2. Procedures

A cash prize of $25 was offered in order to motivate the expert contestants. The rivalry within this group was already high and the addition of the prize incentive insured an all-out competition.

The length of the course exceeded the range of the telemetry system, and only a portion of the race could be monitored. The most stressful section of the run was selected and a "sno-cat" housing the receiver and recorder was positioned to provide line-of-sight telemetry over that section. The telemetry data consisted of only short records as the skiers passed the receiving site.

Blood and urine sampling commenced 24 hours before the scheduled event. However, a severe storm forced a 24-hour delay in the race. Blood samples were drawn at minus 4 hours, immediately prior and after, and 24 hours after the race. Resting physical measurements were also obtained each time that blood samples were drawn. Timed urine samples were collected throughout the 72-hour period.

3. Results

The physical data and telemetered pulse rates appear in Table 3. Mean-pulse rates are given since the expert skiers were within range of the receiver for less than 15 seconds. No clean telemetry data were obtained from the novices.

Table 3 - Skiing, Belknap, New Hampshire, January 13-16, 1964

	Time						
	-48 Hours	-4 Hours	Immed. Prior	Race	Immed. After	+24 Hours	Remarks
Subject: H. Finethy (Expert)	1/13/64	1/15/64	1/15/64	1/15/64	1/15/64	1/16/64	
Age: 35							*Telemetry equipment failure.
Ambient temperature	70	72	75	*	14(outdrs.)	75	
Blood pressure	140/98	155/100	160/100		164/84	120/80	
Body temperature	97.2	97.2	96.7		98.7	98.3	Race time 204.5 secs. on 1/15/64.
Resting pulse	72	76	88		140	70	
Weight			202		202		
Subject: E. Zimmermann (Expert)	1/13/64	1/15/64	1/15/64	1/15/64	1/15/64	1/16/64	(1) Resting on lift to top of mountain.
Age: 30							
Ambient temperature	70	72	75		14(outdrs.)	75	(2) Racing.
Blood pressure	130/80	130/80	120/78		124/64	110/64	
Body temperature	96.8	97.8	97.4		98.3	98.6	Race time 150.4 secs. on 1/15/64
Resting pulse	62	66	68-80	94.5(1)	145	60	
Weight			187	180(2)	187		
Subject: R. Sommerer (Expert)	1/13/64	1/15/64	1/15/64	1/15/64	1/15/64	1/16/64	
Age: 28							(1) Racing data.
Ambient temperature	70	72	75		14(outdrs.)	75	
Blood pressure	120/55	110/65	114/65		116/62	110/64	Race time 204.5 secs. on 1/15/64
Body temperature	97.2	97.8	98.4		98.4	98.7	
Resting pulse	68	68	70	188(1)	120	66	
Weight			151		151		

(continued on next page)

Table 3

Table 3 - Skiing, Belknap, New Hampshire, January 13-16, 1964 (Cont'd.)

	Time						Remarks
	-48 Hours	-4 Hours	Immed. Prior	Race	Immed. After	+24 Hours	
Subject: D. Haswell	1/13/64	1/15/64	1/15/64	1/15/64	1/15/64	1/16/64	
(Novice)							(1) Telemetry data (practice).
Age: 33							
Ambient temperature	70	72	75		14(outdrs.)	75	
Blood pressure	130/85	130/65	126/72 130/75		124/60 158/40	116/74	No telemetry data on race. Race time 220/8 secs. on 1/15/64.
Body temperature	97	97.2	99	160(1)	97.6	98.6	
Resting pulse	120	102	106, 110		164	102	
Weight			160.5		160.5		
Subject: D. Williams	1/13/64	1/15/64	1/15/64	1/15/64	1/15/64	1/16/64	
(Novice)							(1) Telemetry data (practice).
Age: 30							
Ambient temperature	70	72	75		14(outdrs.)	75	
Blood pressure	135/70	135/70	124/76		124/62	118/66	No telemetry data on race. Race time 221.6 secs. on 1/15/64.
Body temperature	99	97	98.2	153(1)	98.4	98.7	
Resting pulse	96	86	92		172	94	
Weight					177		

Table 3

E. Hockey

Hockey was selected for study since it represents a physically strenuous team sport with a moderately large incidence of physical injuries. A typical hockey game consists of three periods, each 20 minutes in length, with a 10-minute intermission between periods. Frequent substitutions and occasional consignments to the penalty box break up the time actually on the ice. With the exception of the goalie, a player does not usually play for an entire period. The relatively short range over which this sport is carried out also makes it ideal for use of telemetry devices.

1. Subjects

The coach of a professional hockey team (Boston Bruins) was monitored throughout a game. Four collegiate hockey players (Harvard) were monitored during two separate games. The collegiate subjects included a goalie, two offensive wings, and one defensive player. Two of the players were sophomores and were therefore regarded as relative novices for this class of competition.

2. Procedures

The coach for the Bruins was monitored during a game on December 12, 1963. A blood sample was drawn and urine collection initiated 10 hours before the game. This timing coincided with completion of team practice on the morning before the game. Blood was also drawn just before, just after, and 24 hours after the game. Urine collection was continued until 24 hours after the game. Heart rate, blood pressure, and oral temperature were recorded at each blood sample period.

The four Harvard Hockey Team players were divided into two groups, two players being monitored on January 3, 1964 during a game with Boston University, and two players being monitored the following day during a game with Norwich. The data collection schedule and results of physical measures appear in Table 4.

Diurnal cycle data were obtained on the collegiate participants a few weeks later. Physical and biochemical data were collected every 4 hours starting at 8:00 a.m. and ending at 8:00 a.m. the following morning (a 4:00 a.m. sample was not collected).

3. Results

The physical data for the hockey coach and players are summarized in Table 4. Telemetry data for the coach appear in Figure 11. Telemetry data for the novice right wing player appear in Figure 12, for the "expert" defensive player in Figure 13, for the "expert" left wing in Figure 14, and for the goalie in Figure 15.

The reactions by the coach to the game are apparent in both the resting physical data and in the telemetry data. Although the Boston Bruins won the game 3 to 2, the third period was extremely tense with the opposition frequently threatening. The progressive rise in heart rate from 104 to 159 during the third period, and fall to 100 ten minutes later, plus a two and a half pound weight loss, is dramatic evidence of cognitive involvement.

Table 4 - Physical Data - Hockey

	Time				Remarks
Subject: Milt Schmidt, Coach	12/12/63	12/12/63	12/12/63	12/13/63	
Age: 49	-10 hrs.	Immed. Prior	Immed. After	+24 hrs.	Boston Bruins (professional team)
Ambient temperature					
Blood pressure	145/95	170/88	176/90	132/64	
Resting pulse	96	88	112	68	Bruins Vs. Chicago;
Body temperature	97.4	97.8	98.0	97.8	Bruins won 3-2; very
Weight	--	204	201.5	--	close game.
Subject: Barry Treadwell	1/2/64	1/3/64	1/3/64	1/5/64	
Age: 21	-24 hrs.	Immed. Prior	Immed. After	+48 hrs.	
Ambient temperature					
Blood pressure	108/65	140/80	138/60	115/75	
Resting pulse	72	64	116	68	
Body temperature	99.2	98.0	99.2	98.2	
Weight	--	175	172	--	
Subject: John Daley	1/2/64	1/3/64	1/3/64	1/5/64	
Age: 18	-24 hrs.	Immed. Prior	Immed. After	+48 hrs.	Boston Arena; Harvard
Ambient temperature					Vs. Boston University;
Blood pressure	150/70	142/70	152/60	125/85	Harvard won 4-3 (close
Resting pulse	94	64	128	66	game at all times).
Body temperature	97.4	98.6	101.5	98.6	
Weight	--	189	183	--	
Subject: Brandon Sweitzer, Goalie	1/2/64	1/4/64	1/4/64	1/5/64	
Age: 21	-48 hrs.	Immed. Prior	Immed. After	+24 hrs.	
Ambient temperature					Harvard Vs. Norwich
Blood pressure	110/75	110/75	125/80	120/75	University; Harvard won
Resting pulse	78	84	68	66	11-4.
Body temperature	99	98.7	98.6	98.4	
Weight		157.5			

(continued on next page)

Table 4

Table 4 - Physical Data - Hockey (Cont'd.)

	Time				Remarks
Subject: William Fryer Age: 22	1/2/64 -48 hrs.	1/4/64 Immed.	1/4/64 Immed.	1/5/64 +24 hrs.	
Ambient temperature		Prior	After		
Blood pressure	144/84	144/88	135/85	120/70	Harvard Vs. Norwich University;
Resting pulse	66	66	108	60	Harvard won 11-4.
Body temperature	98	98	99.2	97.2	
Weight		160	157.5		

Table 4 (Cont'd.)

Pulse Rate Vs. Time
Hockey Game
Coach - Boston Bruins
December 12, 1963

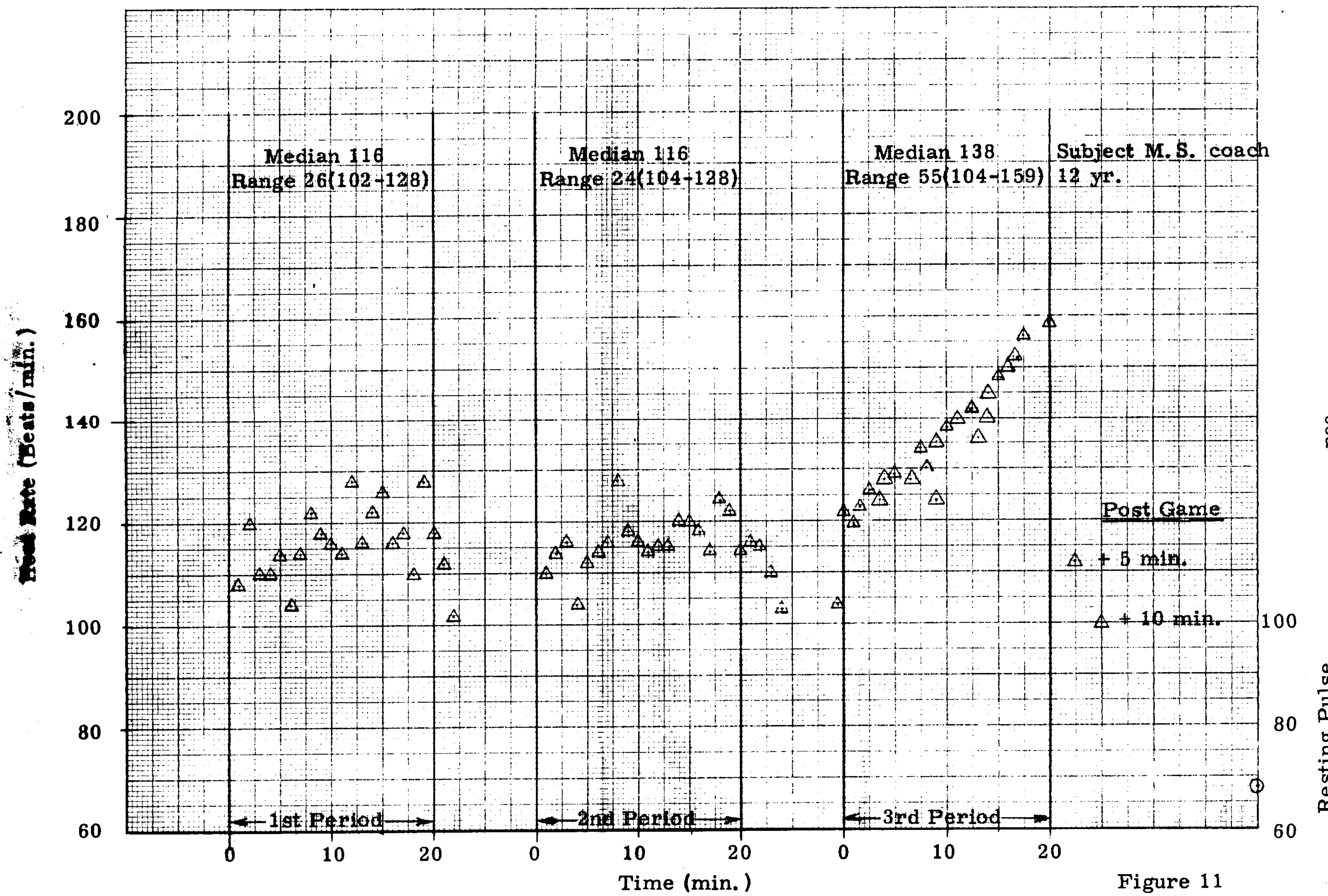

Figure 11

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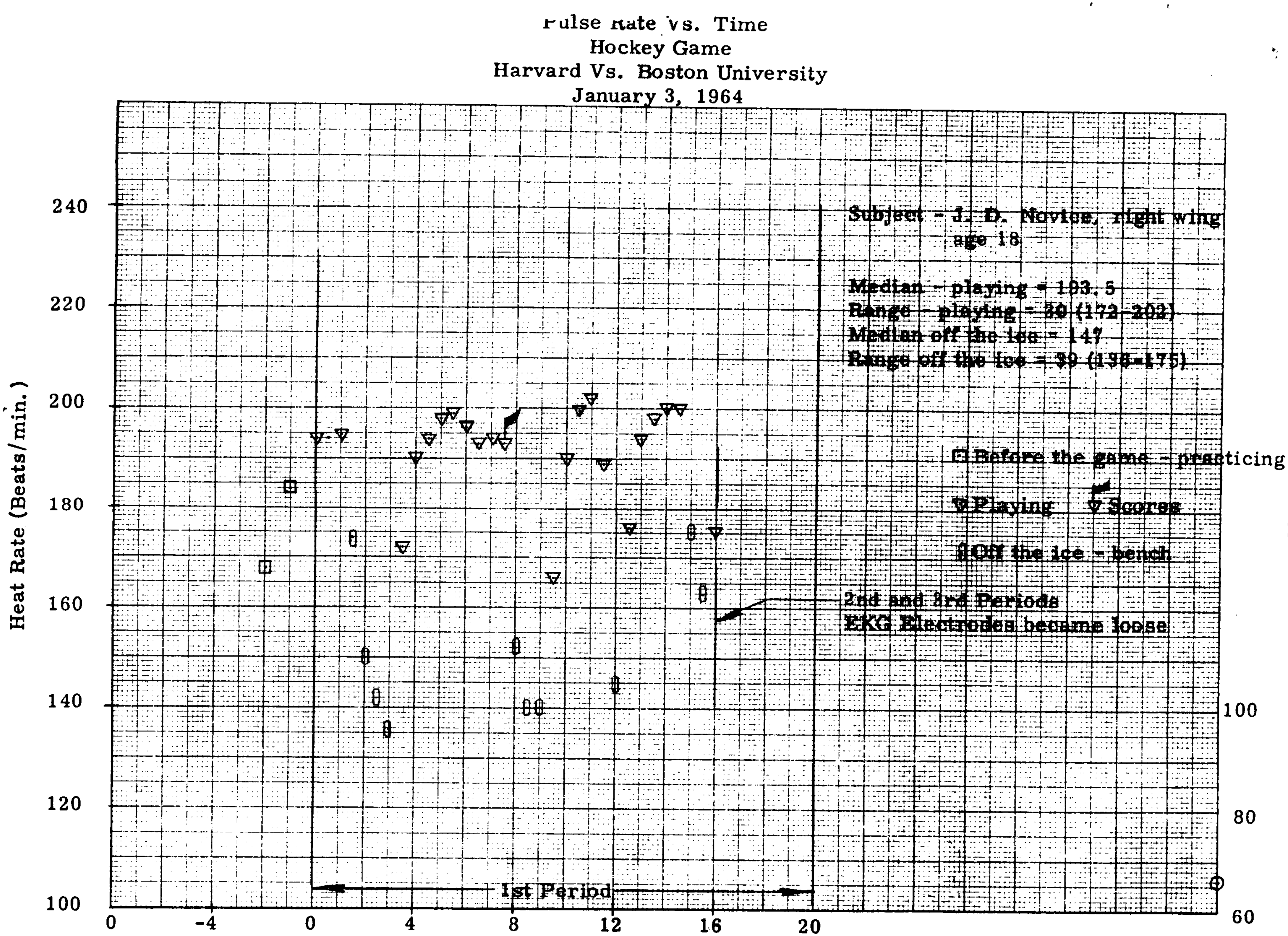

Figure 12

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Pulse Rate Vs. Time
Hockey Game
Harvard Vs. Boston University
January 3, 1964

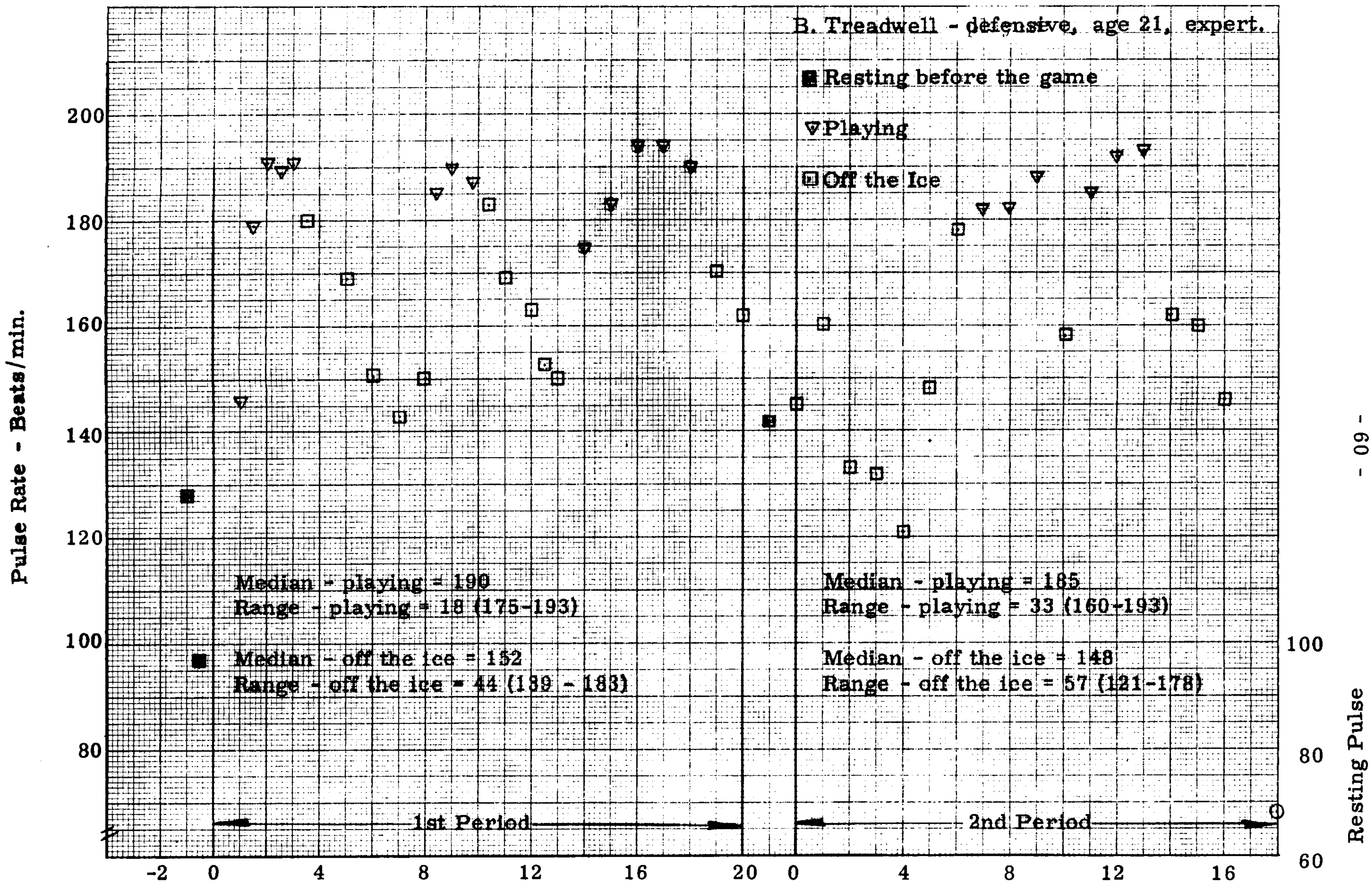

Figure 13

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Pulse Rate Vs. Time
Hockey Game
Harvard Vs. Norwich University
January 4, 1964

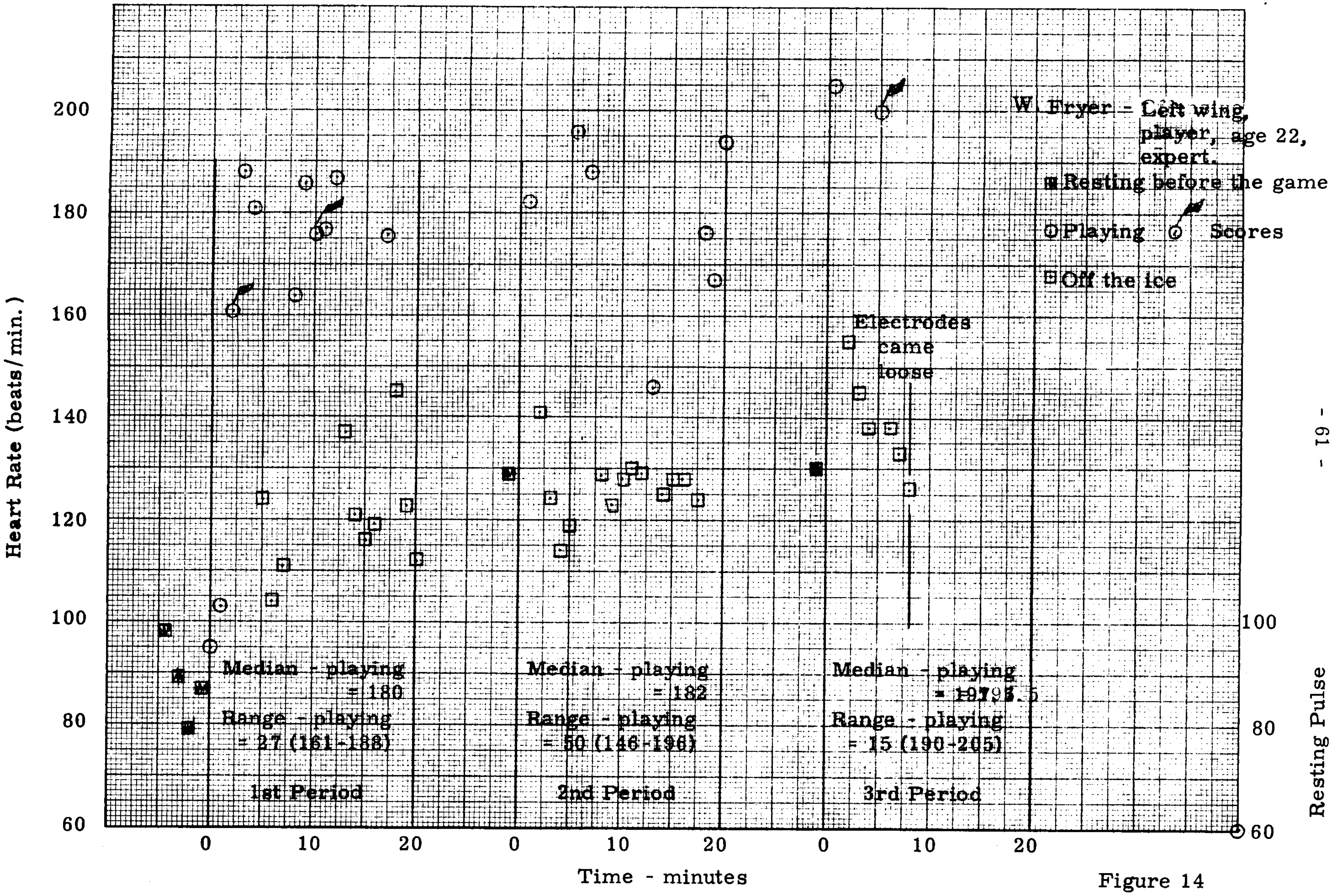


Figure 14

Pulse Rate Vs. Time
Hockey Game
Harvard Vs. Norwich University
January 4, 1964

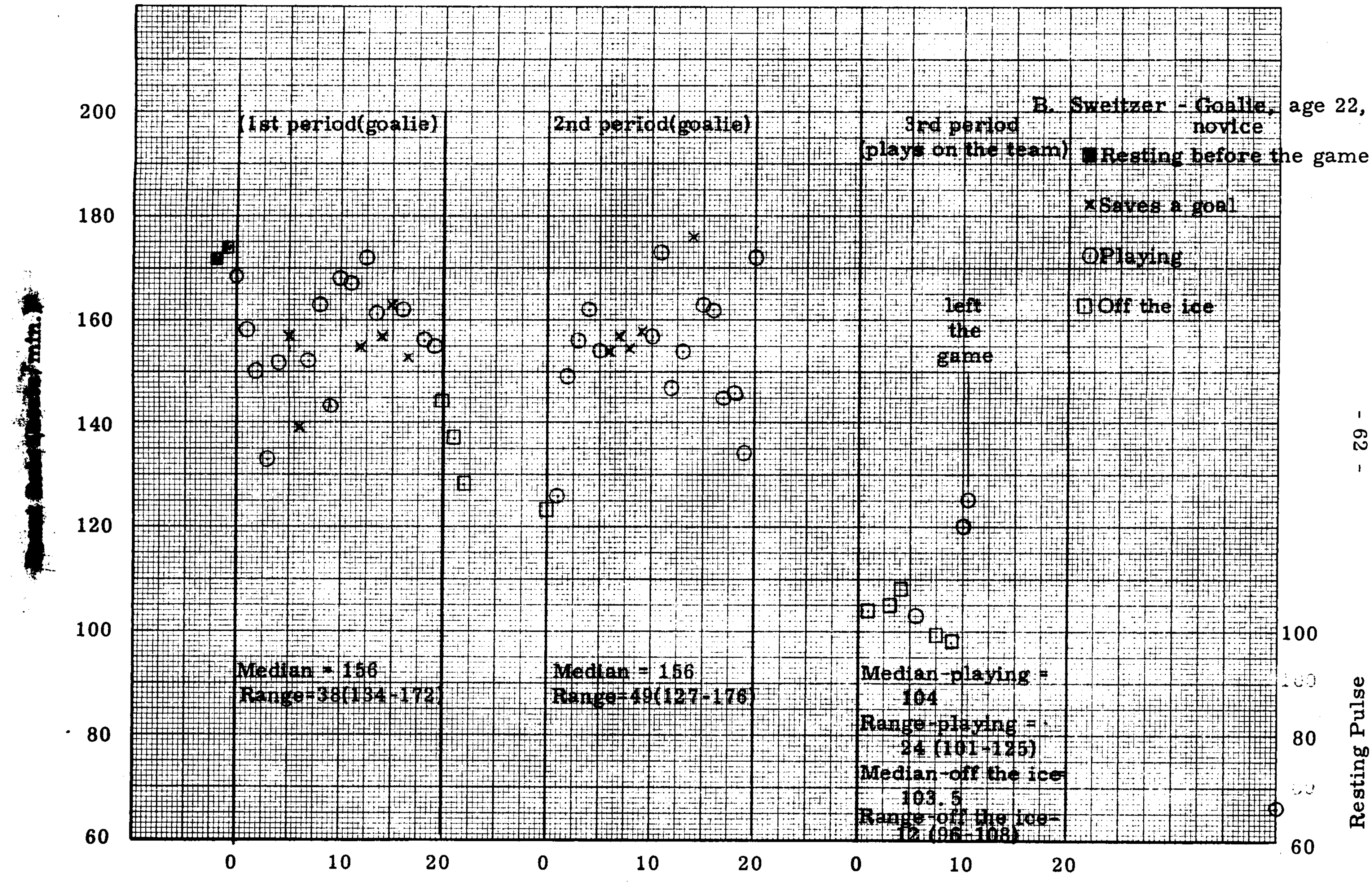


Figure 15

Median heart rates were computed separately from data on the ice and during bench rests for the hockey players. Since substitutions were frequently made, considerable data were obtained both on and off the ice for all players except the goalie.

The game on January 3 was won by Harvard 4 to 3, but the game was close at all times. One subject, J. D., lost six pounds during the game, had heart rates in excess of 200 bpm during the first period, and increased his body temperature nearly three degrees. His pulse rates during the pre-game practice were also high. During periods off the ice, pulse rates fell 37 to 52 bpm during the first minute. Another more experienced subject, B. T., monitored during the same game had pulse rates as high as 193 bpm when on the ice, but had less heat debt, weight loss, and heart rate recovery off the ice. B. T. played a defensive position, whereas J. D. played offensive wing.

Early in the game on January 4, Harvard racked up a commanding lead and went on to win 11 to 4. The left wing, W. F., had a peak heart rate of 205 bpm (the highest observed for any of the hockey players) and scored three of the Harvard goals. His pre-game heart rate was the lowest of those observed, and his rate when coming off the ice fell by as much as 77 bpm in the first minute. By the end of the second period, a substitute goalie came in to replace the goalie being monitored (subject B. S.) who then played a few minutes on the offensive. Heart rates for B. S. while playing as a goalie were generally lower than those observed for other players, and when playing offensive, his rate was even less. However, this game was not regarded as stressful by the players and B. S. knew that the game was "sewed up" before he was relieved as goalie.

F. Polo

Polo was selected as it involves a combination of unusual skills, a certain element of individual risk, and a moderately high degree of physical effort. A polo game consists of six "chukkers" of seven and one-half minutes each. The periods between chukkers vary from three to five minutes and are used primarily to change horses. The game is considered a strong team sport, each team consisting of four men.

Two polo games were monitored, the first on a normal size polo field 300 yards long and 200 yards wide.

The second game was played in the evening in a practice arena approximately 100 yards in length and 50 yards wide. This limited the speed of the game but also increased the physical contact among the players.

The limited range involved in this sport was ideal for telemetry reception.

1. Subjects

Novices were separated from the experts based on the number of polo games in which they had participated. Novices were considered to be those who had participated for less than a year and in less than 20 matches.

The three players monitored during the first polo match (September 25, 1963) were rated as experts. The two subjects monitored during the second polo match (October 10, 1963) were rated as novices.

2. Procedures

The collection of biochemical data was commenced on September 24, 1963, twenty-four hours before the polo match. Blood samples, blood pressure, body temperature, and resting pulse were also obtained from three players at that time. Urine specimens were collected, commencing twenty-four hours prior to and continued for twenty-four hours after the match. One hour before the polo match, data were taken identical to that obtained at minus twenty-four hours. In addition, body weights were taken at game-minus one hour. The same procedures were repeated immediately after the polo match and twenty-four hours later.

During the first two chukkers of the first match, telemetry data were received from each of two players alternatively for 30-second intervals. Full-time telemetry coverage of the third player took place during the last three chukkers. This procedure was necessary since only one channel of the telemetry receiver could be used.

During the second match on October 10, the same biochemical and physical measurement sampling schedule was used. However, no telemetry data were collected due to equipment failure.

3. Results and Discussion

The physical data and sampling schedule are listed in Table 5. Telemetry data from the expert polo players are shown in Figures 16, 17 and 18. Each heart rate point plotted on the graph represents

Table 5 - Polo, Hamilton, Massachusetts

	Time				Remarks
Subject: Neil Ayer Expert Age: 37	9/24/63 -25 hrs.	9/25/63 -1 hr., 15 min.	9/25/63 +15 min.	9/26/63 +23 hrs.	$90^{\circ}F$ on playing field. Monitored first 2 chukkers. Telemetry signal intermittent.
Ambient temperature	$68^{\circ}F$	$72^{\circ}F$	$72^{\circ}F$	$72^{\circ}F$	
Blood pressure	110/75	125/80	125/80	110/75	
Resting pulse	76	76	118	76	
Body temperature	97.8	98.3	97.4	98.3	
Weight		189	188		
Subject: Mike Andrew Expert Age: 25	9/24/63 -24 hrs.	9/25/63 -30 min.	9/25/63 +15 min.	9/26/63 +23 hrs.	$90^{\circ}F$ on playing field. Monitored first 3 chukkers. Electrodes became loose during each chukker.
Ambient temperature	$68^{\circ}F$	$72^{\circ}F$	$72^{\circ}F$	$72^{\circ}F$	
Blood pressure	135/85	145/75	135/75	135/75	
Resting pulse	96	98	118	98	
Body temperature	98.2	99.0	94	98.4	
Weight		158	156		
Subject: Don Little Expert Age: 29	9/24/63 -24 hrs.	9/25/63 -15 min.	9/25/63 +15 min.	9/26/63 Did not make appointment	$90^{\circ}F$ on playing field. Monitored last 3 chukkers.
Ambient temperature	$68^{\circ}F$	$72^{\circ}F$	$72^{\circ}F$		
Blood pressure	135/80	125/65	135/70		
Resting pulse	72	96	72		
Body temperature	97.8	98.8	98		
Weight		200	199		
Subject: Al Mazzetta Novice Age: 38	10/9/63 -24 hrs.	10/10/63 -1 hr.	10/10/63 -15 min.	10/11/63 +24 hrs.	Complete receiver failure.
Ambient temperature	$70^{\circ}F$	$70^{\circ}F$	$70^{\circ}F$	$70^{\circ}F$	
Blood pressure	150/80	160/80	145/70	155/80	
Resting pulse	68	74	80	78	
Body temperature	98.6	98.6	99.4	98.2	
Weight		172.5	171.5		

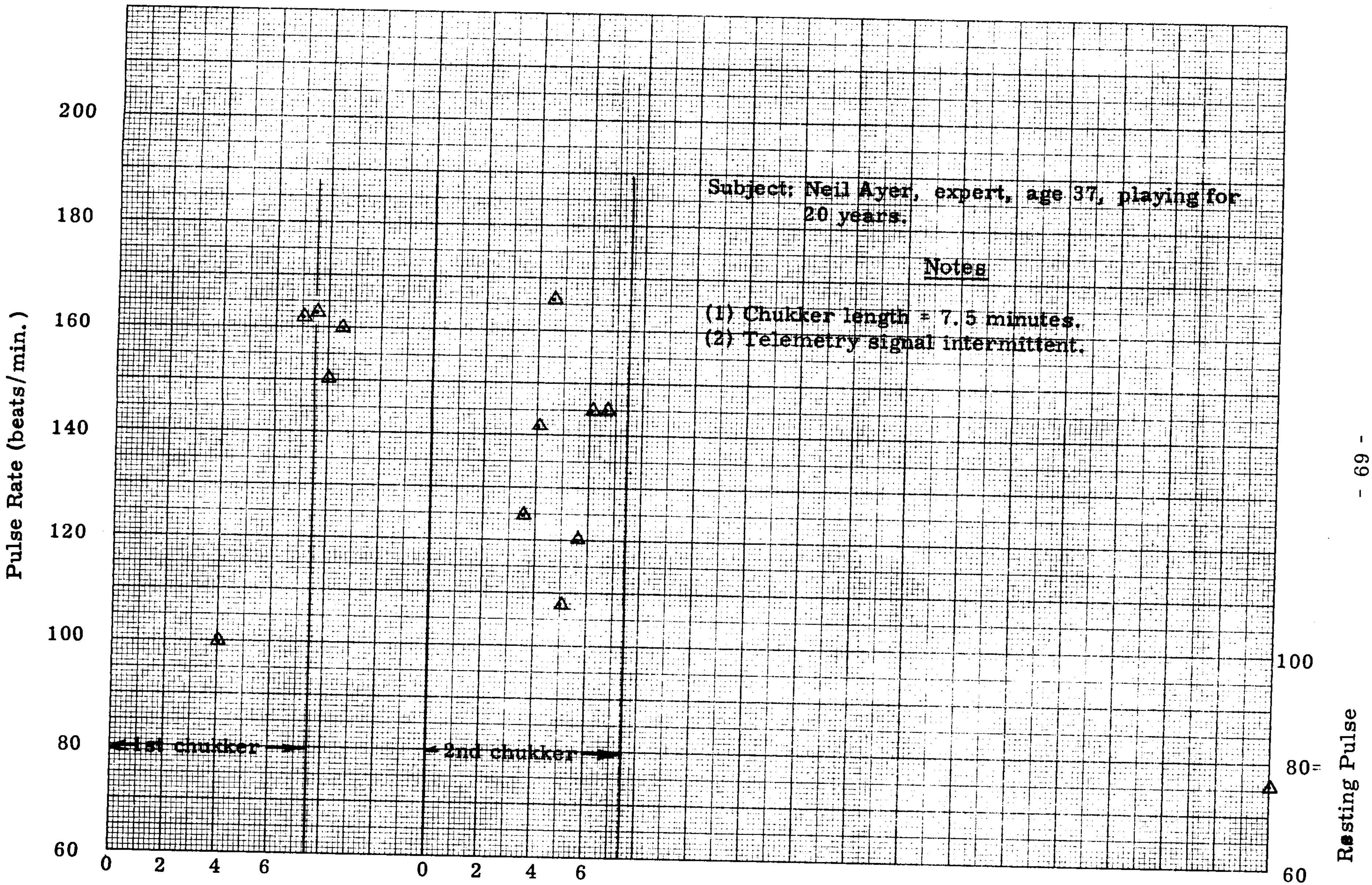
(continued on next page)

Table 5 - Polo, Hamilton, Massachusetts (Cont'd.)

	Time				Remarks
Subject: Charles Coles Novice Age: 42	10/9/63 -24 hrs.	10/10/63 -15 min.	10/10/63 +15 min.	10/11/63 +24 hrs.	
Ambient temperature	70°F	70°F	70°F	70°F	
Blood pressure	125/85	125/80	130/85	125/75	Complete receiver failure.
Resting pulse	60	64	92	60	
Body temperature	98.6	98.6	98.6	98.0	
Weight		184.5	184.5		

Table 5 (Cont'd.)

Pulse Rate Vs. Time in Minutes
Polo Match
Hamilton, Mass.
September 25, 1963



Time - minutes

Figure 16

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Pulse Rate Vs. Time
Polo Match
Hamilton, Mass.
September 25, 1963

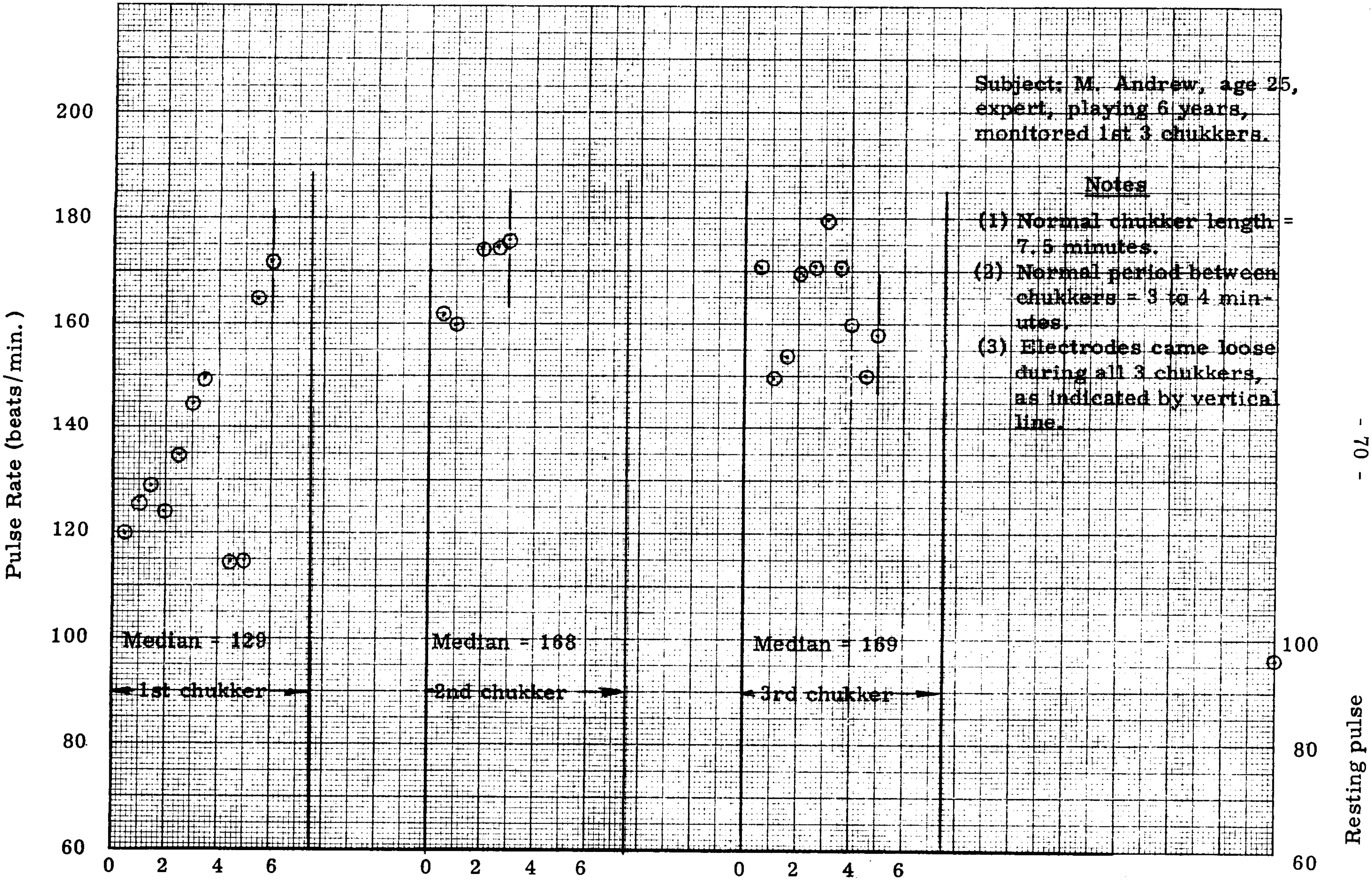

Figure 17

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Pulse Rate Vs. Time in Minutes
Polo Match
Hamilton, Mass.
September 25, 1963

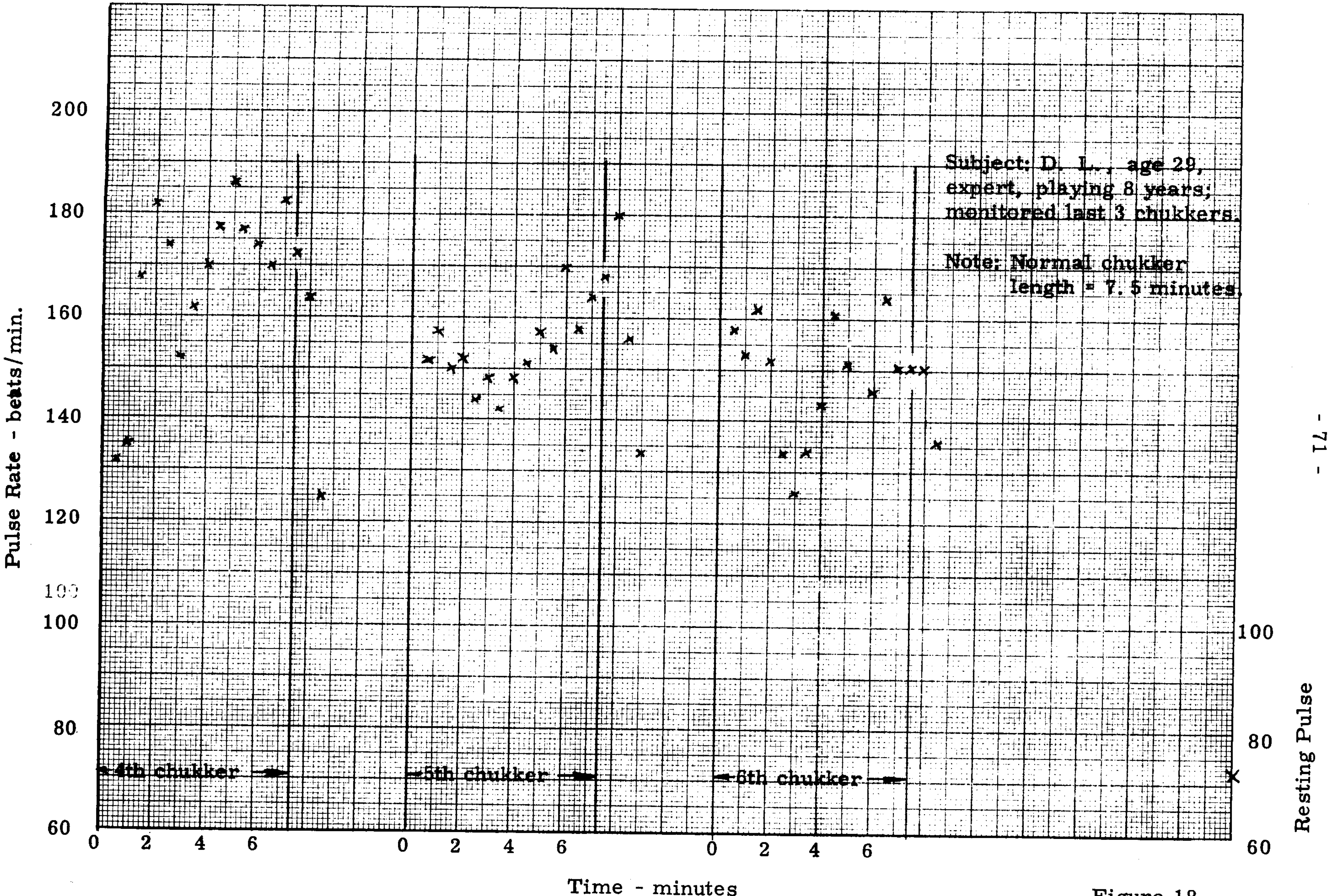

Figure 18

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the average rate computed over a 30-second interval. The medians listed on Figure 17 represent the median value of the several 30-second averages.

Heart rates observed during polo increase in variability as the match progressed. Weight losses and body temperature increases were absent or small, but this may have been partially due to uncontrolled intake of refreshing beverages during the periods between chukkers. This is in contrast to a hockey game, for example, where players were restricted to an intake of one orange.

G. Crew

Crew was selected for study since it represents an extreme type of physically strenuous task in which each participant must carefully coordinate his efforts with those of his teammates. Crew races vary in length and in number of men per shell. Two-man and eight-man shell events over one-quarter mile and 2,000 meters, respectively, were monitored for this study.

The New England Amateur Rowing Association Regatta at Laconia, New Hampshire was the first event monitored. This regatta is one of the more important open competitions used in the selection of individuals and crews to represent the United States at the Olympic Games. The races include single, double, four, and eight man events, and was scheduled for Sunday, August 25, 1963. However, inclement weather forced a number of crews to forgo the races, and the course to be shortened for all events. Because of the weather, three individuals scheduled for monitoring did not participate. Three replacement subjects were monitored during an M. I. T. intrasquad one-mile race on the Charles River in Cambridge on December 7.

1. Subjects

Two "novice" participants, one scheduled to row in a two-man shell and the other in an eight-man shell for 2,000 meters, were selected for monitoring at the NEARA Regatta. These men were classed as novices since they had been rowing in competition for less than a year.

Two experts and a coach (all rated high nationally) were also selected, but did not race due to the inclement weather.

Three "expert" participants were monitored during the M.I.T. races. A coach, coxwain, and stroke were selected, each of whom had competed for at least three years.

2. Procedures

Telemetry coverage was accomplished by use of a chase boat containing the receiver and recorder. Telemetry transmitters were taped to the shell and connected to sternum leads on the subjects.

Minus 24 hour samples of blood were drawn, physical data collected, and timed urine collection initiated. Samples were also collected immediately prior and after the race at Laconia. Plus and minus 4 hour, 24 hour, and immediate samples and physical data were collected from the Cambridge participants. Diurnal cycle data were collected several months later from the Cambridge participants. The schedule for collection of the diurnal data was identical to that used for hockey and sky diving.

3. Results and Discussion

Physical data are listed in Tables 6 and 7. Telemetry data are summarized in Figure 19. Because the course was shortened to only one-quarter mile for the Laconia events, the pulse rates rose progressively over the race. One subject placed first among four shells; the other placed second among eight shells. Peak heart rates were 198 and 191 for the two novices.

Table 6 - Summary of Data - Physical and Telemetered - Crew Races, M. I. T., Boston, Massachusetts, December 7, 1963

	Time					
	-24 Hours	-4 Hours	Immed. Prior	Immed. After	+4 Hours	+24 Hours
Subject: J. Adams Coxwain Age: 21	12/6/63	12/7/63	12/7/63	12/7/63	12/7/63	12/6/63
Ambient temperature	56°F	54°F	54°F	54°F	52°F	50°F
Blood pressure	115/65	115/70	125/70	120/70	120/76	115/75
Resting pulse	78	80	92	100	884	84
Body temperature	98.0	97.8	98.0	97.0	98.8	98.6
Weight			128	126		
Subject: Mark Barron Stroke Oarsman Age: 21	12/6/63	12/7/63	12/7/63	12/7/63	12/7/63	12/6/63
Ambient temperature	56°F	54°F	54°F	54°F	52°F	50°F
Blood pressure	110/65	115/75	135/85	130/85	140/80	130/80
Resting pulse	68	86	80	128	80	64
Body temperature	98.6	98.0	99.2	98.6	99.2	97.4
Weight			158.5	155.0		
Subject: G. Zwart Coach Age: 31	12/6/63	12/7/63	12/7/63	12/7/63	12/7/63	12/6/63
Ambient temperature	56°F	54°F	54°F	54°F	52°F	50°F
Blood pressure	110/65	115/75	120/85	115/80	130/80	125/80
Resting pulse	72	68	76	72	80	80
Body temperature	98.4	98.2	98.9	97.2	99.4	99.0
Weight						

Table 6

Table 7 - Summary of Data - Physical and Telemetered - Crew Races, Laconia, New Hampshire, August 24, 1963

	Time		
Subject: J. Walker*, Novice	-22 hrs.	-10 mins.	+20 mins.
Age: 21	8/23/63	8/24/63	8/24/63
Ambient temperature	$58^{o}F$	$60^{o}F$	$60^{o}F$
Blood pressure	125/80	120/75	110/75
Resting pulse	84	80	104
Body temperature	98.6	98.1	99.00
Weight		170.75	170.25
Subject: L. Tanner*, Novice	-23 hrs.	-2 hrs.	+20 min.
Age: 38			
Ambient temperature	$60^{o}F$	$60^{o}F$	$60^{o}F$
Blood pressure	140/70	155/85	160/90
Resting pulse	84	92	108
Body temperature	98.6	99.3	99.2
Weight		179.0	178.0

*Subjects reported immediately after event.

Table 7

Pulse Rate Vs. Time in Minutes
Crew Races
Laconia, New Hampshire, 8/25/63
M.I.T., Boston, Mass., 12/7/63

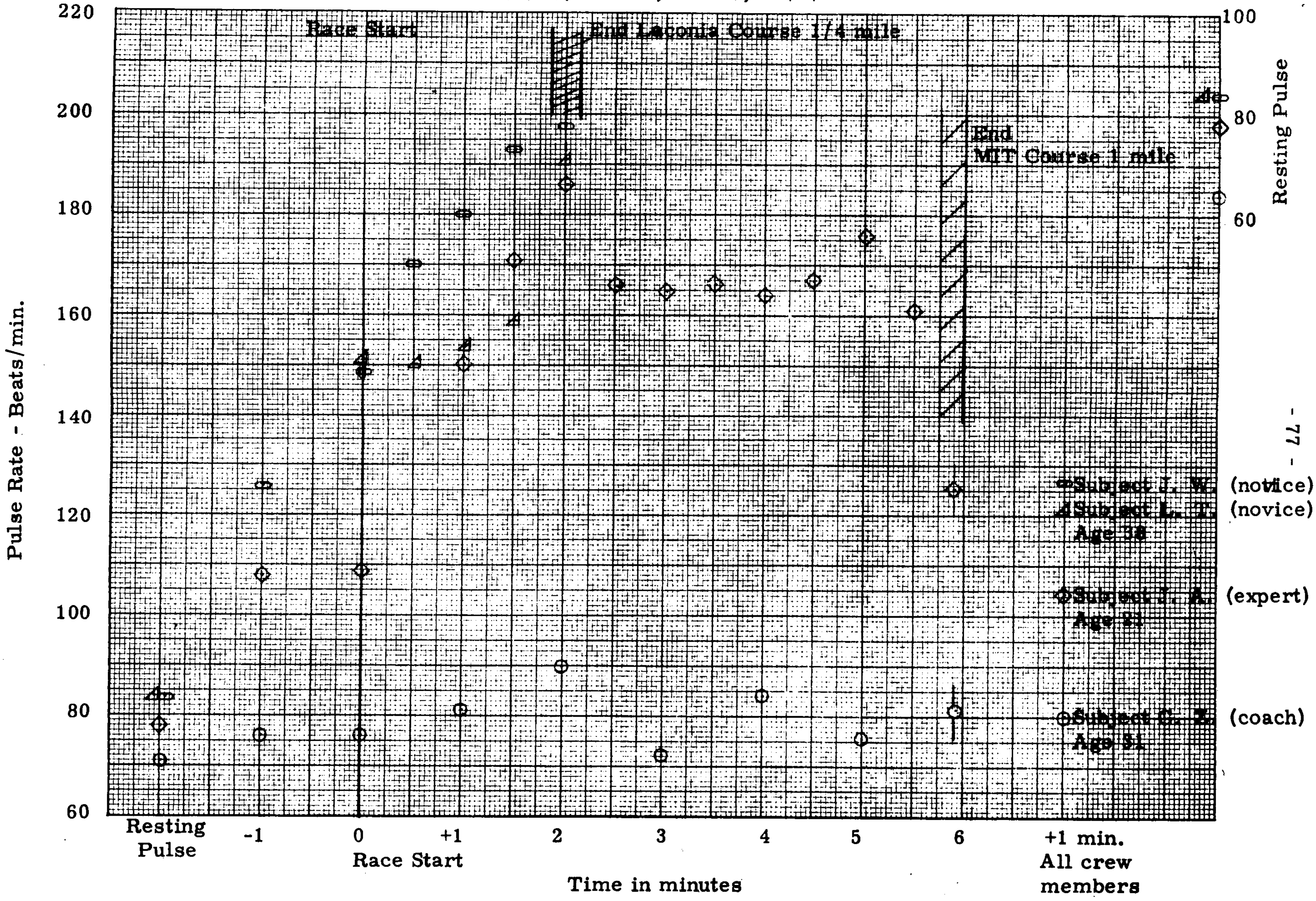

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Figure 29

The longer distance covered during the M. I. T. race is evidenced by the 3.5 lb. weight loss by the stroke, and a surprising 2 lb. loss by the coxwain. Unfortunately, the stroke oarsman severed the wires connecting the transmitters and transducers when entering the shell, and no telemetry data were obtained from him. The coxwain telemetry data were clear and showed pulse rates as high as 186 bpm and a rapid recovery curve following the race. This team finished second out of three shells, but was about two boat lengths behind the winner. There was no evidence of significant stress on the coach during this event, although this finding was not unexpected for an intrasquad race.

H. Track

Track was selected for study since it is primarily an individual sport involving great strength and stamina, particularly for the marathon events. Personal risk is low for well-trained individuals, but marathon runners report almost excruciating pain is encountered at times during a hard race.

Three track events were monitored: a 500 meter, mile, and a marathon event of 10 miles. The first two events were conducted indoors on a closed track and the last was an outdoor road race. The first two events were monitored during an intercollegiate track meet between the Massachusetts Institute of Technology and Brandeis University. The 10-mile road race was an open marathon from Hopkinton, Massachusetts to Newton Highlands and is generally regarded as a prelude to the Boston Marathon.

1. Subjects

For the indoor events, two freshmen competitors were monitored. Although both of these subjects had been running for several years, they had only entered intercollegiate competition within the preceding two months. They may be regarded as relative novices in competition, but were in excellent physical condition.

The two marathon contestants studied were a 42-year old physician from the Bio-Dynamics' staff and his 12-year old son. These subjects were categorized as expert and novice, respectively.

2. Procedures

For the indoor events, adequate telemetry reception was obtained by locating the receiver at the center of the track. For the road races, it was necessary to carry the equipment on a chase car.

The transmitters were worn by the subject on a corset arrangement around the waist. A major source of difficulty arose due to extreme arm and body motion, which, in two instances, severed the connection between the electrodes and the transmitter. Additionally, several subjects contacted expressed reluctance to participate in the program due to the additional burden of wearing the transmitter. A lighter and more compact unit is needed for routine monitoring during actual events.

Blood, urine, and physical data were collected at plus and minus 24 hours and immediately before and after the events (24-hour samples could not be obtained from the younger marathon runner). Timed urine collection was continued throughout the 48-hour period.

3. Results and Discussion

Physical measurements are listed in Table 8. Telemetry data were obtained from the mile event, over the first four miles of the marathon for one subject, and intermittently over the first mile for the other marathon runner. The continuous data are plotted in Figures 20 and 21. The 500-meter runner inadvertently pulled an electrode loose just as his event was getting under way, and no telemetry data were received.

Table 8 - Track Marathon, Hopkinton, Mass. to Boston, Mass.

	Time					Remarks
Subject: John Ryder Age: 17	12/9/63 -24 hrs.	12/10/63 Immed. prior	12/10/63 Race	12/10/63 Immed. after	12/11/63 +24 hrs.	
Ambient temperature	70°F	70°F	70°F	70°F	70°F	*Telemetered data (median).
Blood pressure	115/60	130/80	*	118/76	130/70	Indoor track.
Resting pulse	48	62	185.5	118	48	
Body temperature	98.6	97.6		98.7	96.8	
Weight		160.75		158.25		
Subject: Don Raab Age: 17	12/9/63 -24 hrs.	12/9/63 Immed. prior		12/9/63 Immed. after	12/9/63 +24 hrs.	
Ambient temperature	70°F	70°F	70°F	70°F	70°F	*Telemetry signal was lost when race started.
Blood pressure	145/85	120/80	*	130/72	130/85	Indoor track.
Resting pulse	88	88		118	72	
Body temperature	96.8	98.6		99.6	98.2	
Weight		141		139		
Subject: W. Guild Age: 42	2/21/64 -24 hrs.	2/22/64 Immed. prior	2/22/64 Race	2/22/64 Immed. after	2/21/64 +24 hrs.	
Ambient temperature	70°F	70°F	34°F	70°F	70°F	*Intermittent signal over first mile.
Blood pressure	138/88	160/94	*	160/96	140/74	Telemetry failure-- remainder of race.
Resting pulse	76	88	125	116	72	
Body temperature	97.6	98.7		97	98.4	
Weight		158		153		
Subject: S. Guild Age: 12		2/22/64 Immed. prior	2/22/64 Race	2/22/64 Immed. after		
Ambient temperature		70°F	34°F	70°F		*Median range 36 (182-218).
Blood pressure		100/60	*	110/60		
Resting pulse		76	200	88		
Body temperature		101		97		
Weight						

Table 8

Pulse Rate Vs. Time
Mile Run - M. I. T. - Novice
December 10, 1963

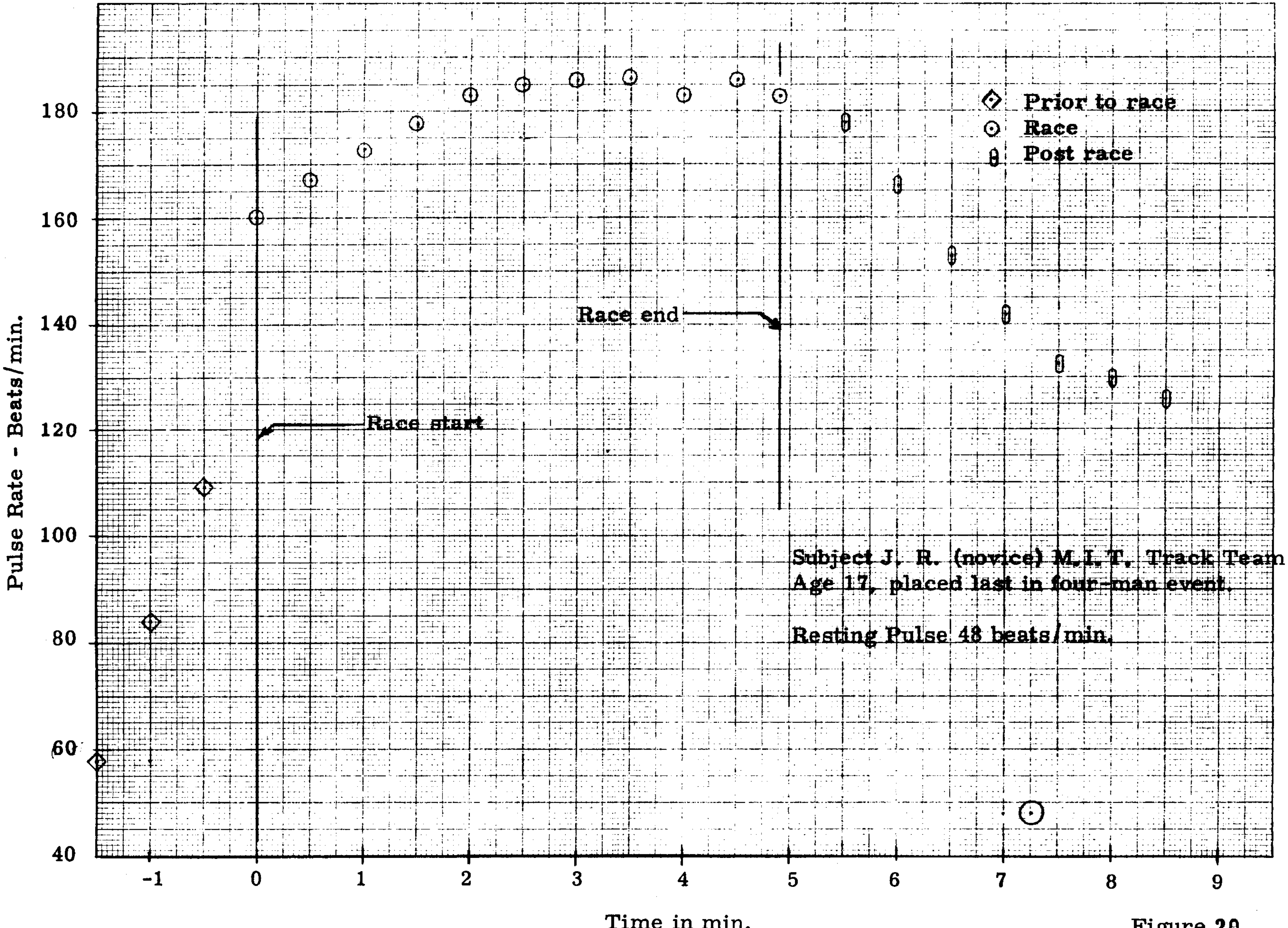

Figure 20

P[illegible] R[illegible] Vs. [illegible]sta[illegible] in [illegible]es
Marathon Race
Total Distance Run = 4 miles
February 22, 1964

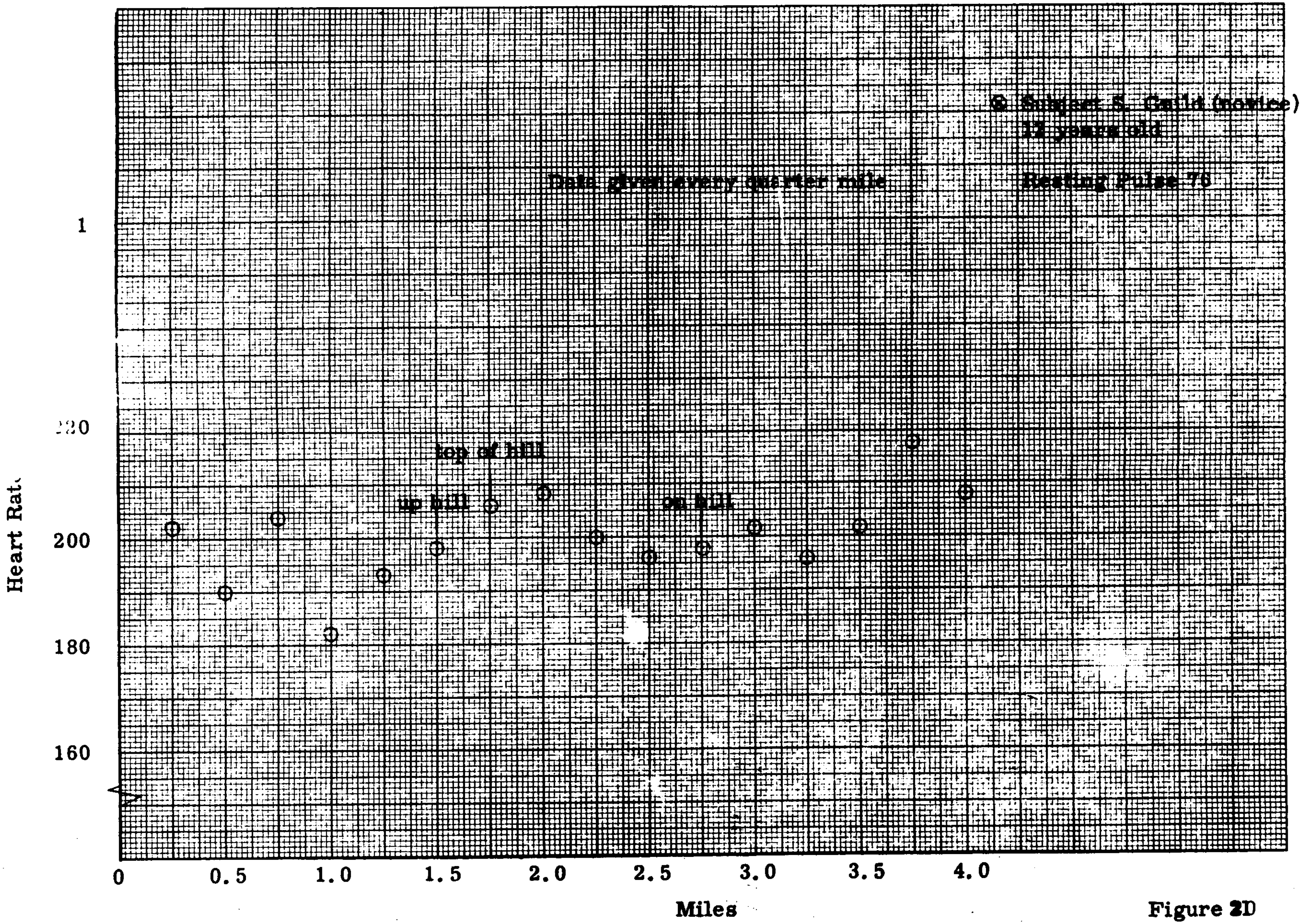

Figure 2D

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V. CONCLUSIONS AND RECOMMENDATIONS

It is concluded that the physical data obtained before and after participation in athletic events together with pulse data obtained during the events show wide individual differences among competitors and between types of events. Differences between measurements from novices and experts prior to the event, during the event, and after the event were noted. However, due to the small number of subjects tested in each sport, no quantitative conclusions may be drawn. These data, together with the biochemical analyses, provide descriptions of the normal stress-responses exhibited by selected competitors in a variety of sportive events. Some of the observed values have been sufficiently extreme to suggest that revisions may be required to the definition of "normal" response to stress.

The logistics associated with the field collection of physiological data from paid or volunteer subjects participating in special or scheduled sporting events were not insurmountable. Reliability of commercial telemetry gear and state-of-the-art electrode attachment should be improved for field studies of this nature. Athletes were generally cooperative, but elimination of blood drawing and a reduction in transmitter size would improve cooperation even more.

It is recommended that:

1. The data gathered during this study should be widely disseminated since no such body of data exists in the literature, and since it may be of value in the fields of sports medicine, occupational medicine, and work physiology.

2. Repeated measurements should be obtained from a large group of individuals participating in the same sport. These data are needed to assess day to day variability in stress response and to search for associations between change in response and change in performance.

3. Repeated measurements should be obtained from individuals undergoing several varieties of training regimens for sports involving either strong physiological or psychological stress. These data will be useful in devising training regimens which provide the best preparation for satisfactory adaptation to stress.

4. The manner in which the response to stress impairs man's capabilities should be studied in highly controlled situations. Basic research is needed on this topic so that tasks which must be performed under stressful conditions can be properly designed.

VI. ANNOTATED BIBLIOGRAPHY

Effects of Prolonged Work and Athletic Activities on Physiological and Psychological Functioning

The literature describing the effects of exercise on physiological function is extensive. In addition, there are numerous reports relating physiological measures to capabilities for performing various physical activities. However, the effects of antecedent strenuous physical exercise on psychological factors have not been systematically explored, nor are the relationships between psychological factors and physical capabilities well defined.

This review of the literature consists primarily of those reports dealing with the effects of strenuous athletic activities on physiological and psychological functions. In several instances where directly related literature is lacking, reports of the effects of mild work over prolonged periods have been included. Reports listed alphabetically in the annotated bibliography are categorized for reference purposes in the following paragraphs.

Effects of prolonged work on physiological functioning have been reviewed and categorized on the basis of: (a) changes in metabolism (Taylor, 1960), (b) oxygen consumption, transport, and pulmonary factors (Astrand, 1964, 1961, Dill, et al., 1962, Knuttgen, 1962, Milic-Emili, et al., 1962, Newman, et al., 1962, Taylor, 1960, and Torreli, et al., 1964), (c) effects on circulating compounds in the blood or excreted in the urine (such as cholesterol, Cureton, 1964, serum enzymes, Gardner, et al., 1964, and Schlang, et al., 1961, adrenal products, Davis, 1956, Frost, et al., 1951, Hoagland, et al., 1955, Marchbanks, et al., 1962, Meehan, et al., 1959, and Thorn, 1952, or eosinophils, Reynolds, et al., 1951, and Davis, 1956), (d) effects on blood pressure (Balke, 1963, and Rubenstein, et al., 1963), (e) effects on renal function (Arnett, et al., 1961), and (f) changes in the ECG, both during and after exercise (more and more reports dealing with ECG or heart rate changes observed during exercise are appearing, such as those by

Bellet, et al., 1962, Cooper, 1964, Hansen, et al., 1964, Kozar and Hunsicker, 1963, Maxfield and Brouha, 1963, Plas, 1962, and Rose, 1964, as opposed to before/after measurements as reported by Beswick, et al., 1961, Etzenhouser, et al., 1959, Hunt, 1963, Isaacs, 1962, Jokl, 1961, Langner, 1961, and Naughton, et al., 1963). Athlete's heart has been described by Wolfe (1962). Many papers describe changes which fall in several of the above categories, and relate or correlate such changes to performance, work capacity, or other "fitness" measures (Astrand, 1961 and 1964, Cureton, and Phillips, 1964, Dill, et al., 1956, Brouha and Radford, 1960, Hyman, 1962, Jokl, 1961, Jones, 1961, Naughton, et al., 1963, Newton, 1963, and Wyndham, et al., 1964).

Reports of the effects of athletic activities on psychological functioning were not found. General reviews (such as that by Ulrich, 1960) suggest that psychological factors are often limiting variables in athletics, and that wide individual differences in performance are often attributed to "motivation", "drive", and other ill-defined factors. Effects of prolonged work on psychological function appear to depend on many non-work factors. In some cases, no effects are noted (Hauty), while in others "fatigue" effects are described with light loads (Bartlett, 1950). No effects were found after prolonged strenuous combat in Korea (Davis, 1956), while the occurrence of psychological states such as "combat reaction" or "combat fatigue" are very real (Gramlich, 1949). One of the more sensitive sensory factors used to illustrate the effects of low oxygen partial pressure, toxemia of pregnancy, etc. is the flicker fusion (FF) level, but even the changes in FF after exercise or prolonged work are small or inconsistent (Graybiel, et al., 1943, and Brozek and Keys, 1944). Subject ratings of discomfort can, under certain conditions, be substituted for measures of physiological response (Fine, 1958) but extensive study of the limits within which such techniques are valid have not been carried out. Tremor has been related to prolonged work (Bousfield, 1932). It is also certain that psychological factors influence physiological mechanisms (Thorn, 1952, and Reynolds, et al., 1951) and there is some evidence that the same physiological responses are associated with performance changes (Hoagland, et al., 1955), although a causal relation has not been established.

Arnett, J. H. and Gardner, K. D., Jr., "Urinary abnormalities from overuse of muscles", American Journal of the Medical Sciences", 241:55-58, January, 1961

A case is presented where a 20-year old college student began passing brown urine 24 hours after performing 150 to 200 deep knee bends in 20 minutes. In addition to having painful thigh muscles, examination of the urine found abundant dark granular casts, leukocytes, and a strong positive test for hemoglobin. The latter was attributed to erythrocyte hemolysis within the urinary tract. Literature is cited in which exercise was reported to cause the appearance in urine of casts, protein, erythrocytes, myoglobin, hemoglobin, and leukocytes.

Astrand, P., Cuddy, T. E., Saltin, B., and Stenberg, J., "Cardiac output during submaximal and maximal work", J. Appl. Physiol., 19:268-274, 1964

Oxygen uptake, heart rate, cardiac output, and blood lactate, hemoglobin, and oxygen content were measured for 11 female and 12 male subjects, exercising on a bicycle ergometer. Studies done at rest, during 3 or 4 submaximal, and during one maximal workload. Individual data for all measurements and conditions are reported. Maximum stroke volume was approximately 50% greater than resting for both sexes, and was reached at about 40% of the individual's aerobic work capacity. A high correlation was noted between heart volume and plasma volume, and between stroke volume, cardiac output, and oxygen uptake during maximal exercise. Possible sources of errors, and comparisons with other studies are presented.

Astrand, P., and Saltin, B., "Maximal oxygen uptake and heart rate in various types of muscular activity", J. Appl. Physiol., 16:977-981, 1961

Seven subjects were studied (only three took part in all 7 forms of exercise) during (a) leg work on a bicycle ergometer, upright, (b) arm and leg work on a bicycle ergometer, (c) running, (d) skiing, (e) cycling supine, legs only, (f) swimming, and (g) arm work only on a bicycle ergometer. Because the subjects who participated in different activities were not always the same, comparisons were made for from 3 to 6 subjects. Cycling while supine produced only 86% of the oxygen uptake when sitting.

Swimming produced 87% of the maximum oxygen uptake while cycling, arm work 70% compared to cycling, running 5% more than cycling, skiing and arms plus leg cycling produced about the same as cycling. The ceiling for maximal oxygen uptake was not dependent on the mass of muscle employed. The results are suggestive of cardiac capacity as the limiting variable.

Balke, B., Experimental Evaluation of Work Capacity as Related to Chronological and Physiological Aging, Civil Aeromedical Research Institute, CARI Report 63-18, Federal Aviation Agency, Oklahoma City, Oklahoma, 1963

Reports of the decline of physical work capacity with age are reviewed and exceptions to this tendency discussed. It is posited that the decline is due primarily to changes in living habit (infrequent exposure to situations with high functional demands). Two examples are cited which show the potential value of regular physical exercise in reversing the progressive decline in physical work capacity with age. One individual (Balke) regularly ran 3 - 6 km three times per week, and after periods of inactivity was able to increase his peak oxygen intake and maximum heart rate to their former values. The other individual, age 53, engaged in a regular exercise program to counter a progressively increasing blood pressure. Work capacity increased 25% during 12 weeks of training and "considerable normalization of blood pressure" was observed.

Bartlett, F., "Human tolerance limits", Acta Psychol., 7:133-141, 1950

A review of Medical Research Council supported studies and those performed elsewhere which show tolerance limits to environmental and task stresses. For thermal stress, there were very little performance changes until a critical region was reached, then there was a decisive and rapid breakdown in proficiency. Limits for speed and load stress are discussed for specific tasks and effects of incentive on performance below stress limits described. Effects of prolonged activity on performance is shown to be a function of many variables; incentive, training, environmental conditions, and load stress.

Bellet, S., Eliakim, M., Deliyiannis, S., et al., "Radioelectrocardiographic changes during strenuous exercises in normal subjects", Circulation, 25:686-694, April, 1962

The electrocardiograms of 135 normal subjects (17-64 years old) obtained during and after work on a cycle ergometer were studied. Heart rates at work averaged 138 beats per minute (range of 120 to 182 beats per minute) indicating that the levels of work varied from light to heavy, with the typical work level constituting moderately difficult work. Sinus tachycardia, increased P-wave amplitude, ST-segment depression of the junction type, and modification (mostly increased) T-wave amplitude occurred regularly during work and frequently after work and were interpreted as normal responses. Sixteen subjects exhibited abnormal responses only during exercise, six subjects only after work, and twelve subjects both during and after. The most frequent abnormal responses observed were persistent ischemic ST-segment depression and T-wave inversion, both occurring more often during work. There was a higher incidence of abnormalities in the age group 40-64 years than in the age group 17-40 years. It was also concluded that a cycle ergometer test was superior to the "Master Two-Step Test" for the detection of latent coronary artery disease.

Beswick, F. W. and Jordan, R. C., "Cardiological observations at the Sixth British Empire and Commonwealth Games", British Heart Journal, 23:113, March, 1961

Resting electrocardiograms of 60 trained track and field athletes (British Empire Games) were presented and compared with those of 47 untrained students from a previous study. Einthoven (RLF) plane vector electrocardiograms and lead field spatial vectorcardiograms were employed. Athletes showed a lower mean resting heart rate than the nonathletes, distance runners exhibiting lower rates than sprint and field event competitors. Athletes also showed an increase in mean T complex time (and spatial magnitude of T) and a lower Q-T/R-R ratio. No differences were found between the two groups as regards vector analysis of RLF and lead field frontal planes. The findings are discussed in terms of possible increased vagal activity and physiologic hypertrophy of the right ventricle in athletes as related to the endurance demands of the respective events.

Bousfield, W. A., "The influence of fatigue on tremor", J. Exp. Psychol., 15:104-107, 1932

Subjects exercised over three periods; tremor records (right index finger) were recorded before and after each exercise session. Rate, amplitude, and standard deviation of tremor movements increased uniformly with exercise. The author concluded that these measures of "tremor oscillations vary directly with the degree of fatigue".

Brouha, L. and Radford, E. P., Jr., "The cardiovascular system in muscular activity", Chapter in W. R. Johnson (ed.) Science and Medicine of Exercise and Sports, Harper & Bros., N. Y., 1960

The authors first review the circulatory adjustments necessary to meet the metabolic requirements of aerobic and anaerobic exercise. Much emphasis is placed on the recovery process following strenuous exercise. None of the various steps in O_2 uptake and transport is regarded as limiting to the normal individual, and it is suggested "that a delicate balance of several limiting factors in all stages of oxidative metabolism exists at peak levels of exercise". Each factor in cardiac output (rate and stroke volume or total O_2 consumption and mean AV difference) is described and changes in blood pressure related to the effects of exercise. The ability of the heart to greatly increase output with only small increase in O_2 consumption (and to utilize lactate) suggests that the heart itself is not limiting during maximum exercise. Much population data is presented regarding physiologic measures during moderate and strenuous exercise and during the recovery period. The authors conclude that muscular work capacity estimates "should be based on the subject's actual ability to perform it and on the speed of recovery after exercise".

Brozek, J. and Keys, A., "Flicker fusion frequency as a test of fatigue", J. Indust. Hyg. & Toxicol., 26:169-174, 1944

Groups of from 6 to 12 subjects were studied under the following conditions: (a) before and after a one-hour treadmill march, (b) treadmill marches at 7.5^{o} incline (10 minute work-rest cycles) at elevated temperatures, (c) reduced caloric intake and 4500 cal/day work, and (d) three days of starvation with decreasing work requirements. Flicker fusion frequency (FFF) was inconsistently elevated after short periods of hard work. Morning-afternoon elevations of FFF were observed in 159 out of 160 cases where 4 hours of marching per day were required with appropriate rest pauses. When working in heat, the FFF decreased by an insignificant amount on consecutive days. Partial starvation produced consistent progressive decreases in FFF, these changes were more pronounced in total starvation.

Cooper, K. H , A Simple Inexpensive Way to Monitor Electrocardiograms on an Actively Exercising Subject, SAM-TDR-64-38, USAF School of Aerospace Medicine, Brooks Air Force Base, Texas, 1964

A procedure is described for obtaining precordial lead ECG tracings on an actively exercising subject. The technique depends on use of standard copper arm electrodes and a chest lead (Beckman electrode) which most closely corresponds to a standard lead (the CR chest lead in the V_2-V_4 position is stated to give best results most frequently). Examples of standard V_4 and CR_4 lead during exercise are given and reduction in motion artifacts demonstrated. It is suggested that "at least 6% of patients suffering from cardiac disease will show, during exercise, ECG abnormalities that subside promptly with rest". Continuous monitoring is also necessary for accurate estimates of work capacity.

Cureton, T. K. and Phillips, E. E., "Physical fitness changes in middle-aged men attributable to equal eight-week periods of training, non-training, and re-training", J. Sports Med., 4:87-93, 1964

Six middle-aged subjects and four controls were studied to assess cardiovascular fitness and heart size changes over a 24-week period. Experimental subjects exercised six days a week, including calisthenics, cross-country running, and handball.

Significant reductions in abdominal girth, body weight, and fat were observed for those who exercised. Performance improved, serum cholesterol fell, heart size decreased, and peripheral resistance decreased with hard training.

Cureton, T. K. and Sterling, L. F., "Factor analyses of cardiovascular test variables", Journal of Sports Medicine, 4(1):1-24, March, 1961

One hundred young male subjects were given a variety of tests related to cardiovascular functioning (at rest and in hard work) and one hundred and four test variables were selected for factor analysis. It was found that certain tests group to measure some part of nine main components which were derived and identified as: brachial pulse wave, oxygen requirement, pulse pressure after work, body weight, adjustment to submaximal work, endurance in an "all-out" treadmill run, vagal tone, splanchnic ptosis, and aerobic efficiency. Tentative descriptions and interpretations are presented.

Davis, S. W., "Stress in combat", Scient. Amer., 194:31-35, 1956

A review of the Korean FAST study results showed that extensive combat stress had no effect 12 to 17 hours later on performance with a battery of psychological tests. Marked blood and urine changes were noted. Flicker fusion levels were slightly reduced.

Dill, D. B., Bock, A. V., Edwards, H. T., et al., "Industrial fatigue", Journal of Industrial Hygiene and Toxicology, 18(7):417-431, September, 1956

A general review of the concept of fatigue as applied to physical work with numerous references to laboratory studies in ergometry and studies in industrial situations. The authors point out that the term "fatigue" can refer to a work decrement, a physiologic state, or a feeling of tiredness. From a purely physiologic point of view, fatigue can only be regarded as a breakdown of homeostatic forces and not to be confused with the psychological state of boredom. Examples are given of fatigue in which (1) there is a marked increase in blood lactate, (2) there is an exhaustion of energy yielding products alleviated by glucose ingestion, (3) inadequacy of oxygen supply contributes to the breakdown, and (4) alteration in the physico-chemical state is observed. The various mechanisms appear to be interrelated and the possibility of simple explanations for fatigue in various situations thus made highly improbable.

Dill, D. B. and Sactor, B., "Exercise and the oxygen debt", Journal of Sports Medicine, 2:66-72, June, 1962

A general review of what is known about oxygen debt and its relation to physical performance. The authors point out that the rate of oxygen consumption following work involves (1) basal oxygen consumption, (2) oxygen consumption attributable to oxidation of lactic acid, (3) another factor repaid at a faster rate than #2 (alactacid), and (4) an oxygen consumption decreasing very slowly during recovery. A rather significant oxygen deficit (as high as 5 liters) can occur without elevations in lactate being found. Considerable attention is also given to what is not understood about oxygen debt, such as: the inability of the aged to accumulate large amounts of lactate and the low lactates recorded in exhausting work at high altitudes. The authors close the article by posing almost a dozen questions concerning the oxygen debt mechanism and the effect of training on the ability to accumulate an oxygen debt.

Etzenhouser, R., Dunn, M., and Dimond, G. E., "Electrocardiogram of weight-lifters", Journal of the Kansas Medical Society, 60(3):121-125, March, 1959

A study of the electrocardiograms of 26 male weight-lifters (age 16 to 40) was made before and after Master's two-step test. One subject demonstrated occasional atrial premature contraction at rest and marked arrhythmia after exercise; one subject demonstrated an inverted T-wave before exercise which reverted to normal after exercise; one subject developed terminal depression of the ST-segment with T-wave inversion. All changes were attributed to physiological adaptations and well within the capacities of the normal heart. Bradycardia and prolongation of the P-R interval, frequently reported in athletes, were not observed. This was cited as evidence that weight-lifting does not involve endurance and, therefore, does not produce any degree of physiological cardiac hypertrophy.

Fine, B., "The comparative effectiveness of some psychological and physiological measures in ranking the impact of diverse environmental conditions", J. Appl. Psychol., 42:353-356, 1958

Subjective rating scales were compared to actual physiological measures during exposure to various environmental conditions. Although the subjective scales were "relatively inaccurate" in approximating the physiological measurements, the ranking of the environmental conditions by both types of measures correlated almost perfectly.

Frost, J. W., Dryer, R. L., Kohlstaedt, K. G., "Stress studies on auto race drivers", Journal of Laboratory and Clinical Medicine, 38:523-25, 1951

The physical and psychological stress of the 500 mile Indianapolis Speedway Race (1950) upon nine race drivers was studied. Various determinations were made one week prior to the race, and, again, one hour after completion or withdrawal from the race. All nine subjects showed large decreases in circulating eosinophils, with at least a 90% decrease in seven. The authors attributed this change to increased adrenal cortical activity. Six of seven subjects tested for urinary 17-ketosteroids showed an increased excretion of at least 50%. There was no consistent response in urinary and serum sodium and potassium, uric acid, or urinary creatinine.

Gardner, G. W., Bratton, R., Chowdhury, S. R., Fowler, W. M., Jr., and Pearson, C. M., "Effect of exercise on serum enzyme levels in trained subjects", J. Sports Med., 4:103-110, 1964

Thirty-one trained or untrained subjects were studied before and after exercise programs. Serum levels of glutamic oxalacetic transaminase (GOT), glutamic pyruvic transaminase (GPT), lactic dehydrogenase (LDH), malic dehydrogenase (MDH), and aldose were measured.

Both trained and untrained individuals exhibited serum enzyme increases after exercise, but large individual differences in magnitude were observed. The rise in serum enzymes following exercise is probably due to increased muscle cell membranes permeability and resultant efflux. The authors consider several alternative hypotheses and suggest that because the increase serum levels vary inversely with training, they are related to tissue hypoxia effects.

Gramlich, F. W., "A psychological study of stress in service", J. Gen. Psychol., 41:273-296, 1949

One-hundred and seventy patients with combat fatigue, combat reaction, and noncombat breakdown were studied, symptoms evaluated, and compared with symptoms prior to service. The nuclear group of symptoms precipitated by stress in service were: tension, anxiety, depression, gastric complaints, sleep disturbance, headache, vasomotor-secretory disturbances, irritability, and fatigue. Combat stress intensified the number of symptoms as compared to service stress in general. Specific symptoms or breakdowns were not related to specific activities.

Graybiel, A., Lilienthal, J. L., and Horwitz, O., "Flicker fusion tests as a measure of fatigue in aviators", J. Aviat. Med., 14:356-359, 1943

Thirty-two aviators were studied before and after flying and on non-flight days. Although very small decreases in flicker fusion were observed, "the correlation (to fatigue) is tenuous and will provide little or no valuable data".

Hanson, J. S. and Tabakin, B. S., "Electrocardiographic telemetry in skiers", New England Journal of Medicine, July 23, 1964, pp. 181-185

Four subjects, members of a college ski team, carried miniature transmitters for telemetering EKG during competition in cross-country, downhill, and jumping events. Methods for attaching electrodes and research procedure are discussed. Greatest success was obtained by preparing the skin surface area, applying electrode paste, and employing adhesive electrodes with snap-on attachments for the leads. Clear electrocardiograms were obtained at distances in excess of 500 feet. The electrocardiograms in this study were used solely to investigate the heart rates prior to, during, and after competition. Anticipatory heart rates for all three events exceeded 93 per minute, with a high of 166 per minute. For two competitors in cross-country, heart rates of 166, 187, and 200 were recorded during the race.

Hauty, G. T. and Payne, R. B., Effects of Work Prolongation Upon Components of a Perceptual-Motor Task, USAF School of Aviation Medicine, Report No. 6, Project No. 21-1601-004

After seven hours of continuous performance with a complex compensatory pursuit task in a flight simulator, no significant impairment in performance was noted.

Hoagland, H., et al., "Adrenal stress responses of normal men", J. Appl. Physiol., 8:149, 1955

Comparisons of adrenal responses were studied in young men (16-20 years of age) in relation to the difficulty of a task. The latter consisted of operating a pursuit meter (simulating flying an aircraft in pursuit of another) while breathing air with various oxygen contents (10.5%, 12%, 13%, 21%). Four groups of five men each were tested 8 to 10 times, once per week, with the tests lasting either two or three hours. In comparing the data obtained with those of other studies, it was concluded that young men demand very little of the adrenal cortical mechanisms to meet stresses which increase these same responses in older men. An eosinopenia following stress correlated better with the urinary excretion of adrenaline than with that of ketonic 17-ketosteroids and it is suggested that a non-adrenal factor might be involved. Evidence was presented indicating that the better the performance of an individual, the lower his increase in 17-ketosteroid output. The latter was attributed to higher pre-test values, a possible indication of better performers being "keyed up" prior to the test.

Hunt, E. A., "Electrocardiographic study of 20 champion swimmers before and after 110-yard sprint swimming competition", Canadian Medical Association Journal, 88:1251-3, June 22, 1963

Electrocardiograms and blood pressures were recorded on 19 lightly trained swimmers at rest several days before competition and immediately following competition in a 110-yard sprint. Heart rates averaged 61 per minute at rest and 113 per minute three minutes after competition. Blood pressures averaged 117/70 at rest and 165/47 two minutes after competition. The PR interval was prolonged in 12 cases from 0.04 to 0.10 seconds. Eight subjects showed ST depression but only two cases were considered "true" depression. All subjects showed a loss in T-wave potential (eight showed inversion), with certain instances of late development (e.g., 12 minutes after competition). All of these changes were held to be normal physiologic responses to the stress of physical effort and competition.

Hyman, A. S., "The estimation of cardiovascular physical fitness", J. Sports Med., 2(2):86-88, June, 1962

Because of such contradictions to tradition as the high level of fitness demonstrated by "cardiac athletes", the author emphasizes the need for heart examinations both at rest and in exercise. Simple tests are listed as heart rate, blood pressure and various pulmonary determinations. More complicated tests are listed, such as electrocardiogram, arteriogram, ballistocardiogram, x-ray of three-dimensional heart and aorta, and blood chemistry and gas exchange data. The author presents two formulae for measuring "cardiovascular-pulmonary" fitness, termed the Age Adjusted Respiratory Index (involving age, vital capacity, and breath holding ability) and a Cardio-Pulmonary Index (involving the same factors plus maximum expiratory pressure, systolic pressure, diastolic pressure, and heart rate). The author does not attempt to justify the combination of such heterogeneous parameters in a single index.

Isaacs, et al., "EKG 'notching' and 'shouldering' in athletes and untrained men", Cardiologia, 41:121-6, 1962

Seventy-four electrocardiograms of tournament wrestlers, twelve electrocardiograms of championship weight-lifters, and electrocardiograms from fifty-five male student "controls" were analyzed for "notching" or "shouldering" of the ascending limb of the S-wave before reaching the iso-electric line. The three groups differed with regard to frequency of notching and shouldering, with the athletes demonstrating a much higher incidence. The authors suggest three possible explanations: (1) the anomalies are inherent and responsible, in part, for the athlete's success, (2) they represent a characteristic acquired through training, and (3) they have no relationship to the athlete's cardiac efficiency.

Jokl, E., "Ballistocardiographic studies on athletes", American Journal of Cardiology, 4(1):105-117, July, 1959.

The purposes of this paper were (1) the presentation and analysis of ballistocardiograms of ex-athletes, students not in training, students in serious sports training, and in older men undergoing a physical rehabilitation program, and (2) the correlation of the results with certain physiologic concepts. It was found that systole takes up a much smaller fraction of a cardiac cycle in athletes. As athletes also have a lower resting heart rate, this means that the diastolic interval is made even longer. Quantitative differences were found between athletes and students not in training. Ex-athletes demonstrated a decreased cardiovascular fitness as a result of inactivity. It was also found that weight-lifters' hearts were on the whole functionally inferior to runners, indicating that this activity does not contribute to endurance training. Cardiac efficiency, as measured by ballistocardiography, was found to improve as a result of training regardless of the age group. The importance of physical exercise in reversing the effects of sedentary living on the heart is emphasized by the author.

Jokl, E., "Effect of sports and athletics on the cardiovascular system", American Journal of Cardiology, 7:320, March, 1961

A survey of the literature and discussion of the physiologic effects of exercise and training. Particular attention is paid to recent advances in Bernard's concept of a "milieu interne" and advances in understanding of cardiac control, with special relation to the acute and chronic effects of exercise. Data is cited showing the changes in oxygen uptake, cardiac capillarization, skeletal muscle vascularization, blood pressure, heart rate, lung ventilation, cardiac volume, ballistocardiogram, and electrocardiogram.

Jones, F. and Luft, U. C., "The assessment of physical competence in relation to body mass, composition, and age", Journal of Sports Medicine, 1(2):96, September, 1961

A panel discussion concerned with the biochemical and physiological aspects of exercise, with special reference to work capacity measures and factors limiting performance. It is pointed out that the factors which limit work capacity include: (1) the quantity of active tissues, (2) the quality of metabolic activity as determined by the sources of energy, and (3) the competence of the oxygen transport system. Attention is called to certain studies which have found that basal metabolic rate, cardiac output, hemoglobin content, and maximum oxygen uptake show a better relationship to lean body mass than to total mass. The importance of this parameter is emphasized as regards comparison among individuals.

Knuttgen, H. G., "Oxygen uptake and pulse rate while running with undetermined speeds", Acta Physiologia Scand., 52:366-71, July-August, 1962

Oxygen uptake and heart rate determinations were made on two well-trained athletes running at different speeds on a treadmill. Two series of experiments were performed, one in which the subjects were allowed to determine their own stride lengths and one in which the stride lengths were determined by the subjects running in time to a metronome. Both parameters showed a rectilinear relationship when plotted against the second power of running speed, indicating that kinetic energy is the dominant factor in running. Earlier evidence was supported that well-trained runners increase their running speed by increasing their stride lengths and not by increasing stride frequency.

Kozar, A. J. and Hunsicker, P., "A study of telemetered heart rate during sports participation of young adult men", J. Sports Med. & Phys. Fit., 3:1-5, 1963

Twenty-three adults (age 18-39) were studied during participation in handball, paddleball, tennis, badminton, volleyball, and bowling. Mean heart rates for handball, paddleball, tennis, and badminton did not differ significantly. Volleyball heart rates were significantly less than in the above sports, and significantly more than in bowling. The maximum rate observed (186 beats per minute) was considerably less than customarily reached in maximum work capacity tests, and the time required to reach peak rates (8 to 22 minutes) considerably more than reported in most laboratory studies. The technique described for securing electrodes and insuring low resistance has since been improved by other investigators (see, for example, NASA Tech Brief 64-10025).

Langner, P. H., Jr., "Errors encountered in records of the post-exercise electrocardiogram", American Heart Journal, 62:566-77, October, 1961

Because of the increased use of post-exercise electrocardiograms as a part of routine health examinations, the author calls attention to five errors in procedure for such a test:

1. Taking one series of leads immediately after exercise and thereby not allowing sufficient time for the appearance of abnormalities.

2. Employing a single test, not long enough to elicit abnormal responses.

3. Loose electrodes which cause wandering base line.

4. Starting the recording too long after exercise is terminated.

5. Recording too many leads on a one-channel machine, thus causing too great a time lapse.

The author also recommends that post-exercise electrocardiogram test be administered by two persons.

Marchbanks, V. H., Hale, H. B., and Ellis, J. P., Stress Responses of Pilots Flying 6-Hour Overwater Missions in F-100 and F-104 Aircraft, Brooks Air Force Base, School of Aerospace Medicine, Texas, August, 1962, SAM-TDR-62-112

The stress of overwater flights on two groups of pilots flying 6-hour missions (approximately 2, 300 nautical miles) was studied. A third group of pilots on an off-duty day were used as a control. Both flying groups showed elevations in urinary excretion of urea and uric acid but only one group showed higher urinary sodium and potassium. No significant changes were reported for urinary phosphate. Elevations in corticosteroid levels were found in plasma but not urine in the flying group. Similar elevations were found in urinary epinephrine and norepinephrine. Differences were found between the two flying groups and were attributed to such factors as aircraft characteristics, weather conditions, responsibility, and flying experience. For example: one flight encountered turbulence and showed an increase in plasma corticosteroids and other evidences of severe stress in individuals were found in (1) a pilot known to be apprehensive, (2) a pilot separated from his group for 2-1/2 hours because of instrument failure, (3) a flight leader, and (4) a unit commander.

Maxfield, M. E. and Brouha, L., "Validity of heart rate as an indicator of cardiac strain", J. Appl. Physiol., 18:1099-1104, November, 1963

Two series of experiments were conducted to investigate the feasibility of employing heart rates as a simple measurement of cardiac strain induced by work. In the first series, the relationships between total cardiac cost (total heart beats during rest and recovery) and work level, and between cardiac recovery cost (total heart beats during recovery) and work level were studied. In the second series, similar comparisons were made with thermal stress (climatic chamber) while working at a fixed intensity. Work was performed in both series on either a cycle ergometer or a treadmill. Total cardiac cost and the derivative "work per beat" were found to provide reliable measurements of cardiac strain in any environment. Cardiac recovery cost and heart rates determined during the first three minutes of recovery showed a linear relationship to total cardiac cost and, therefore, provide a simple measurement of cardiac strain induced by work.

Meehan, J. P. and Jacobs, E., Physiologic Production of Catechol Amines in Response to Several Physical Stresses, Aerospace Medical Laboratory, Wright-Patterson Air Force Base, Ohio, September, 1959, WADC Technical Report 59-534

The effects of exercise, a cold pressor test, and positive acceleration (centrifuge) on physiologic production of adrenaline and noradrenaline were studied. The subjects were male college students, age range of 18 to 26 years. Chemical techniques were employed for blood analyses from samples taken from the antecubital vein. Exercise consisted of the Harvard Step Test and treadmill walking (60 minutes, 3 m.p.h., 5% grade). Plasma levels of noradrenaline increased significantly in exercise and showed an apparent positive relationship to the severity of the limited samples of exercise stress. The cold pressor test (hand immersion in ice bath) and positive acceleration did not produce these changes. Resting levels of adrenaline and noradrenaline cannot be used to predict performance in any of the four stress situations studied.

Milic-Emili, G., Petit, J. M., and DeRoanne, R., "Mechanical work of breathing during exercise in trained and untrained subjects", J. Appl. Physiol., 17:43-46, January, 1962

A comparison was made of the mechanical work of breathing during exercise between athletes and non-athletes. Measurements were made from esophageal pressures and tidal volumes while exercising on a cycle ergometer. At all levels of pulmonary ventilation, the mechanical work was found to be the same for both groups. At all levels of oxygen consumption, pulmonary ventilation and mechanical work of breathing were found to be lower in athletes. However, the amount of oxygen thus gained by the athletes was never in excess of 1% of the total oxygen uptake.

Naughton, J., Sevelius, G., and Balke, B., "Physiological responses of normal and pathological subjects to a modified work capacity test", The Journal of Sports Medicine, 3(4):201-7, December, 1963

Four subjects performed a work capacity test involving treadmill walking at increasing grades (2 m.p.h., 3.5% grade increase every 3 minutes). They were a well-trained subject, an untrained person in good health, a patient with coronary artery disease, and a patient with aortic stenosis. Recordings were determined at various times of work for blood pressure, heart rate, cardiac output, respiratory gas exchange, and electrocardiogram. All four subjects showed an increase in systolic pressure during work while only the well-trained subject had a decrease in diastolic pressure. The patient with aortic stenosis never attained very high systolic pressures (maximum of 142 mm Hg). The two healthy subjects showed similar increases in heart rate, the coronary subject was consistently lower at the various levels of work, and the subject with aortic stenosis recorded comparatively low heart rates before being forced to stop exercise after a short time. Ventilatory efficiency found differences between all four subjects with the well-trained subject most efficient, followed by the untrained subject, the coronary subject, and the subject with aortic stenosis. A similar trend was observed in cardiac minute volume. The untrained subject showed the greatest stroke volumes at the highest work intensities, the trained subject considerably lower, and the coronary patient lowest. The patient with aortic stenosis showed quite high values at a considerably lower work rate. The authors present the data and observations as evidence that the modified work capacity test described has considerable value as a research tool and for diagnostic purposes with cardiac patients.

Newman, F., Smalley, B. F., and Thompson, M. L., "Effect of exercise, body, and lung size on carbon dioxide diffusion in athletes and non-athletes", J. Appl. Physiol., 17:649-55, July, 1962

A group of 11 athletes was matched quite closely with a group of 9 non-athletes and comparisons were made between the two groups for pulmonary permeability to carbon monoxide, carbon monoxide diffusing capacity, heart rate, oxygen uptake, and lung ventilation during rest and work (up to and including maximal oxygen uptake). Athletes exhibited significantly higher maximal values for pulmonary permeability and diffusing capacity, as well as for oxygen uptake. There were indications that the first two parameters could be improved by means of physical conditioning. Athletes tended to show higher values for pulmonary permeability than non-athletes at similar levels of oxygen uptake throughout the range of work.

Newton, J. L., "The assessment of maximal oxygen intake", Journal of Sports Medicine, 3(2-3):164-169, June-September, 1963

The purpose of this study was to evaluate four different methods of assessing maximal oxygen uptake: modified Balke Treadmill Test, Cureton "All-Out" Run, a treadmill test adjusted to the capacity of each subject, and cycle ergometer with similar adjustment to individual capacity. Seven subjects varying in age (19-70 years) and physical conditioning (maximal oxygen consumption, 30-68 ml/kg/min) performed each of the tests. The highest values for oxygen consumption were obtained with either the Balke Test or the adjusted treadmill test. Values obtained with the cycle ergometer test compared quite favorably but, with one exception, were always somewhat lower. Values obtained with the Cureton Test were, with one exception, considerably lower than with the other three tests. The author concludes that, in a laboratory situation, a test involving walking on a treadmill is preferred since maximal oxygen uptake responses are elicited and he feels that it is a more familiar activity.

Plas, F. and Talbot, P., "Electrocardiography in sports medicine: changes in ventricular repolarization observed during physical activity", Journal of Sports Medicine, 2(3):141-151, September, 1962

A group of studies were conducted to determine changes in the electrocardiogram during static and dynamic effort and, also, after bouts of prolonged effort (a day's cycling in a race such as the Tour de France). The modifications found in the EKG following the static effort involved in a Flack Test are held to be important. It was also found that, as a result of training, the T-wave during exercise increases in amplitude. During competition, a variety of changes were found in the ST-segment and the T-wave: ST-segment elevated, T-wave becomes bifid, merging of the ST-segment with the T-wave, and ST-segment remains raised while the T-wave becomes negative. It was also reported that, in cases of abnormal exercise EKG's, prolonged interruption of training is usually sufficient to return the electrocardiogram to normal.

Rose, K. D., "Physiology of running studied by use of radio telemetry", Journal of Sports Medicine, 4:188, 1964

A group of middle distance and distance runners was studied during repetitive 440-yard sprints. Electrocardiograms and body core temperatures were followed during the training sessions by means of telemetering equipment utilizing lightweight transistorized transmitters. Post-sprint decreases in heart rates were accompanied by increased amplitudes of QRS and T-wave amplitudes. "T-wave recovery times" following running were shorter in runners exhibiting better physical condition and this parameter is suggested as a means of evaluating and selecting competitors. Little change in body temperature was observed until after the training session had terminated (no mention was made of the direction and magnitude of the change).

Reynold, A. E., Quigley, T. B., Kennard, H. E., and Thorn, G. W., "Reactions of the adrenal cortex to physical and emotional stress in college oarsmen", New Eng. J. Med., 244:754-762, 1951

Eosinophil levels were used as an indication of adrenal activation in members of a crew team. Measures were obtained before and after practice runs, time trials, and the actual race. Reduction in eosinophils was greatest when there was a high degree of emotional stress. Thus, the time trial and the actual race produced greater reduction than did practice runs at equivalent speeds. Eosinophil reductions by the coxswain and coach were as great as for the crew, although physical work output was much less. The interactions of psychological and physiological stress on adrenal activity are discussed.

Rubenstein, E. H., Braslavsky, M. B., and Von Der Walde, F. E., "Changes in arterial pressure during physical exercise", Acta Physiologica Latino Americana, 13:130-137, 1963

Twenty-four male subjects (average age of 21 years) performed daily exercise on a motor-driven treadmill for 5 to 6 minutes at a speed of 2 to 7 m.p.h., on a grade of 5-15°. Arterial pressure was recorded via an indwelling needle in the brachial artery. Following exercise, each subject performed a Valsalva maneuver for 10 seconds against a mercury manometer. Blood pressure recordings were obtained 5 to 10 minutes before exercise, at the start of exertion, at one-minute intervals during work, and for up to two minutes afterwards. At the start of work, systolic pressure was elevated while no change was found in diastolic pressure. After 10 seconds, decreases were recorded in both, along with a rapid increase in heart rate. Systolic pressure then increased again and reached a plateau, while diastolic pressure remained lower and unchanged. Heart rate and systolic pressure were directly related to walking speed but not to degree of elevation of the treadmill. The return of systolic pressure to resting values was found to be directly related to intensity of exercise, the greater the exercise load the faster the decrease in pressure.

Schlang, H. A. and Kirkpatrick, C. A., "The effect of physical exercise on serum transaminase", American Journal of the Medical Sciences, 242:338-341 September, 1961

The effect of physical exercise on serum transaminase was studied in 27 subjects in the armed forces (average age 21 years). A variety of exercise routines was used: calesthenics, running, rowing, etc. Exercise of a moderately strenuous nature caused marked elevations in serum glutamic-oxalacetic transaminase (but only slight elevations in glutamic-pyruvic transaminase). It was pointed out that confusion exists because of the frequent use of increased transaminase levels for this purpose. Since the study also demonstrated that exercise-induced elevations in transaminase returned to normal within 12 to 16 hours, this could be used to resolve the problem.

Taylor, H. L., "Exercise and metabolism", Chapter in W. R. Johnson (ed.), Science and Medicine of Exercise and Sports, Harper & Bros., N. Y., 1960

The author has interwoven the results of his own research and that from 80 references into a treatise on oxygen consumption and work. Since O_2 consumption is the most widely used measure of energy expenditure, the chapter begins with a discussion of measurement techniques and the principal sources of error (high rates of flow and oxygen debt). Energy expenditure of walking is described in great detail and the dependence on body weight documented. The relatively uniform mechanical efficiency of walking is then contrasted to the large individual differences in running or swimming. Changes in mechanical efficiency of work directly related to changes in blood sugar are described and questions for further research raised. The measurement and implications of maximal oxygen intake are reviewed and the limiting factors (respiration, cardiac performance, and peripheral factors) examined. Work is cited to show that normally respiration is not a limiting factor, that the arterial blood is adequately saturated during maximal oxygen intake. Taylor recommends additional study of cost of breathing as a dependent variable. Changes in cardiac output with exercise for the trained and untrained individual are presented which suggest that it may be limiting only for the untrained. Evidence that peripheral factors are the principal factor limiting maximum oxygen intake is then presented. Oxygen debt is described chemically and individual differences in ability to produce a large debt or high lactate concentration are related to fitness. Metabolic explanations of the rapid and slow phases of oxygen debt payment are not satisfactory, according to the author.

Thorn, G. W., "The adrenals in health and disease", Trans. & Studies Coll. Phys. of Phila., 19:95-113, 1952

A review of the chemical nature of adrenal cortical and medullary compounds and their physiological action is carried out in detail. Hypothalamic-pituitary-adrenal relationships and an example of a physical stress response study are described. The paper provides a rich source of references regarding specific actions of various steroids on selected enzyme systems, organs, and functions. Although a large portion of the paper is devoted to clinical applications and techniques, this information may also be of value in interpreting the results of field stress studies (i. e., effects of oral cortisone treatment wear off in 6 to 8 hours, whereas intramuscular administration may distort measurements for up to 48 hours).

Torelli, G. and Brandi, G., "The components of nervous regulation of the ventilation", J. Sports Med., 4:75-78, 1964

Rate and depth of respiration have been reported to increase as soon as exercise begins. The causes of this rapid response were investigated in three series of experiments with two 22-year old students. It was found that, in fact, the increased ventilation occurred before exercise began in conditioned subjects. This conditioned reflex can be extinguished by nonreinforcement. Without anticipation, the speed of reaction of ventilation changes still exceeded those which can be attributed to a chemical mechanism and was hypothesized to be controlled by a nervous mechanism. The change due to the conditioned reflex was mainly sustained by an increased frequency, that due to the nervous mechanism was essentially sustained by increased depth.

Ulrich, G., "Stress and sport", Chapter in W. R. Johnson (ed.), Science and Medicine of Exercise and Sports, Harper & Bros., N. Y., 1960

The author analyzes the effects of physical and psychic stressors on physiologic functions and certain behavioral correlates. The mobilization of potent humoral compounds by either physical or psychic stress makes it difficult to isolate the magnitude of the physiologic response due to each type of stress when both are present. The effects of psychological stress are described in great detail, both in terms of physiological and behavioral responses. However, the effects of physical activity on psychological functioning, or behavior, are not described. The author concludes that study of the psychic component of the sport stressor is crucial, yet relatively little research has been directed towards this element.

Wolfe, J. B., "The heart of the athlete", Journal of Sports Medicine, 2:20-2, March, 1962

The author presents evidence as to why the term "athlete's heart" should be re-defined so as to remove the implications of malfunction and disease. In studies conducted by the author, he has never observed abnormal cardiac enlargement, myocardial damage, or distorted configuration in an athlete. He cites other studies supporting his general thesis. A suggested modern definition for "athlete's heart" is presented as: "...a better developed, physically more adequate organ which functions more economically than the heart of the physically untrained".

Wyndham, C. H., Cooke, H. M., Munro, A., et al., "The contribution of physiological factors to the performance of moderately heavy physical work", Ergonomics, 7:121-137, April, 1964

The objective of this study was to determine whether physical working capacity (maximum oxygen uptake) or mechanical efficiency are important factors in the determination of the level at which a worker might perform heavy physical labor. The subjects were 28 African laborers working in underground rock stopes. The following determinations were made: maximum oxygen uptake by means of a bench-stepping test, a work performance test above ground that duplicated underground tasks, and the mechanical efficiency while performing underground work. Analysis of the data showed that neither of the two factors was of any importance in determining a person's level of performance. It was concluded that motivation of the individual or the working group was the dominant factor in determining level of performance.