Basketball Research in Fatigue

By

H. C. CARLSON, M. D.

PUBLISHED BY THE
NATIONAL ASSOCIATION OF BASKETBALL COACHES
OF THE UNITED STATES

1945

Basketball Research in Fatigue

By

H. C. CARLSON, M. D.

Director of Student Health and Basketball Coach

University of Pittsburgh

EDITED BY

GEORGE R. EDWARDS

Basketball Coach, University of Missouri

Price $1.00

PUBLISHED BY THE

NATIONAL ASSOCIATION OF BASKETBALL COACHES OF THE UNITED STATES

EDWARD J. HICKOX, *President*

Springfield College, Springfield, Mass.

1945

Dedicated to the
Healthy Structural and Functional
Development of American Youth

COPYRIGHT, 1945, BY H. C. CARLSON, M.D.

FOREWORD

THE tremendous amount of statistical facts gathered for this report would not have been possible without the kindly efficient cooperation of very many wonderful people. The research is based upon sound established physiological facts. It required severe exhaustive physical efforts and intense prolonged periods of clerical work to correlate those figures.

The methods were developed first with the students at the University of Pittsburgh. They were confirmed in many nearby Junior and Senior high schools. Later, they were utilized by College and University basketball teams to set up this work. The Aircrew students at Pitt in their conditioning program offered a rare opportunity in nearly perfect controls. Sound technical advice was offered by capable medical men. The actual direction of the tests was done by athletic men, skeptical but efficient in their operations. The clerks handled an infinite number of figures. Without the help in editing, and the advice and execution of illustrations, this work would never have been published.

We would like to thank here, by name, everyone who helped, but that would be an impossibility. We trust that the men inadvertently missed will feel that they have helped in a big way to discount some of the superficial and unfounded criticisms of aggressive competitive athletics.

Some of the men who conducted these strenuous tests in secondary schools and graciously reported names and figures include the following: Dan Rice of Braddock, Jim Klein of Herron Hill Junior High, Clifford Wells of Logansport, Indiana, Robert Baierl of Munhall, Walter West of Wilmerding, Captain William Palmer and F. Walter Jones of Shadyside Academy. The clerks who handled the statistics of the above tests were former students and basketball players at Pitt and are now in the armed services. They include Captain Mel Port, Lt. Edward Strall, Lt. Edwin Masten and Lt. Larry Paffrath.

Medical advisers included associate doctors George Kowallis, Howard Bolton, Joseph Staley and Paul Zehfuss of the Men's Student Health Service at the University of Pittsburgh. Nurses Lorena Dobrick, Ethel Woomer, Jane McConnell and Dolores

Gregg cooperated in compiling statistics and in the typing. The original college and university varsity basketball teams and their coaches who gave impetus to the task are listed below:

Allegheny College—K. J. Lawrence
Bethany College—John Knight
California Teachers—Theodore Siedle
Capitol University—William Bernlohr
Carnegie Tech—Max Hannum
Carroll College—John Breen
C. C. of New York—Nat Holman
Compton Junior College—Tay Brown
Concordia College—William Ackerman
Creighton University—Ed Hickey
Evansville College—William Slyker
Franklin & Marshall—J. Barn
Geneva College—E. P. Weltner
Georgia Tech—Roy Mundorf
Grove City—John Lovelass
Harvard University—Wes Fesler
U. of Illinois—D. R. Mills
U. of Missouri—G. R. Edwards
Mt. Union College—Robert Wright
U. of Nebraska—Joseph Beech
Northwestern U.—A. C. Lonberg
Niagara U.—John Gallagher
U. of Oregon—Howard Hobson
U. of Pittsburgh—H. C. Carlson
Purdue University—Ward Lambert
Dutch Fehring
Slippery Rock Teachers—
Kerr Thompson
So. California U.—Sam Barry
Syracuse University—Lew Andreas
Temple University—
Ernest Messikomer
Western Reserve U.—Roy Clifford
U. of Wisconsin—H. E. Foster and
Fred Wagner
U. of Wyoming—E. S. Shelton

The tests conducted in ten of the twelve weeks conditioning course of the Pitt Engineers added further evidence of the soundness of procedures. Frank Carver, Charles Hartwig, Bob Hoel, Ralph Mitterling, and Michael Josephs have our deepest appreciation for this particular series.

The wholesome cooperation of everyone in the Pitt Aircrew Training Detachment clinched the validity of the test as a most reliable functional evaluation of physical condition. Major Earl Bartholomew, Captain James P. Smith, and Captain John Grant of the A. A. F. cooperated in this option of army conditioning. Clerks Walter Ridley, Harold Guillaume, John King, John Wooley, and Jack Gilbert handled mountains of figures to rate the deserved accolade of every champion of athletics. The direction of this series was under the able guidance of Stanley Olenn and Robert Hoel, who also directed a program for the Army Specialized Training Reservists confirming the value of the procedure.

With deep appreciation to the foregoing helpers, it must be recorded that this work would not have been reported without the help of two other gentlemen. George Edwards, of the University of Missouri, an outstanding gentleman, coach, and writer, had the patience, energy, and ability to present a winning case against the uninformed. Wendell Gullion of the University of Pittsburgh Press

has advised, tolerated, and labored freely in a project beyond the limits of his position, unrelated to the cause of athletics.

A reliable easily administered fitness test has been developed. The value of hard physical work with sound bodies in competitive athletics has been established factually. Athletics has been justified as part of the school curriculum. The coach is confirmed as a teacher and newer heights of accomplishment have been placed before him. The fundamentals of functional fitness have been crystallized. It is hoped that further good may be derived from this project.

Our inadequate words fail to express our appreciation to all of the contributors.

H. C. C.

March 1945

TABLE OF CONTENTS

PART I—THE PROBLEM EXAMINED

Page

Protests Against Strenuous Athletics....13
The Nature of Fatigue....15
Purpose and Construction of a Fatigue Curve....16
Elements in Test Selection and Standardization....17
Details of Test Administration....19

PART II—STATISTICAL DATA

Confirmation of Fatigue Curve Pattern....22
Condition in Costs and Recovery from Measured Efforts....25
1. Junior High School Series....25
2. Senior High School Series....26
3. Graduate Student Series....27
4. University of Pittsburgh Engineers Series....27
5. Series of Older Individual....33
6. Aircrew Series—Leg Muscles....35
7. Aircrew Series—Other Muscles....37
8. Army Specialized Training Reservist Series....37
9. Shadyside Academy Basketball Team Series....38
10. University of Pittsburgh Basketball Team Series....38

PART III—INTERPRETATIONS OF FINDINGS

Crystallization of Three Coaching Objectives....39
Good and Bad Days....40
Spurters and Pacers....40
Tiredness from True or False Fatigue....42
Physical Fitness a Division of Functional Fitness....44
Player Application and Uses of the Fatigue Curve....46
Health and Happiness Promoted by Basketball....49
Physical Trauma Versus Emotional Trauma....51
Summary of Interpretations of the Fatigue Curve Studies....53

LIST OF ILLUSTRATIONS

Figure No. Page

PART I

VARSITY ATHLETIC GROUP SERIES

1. Three Fatigue Curves of One Individual
   One Individual's Curve of Improvement for Thirteen Weeks 20
2. Three Average Fatigue Curves of the Same Athletic Group
   One Curve of Improvement of the Group for
   Fourteen Weeks 20

PART II

JUNIOR HIGH SCHOOL SERIES

3. Measured Efforts in Fatigue Curves of First and Fifth Tests 24
4. Costs in Heartbeats in Curves of Condition
   for Measured Efforts 24

ENGINEERS SERIES

5. Composite Curve of Improvement
   Over a Period of Ten Weeks 28
6. Declining Composite Curve of Costs in Heartbeats
   Over a Period of Ten Weeks 28
7. The Composite Fatigue Curve of Engineers for Ten Weeks . 29
8. The Composite Curve of Condition for Ten Weeks 29
9. Composite Fatigue Curves of First and Fourth Days
   Showing Increasing Production 30
10. Composite Curves of Condition and Costs in Heartbeats
    For the Production of the First and Fourth Days 30

SERIES OF OLDER INDIVIDUAL

11. Twenty-first and Seventy-fifth Fatigue Curves 32
12. Twenty-first and Seventy-fifth Curves of Condition 32

AIRCREW SERIES—LEGS

13. Composite Fatigue Curves Improving for
    Ten Consecutive Days 34
14. Four Composite Curves of Condition with
    Subsequent Improvement 34

15. Eight Composite Fatigue Curves—
Progressively Improved Production 36
16. Four Composite Curves of Condition.
Progressively Decreased Costs.....36

PART III

17. Sample Fatigue Curves Showing Variations in
Ability and Endurance.....47

PART I. THE PROBLEM EXAMINED

For a decade preceding the outbreak of the present war there was a growing number of persons, claiming some prominence in the field of health, who received wide spread publicity through statements asserting that school and college athletics were so strenuous that participants were damaged physically. These critics submitted as proof for their assertions a few cases of collapse of players, and then demanded that school and athletic authorities reduce the vigor of playing periods and increase the time for rest. Basketball, being both vigorous and popular, was a favorite target of these spellbinders whose campaigns received enough support to force some coaches to "ease up" in their training of players. In fact, a few coaches also became persuaded that the game was too tough for growing boys, and joined in the propaganda to reduce its speed.

Arguments that basketball and other strenuous forms of school athletics harmed too many players were, without exception, based on a small number of individual cases. Careful thinkers usually refuse to draw general conclusions from a few specific cases, but many conscientious people are not careful thinkers. Coaches and other school athletic authorities found this faulty logic difficult to combat and, in addition, were handicapped by lack of scientific facts with which to answer the arguments.

At present there is a noticeable decline in protests concerning the evil effects of strenuous exercise because of war time results in the physical training of soldiers and sailors. Military leaders have maintained consistently that soft living during the last years of peace caused physical deterioration of vast numbers of American youths. Results of medical examinations for draftees sustained their contentions. Four million of thirteen million were rejected as structurally unfit. Too many of the structurally acceptable nine million were functionally unfit. Almost one million of the accepted nine million have been discharged as unusable. With the acceptable young men under their control the commanders of the armed forces immediately established schedules of physical training activities far more rigorous than coaches had ever dared to enforce. The valuable contributions of this conditioning program to the health

of the men and women in the armed forces have been so widely recognized that it would appear that those who insist school athletics have been too exhausting would be silenced forever.

It is well to note, also, that one of the most important divisions of the military physical fitness program consists of the strenuous games long conducted in high schools and colleges. Basketball, the sport formerly condemned because of its health hazards, has been wholeheartedly endorsed by military leaders. The game has been included in almost all training schedules with facilities and equipment provided in camps wherever Americans are stationed.

Soon, though, a welcomed peace will return and, if historical experience is repeated, demands will be heard again that basketball be made less of a physical strain upon the players. Again it will be argued that exhaustive activities damage the organic system, and that training for peace should not be so strenuous as it was for war. The purpose of this research work centers around a desire to find exactly what effects upon the participant may be anticipated in a program of fatigue producing activity. To that end a test was divised which was vigorous and exhausting, and a careful analysis of the accurately recorded results was made. This report of the experiments furnishes the ammunition to combat future campaigns aimed at making basketball an easier game. The study has been sponsored by the National Association of Basketball Coaches, and the expenses for publication were met by a research fund provided by the National Collegiate Athletic Association.

Briefly the project consisted of inducing fatigue in a large number of persons by the use of measurable and controllable series of vigorous work periods. The recorded results covered the time of the effort; production or amount of work done; improvement in production and application through training; and the effects upon the body as indicated by pulse rates. The findings represent the recording of approximately 20,000 cases numbering among them subjects ranging from adolescence to sixty years of age. Specific interpretations of these findings are submitted following the statistical reports, but a general and positive conclusion can be stated now. The results prove that *vigorous physical exercise, properly graduated and conducted in the presence of health, is not harmful, but actually is a medium which develops in the individual a capacity to do larger amounts of work with less discomfort.*

The Nature of Fatigue

The condition of fatigue is so familiar that explanations concerning it hardly seem necessary, but since the term is often indefinite and inexact in its use a brief review of the topic and of the meaning employed in this report is attempted.

Simply stated, fatigue is that condition induced by work which results in a diminished capacity for work. The mass of scientific data dealing with the types of fatigue; the symptoms and causes; organic and chemical changes which take place in the body; and the effects of such factors as disease and environment is too lengthy and complex for comprehensive presentation here. As a background, though, it seems wise to summarize some of the general facts proved by careful investigators in the field.

1. Regardless of the type of work undertaken, the fatigue which results from it is both specific and general. Not only are the muscles and organic systems actively engaged in the effort strongly affected, but the whole individual becomes involved, including all of his body and his mental processes as well.

2. As fatigue products increase due to continued work, all voluntary muscular contraction becomes slower and less intense.

3. Extension of the work period ultimately develops fatigue products of an amount sufficient to cause complete cessation of the effort. Should one possess enough will power or emotional drive to attempt continuation of work after maximum fatigue is reached exhaustion or collapse ensues and all voluntary muscular control ceases. Collapse, however, may be likened to a fuse in an electrical circuit in that it cuts off the flow of energy before damage to more important installations can be done. In other words, fatigue is one of nature's most effective mechanisms of self-preservation because it institutes inhibitions well within the bounds of safety.

4. The onset of fatigue is postponed; its inhibitions reduced; and recovery hastened when one is conditioned to the task. This means, of course, that frequency and regularity of vigorous activity builds organic and muscular systems which both resist the onset of fatigue and allow quicker recuperation from its effects.

5. Rest is the best and only certain cure for fatigue. Prolonged rest, though, tends to counteract the conditioning developed by exercise. A capacity to perform hard work over an extended period of time is the goal of physical fitness programs. It is achieved by

graduated periods of vigorous effort and rest which follow each other in fairly rapid succession.

This study sought to eliminate subjects suffering from ill health, and to provide approved hygienic surroundings for participants in the tests. The presence of illness or disease, or exercise in an unhealthful environment, encourages the production of fatigue materials in the worker, and adds complex factors which are not to be considered in this report. It is assumed that vigorous physical activity, like the playing of basketball, will be limited to those in good health. Treatment and care of those unsound in body are the responsibilities of experts in the medical and allied fields. It has been pointed out that most of the examples of players damaged by school athletics involve persons whose health was poor at the time of participation, and who should have been on the sidelines or in bed.

The supervisor of hard work and the coach of athletic teams, however, must assume some responsibilities in the fields of health and hygiene. Proper administration of the activity requires the elimination of the ill by thorough medical and physical examinations given by qualified experts. In addition, the coach or supervisor should see that the surroundings are healthful and that such environmental influences as temperature, lighting, ventilation, and sanitation meet high hygienic standards.

Purpose and Construction of a Fatigue Curve

A fatigue curve of performance is simply a graphic representation showing accurate comparisons of the amounts of work done in a succession of work periods of prescribed duration. The curve is a pictorial method of presenting for easier interpretation the scoring data compiled in a series of tests, and is commonly used in statistical studies.

Such a curve could be plotted, for instance, by counting the number of bricks thrown from a wagon in a series of work periods of uniform length and conditions. The subject, we will say, is charged with throwing out single bricks as fast as possible for ten seconds; then rest for ten seconds; and repeat throwing and resting for ten consecutive periods or innings. With conditions established which require the same effort on each throw, and assuming the worker puts forth maximum effort during each period, the develop-

ment of fatigue will cause gradual reductions of the number of bricks thrown in each successive inning. For example, if he unloads forty bricks in the first inning he will have less energy for the second and may throw only thirty-eight. The numbers mentioned are merely illustrative, the intention being to show a fact proved by many experiments that strenuous physical efforts result in lowered production. The number thrown in each inning is entered on a chart, and the points connected by a line which gives a curve showing the effects of fatigue upon a single worker in one test.

Elements in Test Selection and Standardization

Since bricks are neither readily available nor does their throwing have any counterpart in basketball it was necessary to choose a skill commonly used in vigorous games. It seemed wise, also, to select a type of activity which would involve muscles already conditioned by frequent use in order to avoid undue discomfort for the subjects. In addition, the movement should be one lending itself readily to standardization and to accurate measurement.

For the experiments, therefore, the choice fell upon spot running since the leg muscles normally are well conditioned; similar footwork is found in basketball; the activity is vigorous, and the effort can be measured easily and accurately by counting the number of times the right foot contacts the floor. As ultimately established, each participant was checked during ten innings in which he alternately ran in place for ten seconds and rested for ten seconds. The number of right foot contacts was recorded for each inning; and the total contacts for ten consecutive innings constituted an individual's "production". Most subjects repeated the test a number of times. The scores made in these repetitions, it will be noted, showed increased production, and thus demonstrated the effects of training and development of mastery of the exercise.

After selecting the skill and deciding upon administrative procedures and regulations, the next step consisted of establishing the pattern of a 100 per cent fatigue curve as a basis for comparison. If the runner applied himself and performed with maximum energy in each period, as was requested, the development of fatigue products would cause a decreased score in the following period.

A 100 per cent fatigue curve may be produced, then, only when the number of foot contacts decreases in each successive inning.

Should the subject fail to put forth his best effort,—"go all-out" —in any one inning that failure would be apparent by no score decrease in the next period. In fact, a self-imposed easy session usually is followed by one with an increase in foot contacts. Lack of steady decrease in scores indicates an error in "application" by the runner, and shows that there are inhibitions operating within him guarding from overwork. In calculating these errors 10 per cent is subtracted for each period in which no decrease in score occurs. Thus, a 90 per cent fatigue curve indicates that the runner failed to do his best in one period.

After the pattern of the 100 per cent curve was established in preliminary tests, it was found that repetitions of the test could be used to measure improvements in Production and Application. That is, when a subject later repeated the test, his production record tended to increase. The improvement could be charged to mastery of the skill, to more intense application, or to better physical condition developed by the previous test. Of the three possibilities it was found that the improvement in production resulted almost entirely from better condition brought by the training.

The next and last step was to measure how much these vigorous work periods affect the various organic systems of the participants, and whether or not any of them had been damaged. In this measurement time did not allow complete examination of all vital organs, but since the actions of the heart give accurate indications of physical fitness the pulse rates were recorded. Physical fitness is more than an ability to execute a skill; it involves an ability to recover rapidly from the effects of fatigue. Pulse rates taken just before a measured work period, and for several periods immediately after the effort give a true picture of the speed of recuperation. A series of individual fatigue curves combined with pulse records, thus can be used to measure amount of effort; to note improvement of production and application; and to show the effects of exercise upon physical condition.

In these tests the heart rate was recorded before the subject began spot running and immediately upon ceasing. Then additional pulse recordings were made after two, four and six minutes of rest. The statistical data collected show clearly that regulated

periods of strenuous physical activity such as is common in school athletic programs results in improvements in condition or endurance, production, and application. Stated in a negative manner: Strenuous exercise given under proper supervision does not harm the healthy participant.

Incidently, the data obtained in these experiments crystallized specific objectives in other aspects of basketball coaching by supplying information concerning good and bad days; spurters and pacers; progress and regress; true and false fatigue; functional fitness; physical and emotional trauma. These topics will be treated more fully in Part III dealing with interpretations of test results.

Details of Test Administration

The only equipment needed consisted of pencil and paper for each subject and a stop watch, or watch with a second hand, for the supervisor. A brief explanation of how spot running is done followed by a demonstration by the director preceded the first test. The subject then performs a preliminary trial to facilitate the coordination of action and the count.

To obtain a uniform start of all participants the supervisor may call, "Five seconds to go", "Four", "Three", "Two", "One", "GO". The subjects will soon adopt action indicative of each individual and the curves will be authentic. The work period is ten seconds long, and is terminated by the director's command to "Stop."

Each subject silently counts the number of times his right foot contacts the floor during the ten second period. This is followed by ten seconds of comparative rest during which interval the subject records his score on his paper, and assumes position for the second work period which is started and conducted as was the first.

After several preliminary innings of work and rest the director explains that "speed" is the index desired, and reiterates that "speed" and "more speed" is wanted. Then, a sample test is run for ten innings with speed continuously emphasized by the instructor and repetitions being called for when the scores indicated less than maximum effort was being expended.

Papers are collected after this preliminary test and individual fatigue curves are plotted. The difference between the fastest and the slowest periods are noted as well as erratic and indifferent per-

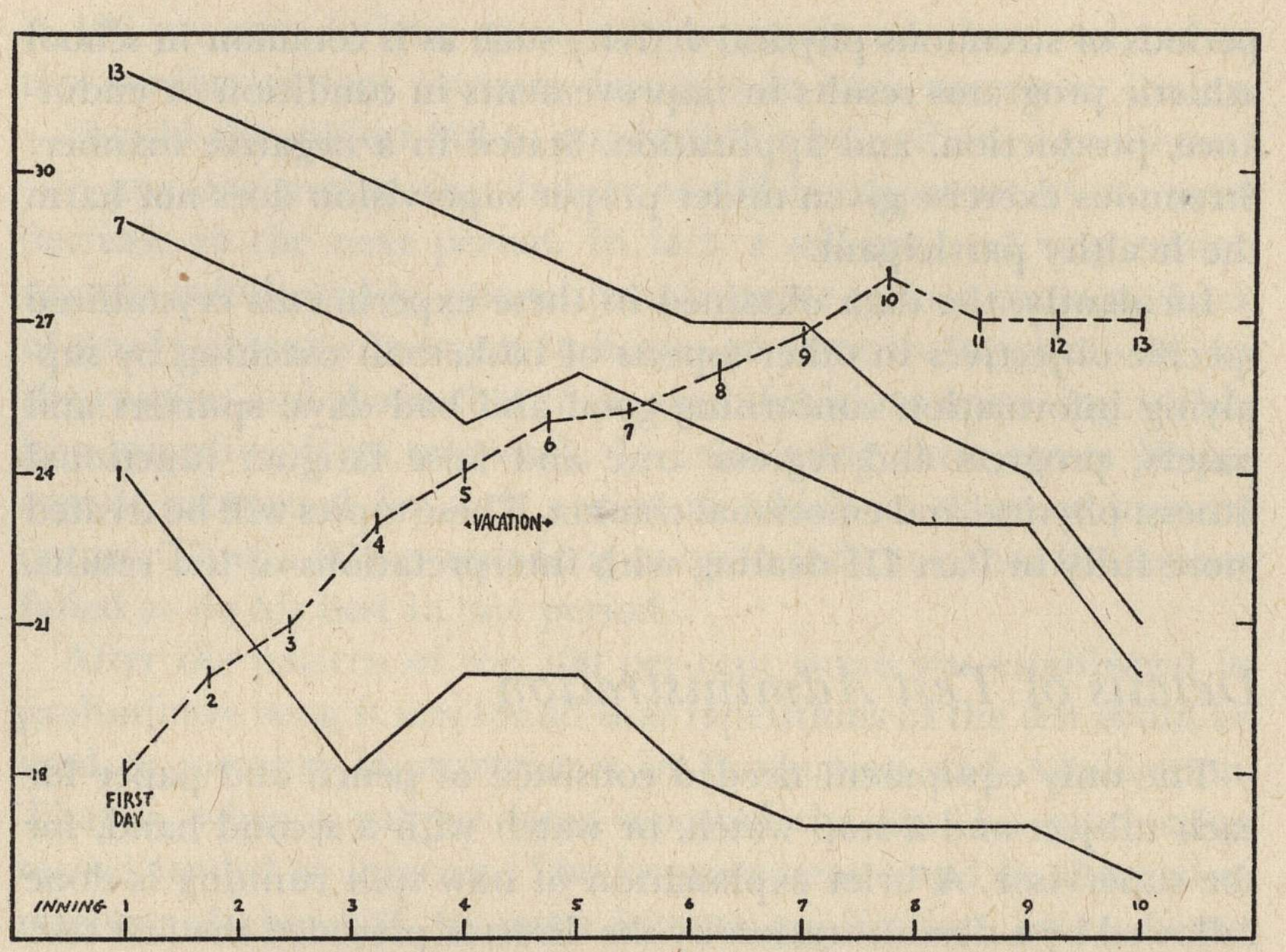

Figure 1. Three Fatigue Curves of One Individual and One Individual's Curve of Improvement for Thirteen Weeks.

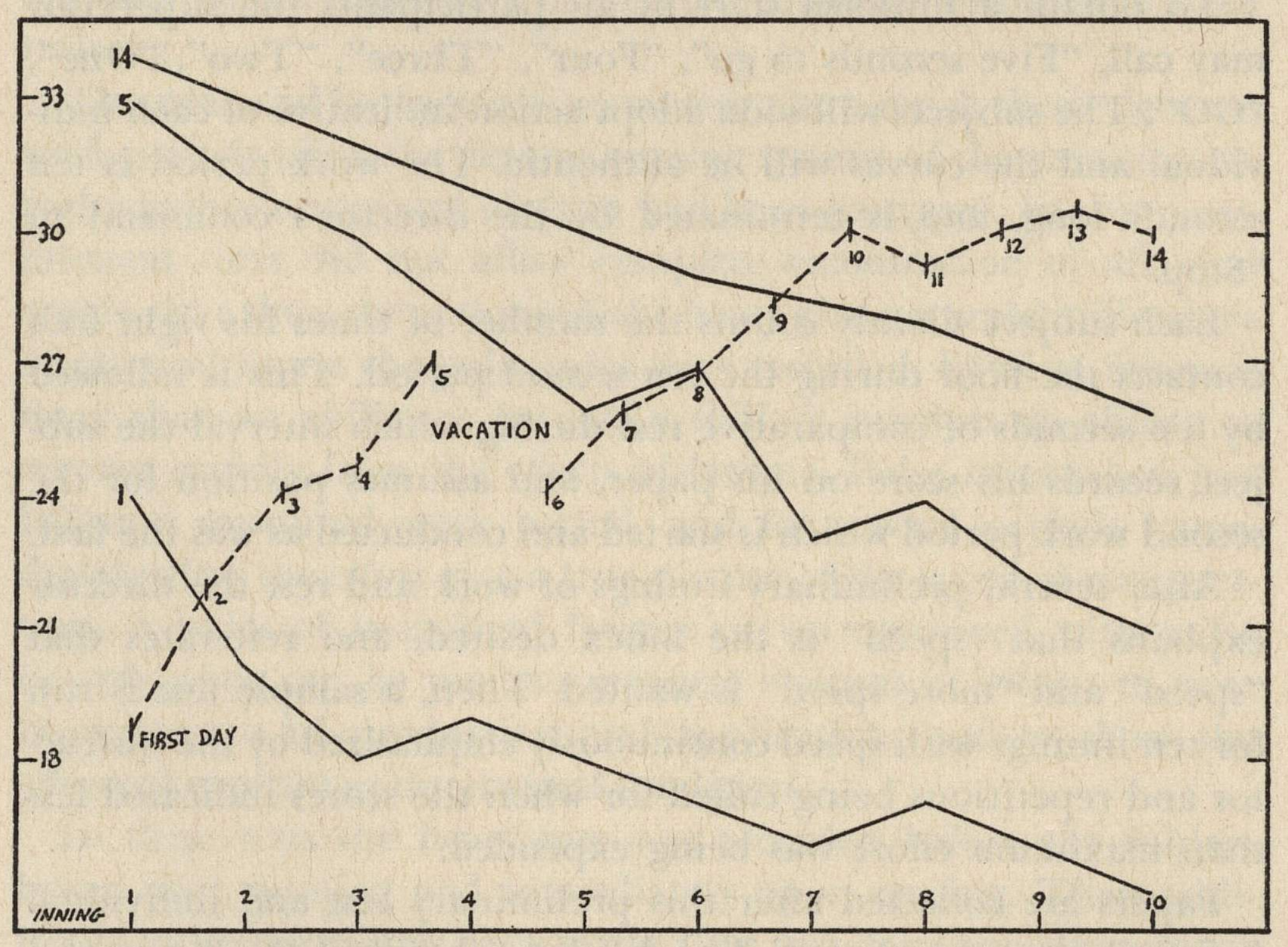

Figure 2. Three Average Fatigue Curves of the Same Athletic Group and One Curve of Improvement of the Group for Fourteen Weeks.

formance. When the graph indicates need of more application a discussion between the tester and subject is indicated. The way is often paved for instruction, inspiration and improved application. With repeated fatigue curve production there comes a smoothening out of the curves as the subject learns to apply himself.

Counting of pulse rates, like that of foot contacts, was done by the subjects. By use of a 3-2-1 starting signal each subject felt of his pulse and counted heart rates for ten seconds. Multiplication by six gave the minute heart rate. A ten second check of the pulse was made just before the first work period. Another check followed the tenth period; and additional checks were made at two, four, and six minutes after work ceased.

Samples of fatigue and improvement curves are shown here in Figure 1 for the purpose of illustration. The subject was a high school football player who was so much larger than most of his opponents that he seldom was called upon for "all out" effort. The habit of partial effort he developed was reflected in the first fatigue test. The first curve shows that he worked hard for two innings; then loafed for two periods; and finished with a production which clearly indicated that he had not done his best. His seventh curve showed he had moved towards the goal of consistently doing his utmost. The "Curve of Improvement" shown here is composed of the averages of fatigue curve performance compiled in the series of tests given this individual.

PART II. STATISTICAL DATA

SIMPLE instructions for the production of fatigue curves were forwarded to members of the National Association of Basketball Coaches. Results were received from thirty nine teams presenting one fatigue curve from each of 496 varsity basketball players. The tests had been given by different directors under different circumstances of grasp, interest, and accuracy.

The players, conditioned to basketball competition, demonstrated their particular and aggregate average approach and execution to an assigned task as shown in the following table. The inhibiting effects of fatigue become apparent in the figures of each team and the aggregate of all teams. The italic numbers present errors of application but the general pattern of declining

COLLEGE	No.	Inning 1	2	3	4	5	6	7	8	9	10	Application
Allegheny Col.	11	366	318	300	*306*	289	279	*282*	278	*284*	286	60%
Bethany	14	600	*641*	593	548	502	*520*	491	*561*	*518*	*514*	50%
Calif. Teachers	10	223	*226*	215	200	195	182	*186*	171	*182*	*178*	60%
Capitol U.	12	339	314	*316*	313	295	*297*	291	*291*	*296*	*302*	50%
Carnegie Tech	7	278	255	*263*	243	232	206	*231*	*228*	*229*	*208*	50%
Carroll Col.	16	642	581	578	569	534	533	526	*548*	*526*	*587*	70%
Cedar Rapids C.	10	*342*	377	372	*377*	359	*363*	*359*	*367*	*370*	*363*	30%
C.C. N.Y.	10	331	*338*	320	*370*	*354*	*321*	*338*	*339*	*333*	304	30%
Compton Jr. C.	9	213	*222*	209	206	*207*	203	194	*218*	*217*	*217*	50%
Concordia C.	16	362	*368*	349	*360*	340	335	*357*	322	314	*332*	40%
Creighton U.	12	339	310	299	284	280	272	*275*	*272*	264	*276*	70%
Evansville C.	12	319	316	307	296	*302*	289	286	*294*	*289*	*309*	60%
F. and M. C.	11	373	*374*	358	304	276	275	245	227	*230*	*227*	70%
Geneva	15	556	541	*637*	*584*	530	511	*526*	*525*	*518*	*539*	40%
Georgia Tech	8	241	231	226	223	202	197	187	*191*	181	175	90%
Grove City C.	11	375	*382*	*376*	368	*374*	356	351	*351*	*353*	347	50%
Harvard	10	264	250	*255*	234	229	*234*	228	224	*232*	*258*	60%
Ill. St. Norm.	16	376	368	348	332	314	*317*	311	*317*	*327*	*354*	60%
Illinois U.	15	592	546	535	476	463	452	438	*451*	*442*	*466*	70%
Missouri U.	16	449	429	405	373	356	349	*379*	*353*	*357*	*351*	60%
Montana S.	9	298	294	*298*	270	242	*249*	233	230	*255*	*257*	60%
Mount Union C.	20	827	*886*	829	826	*826*	*851*	*849*	812	*901*	*816*	40%
Nebraska U.	16	*352*	393	383	379	337	329	*335*	*339*	*340*	*386*	50%
Niagara U.	13	511	463	439	394	384	378	*384*	377	371	*385*	80%
Northwestern	16	425	383	372	354	341	315	304	*309*	279	*305*	80%
Ohio Northern	16	373	310	297	*336*	*337*	*316*	*331*	*326*	*329*	*319*	30%
Oregon U.	12	367	337	336	314	313	296	*301*	*312*	*317*	*317*	60%
Pittsburgh U.	12	291	276	270	253	247	*252*	229	*235*	*243*	*239*	60%
Purdue U.	16	438	*440*	410	400	382	373	363	358	354	344	90%
Slippery Rock	13	303	287	267	261	257	252	*257*	*252*	248	*251*	70%
So. Calif. U.	10	276	266	254	250	233	*233*	225	*229*	*234*	*227*	60%
So. Ill. Norm.	19	649	645	616	578	573	544	540	*542*	*541*	*544*	70%
Syracuse U.	16	782	766	718	674	637	606	*609*	595	574	*631*	80%
Temple U.	15	*372*	*378*	391	388	385	383	373	363	355	348	80%
West. Ontario	6	125	118	115	110	*117*	*114*	*111*	109	*114*	*120*	50%
West. Reserve	10	294	269	262	246	241	*245*	*248*	*252*	*253*	*249*	50%
Wisconsin U.	5	*120*	131	128	119	108	*108*	103	101	*108*	*111*	60%
Wooster Col.	15	446	388	339	329	*331*	311	308	*343*	*308*	*332*	60%
Wyoming U.	16	449	437	*442*	*440*	434	403	*423*	*410*	*429*	*438*	40%
	496	15278	14864	14427	13887	13358	13049	13007	*13022*	*13115*	*13212*	70%

returns is apparent. The preponderance of errors in the later innings fits the established picture of increasing errors in the presence of fatigue.

Another sample illustrates how a group improves through application and conditioning. Charted in Figure 2 is the composite curve first produced by a squad of University of Pittsburgh varsity athletes; similar curves are produced in the fifth and fourteenth tests; and the curve of improvement which shows the progress made in fourteen weeks. Toward the end of the series there were individuals who produced 100% application curves. The aggregate of all days for all individuals and groups helped to prove the pattern of fatigue curves of the physiology laboratory tests. The italic numbers indicate errors of application.

Phys. Ed. Class No.		Inning 1	2	3	4	5	6	7	8	9	10	Application
*1st day	9	214	183	169	*172*	167	159	155	*157*	*155*	152	70%
2nd day	12	313	303	288	256	*264*	*262*	247	*250*	*252*	233	60%
3rd day	9	256	239	232	220	218	211	210	206	199	*200*	90%
4th day	13	379	365	345	323	*325*	315	300	297	289	274	90%
*5th day	15	496	466	451	421	407	*409*	371	*374*	359	337	80%
After Vacation												
1st day	13	356	353	338	323	*331*	313	304	297	282	276	90%
2nd day	6	181	173	171	164	161	159	153	145	137	135	100%
3rd day	13	407	395	380	363	356	341	330	321	*323*	309	90%
4th day	10	331	311	309	291	289	285	276	264	263	253	100%
5th day	11	382	363	*364*	341	332	324	312	302	*310*	294	80%
6th day	9	294	*294*	271	*271*	266	265	257	243	239	224	80%
7th day	11	370	367	356	335	331	324	321	309	304	295	100%
8th day	12	407	*407*	382	368	*375*	356	342	*354*	329	320	70%
*9th day	13	451	434	420	409	391	384	376	365	357	309	100%
	944	28161	27445	25617	*25730*	25059	24413	24153	23947	23660	23389	90%

* Plotted in fatigue curves on Figure 2.
Average daily Production plotted in the curve of Improvement.

Totals by innings of all days show a 90% Application Curve.

It does not appear entirely a coincidence that the most successful athletes in the foregoing series had the best fatigue curves in production and application. Further the best athletes appeared to improve better than the less successful athletes.

Three particular athletes will be cited by name in the above series. Cosgrove, a swimmer; Rhoades, a polevaulter; and Guadanangi, a catcher, produced erratic curves at first. Later they produced better curves with 100% Application. The first two broke previous records after they had reached the higher quality of fatigue curve. The last developed better than had been anticipated by himself or coach. As the quality of their fatigue curve dropped, so did their other performance. This is not the place for philosophical discussion, and for the present we shall merely state that those

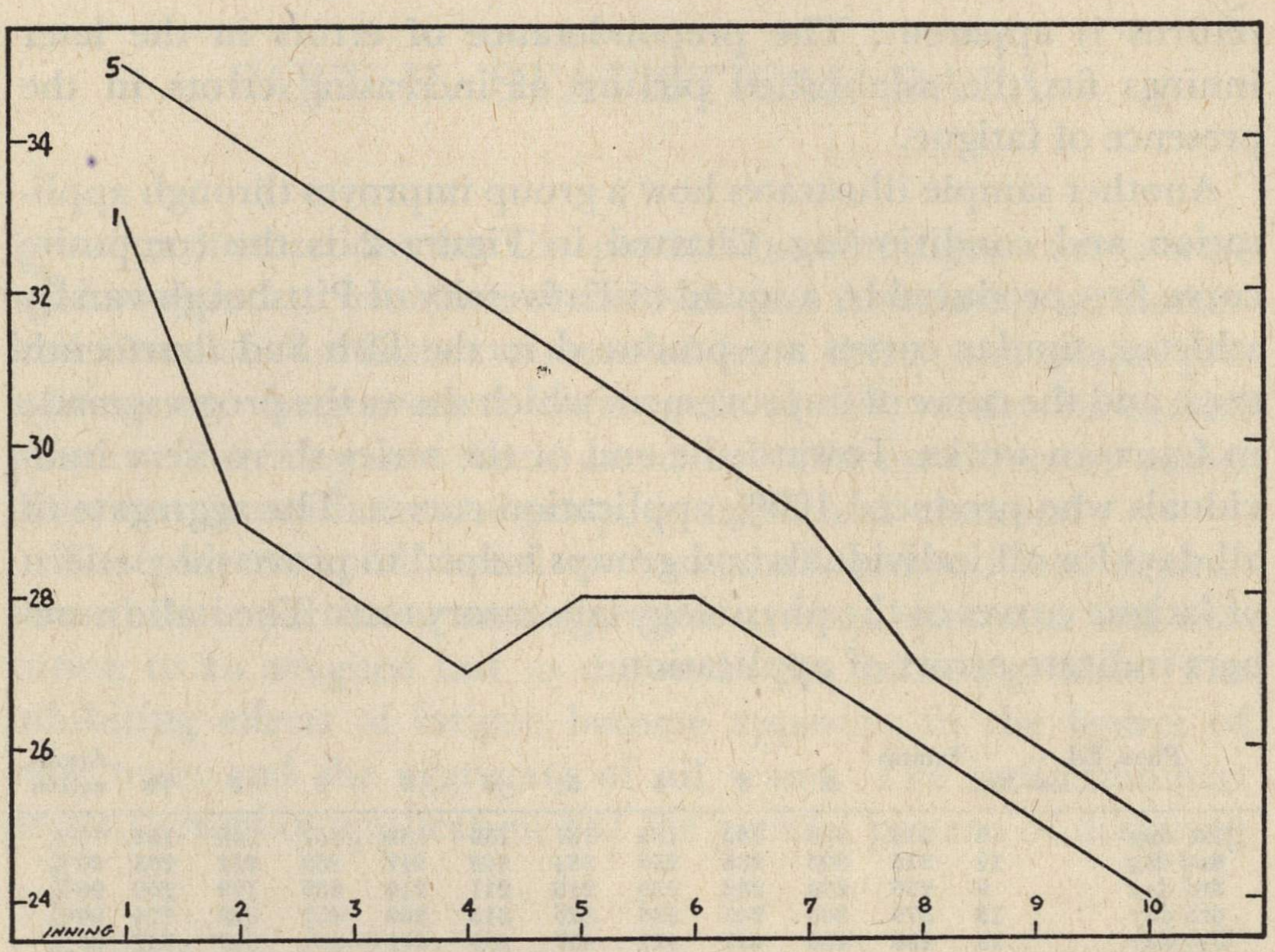

Figure 3. (Junior High School Series) Measured Efforts in Fatigue Curves of First and Fifth Tests.

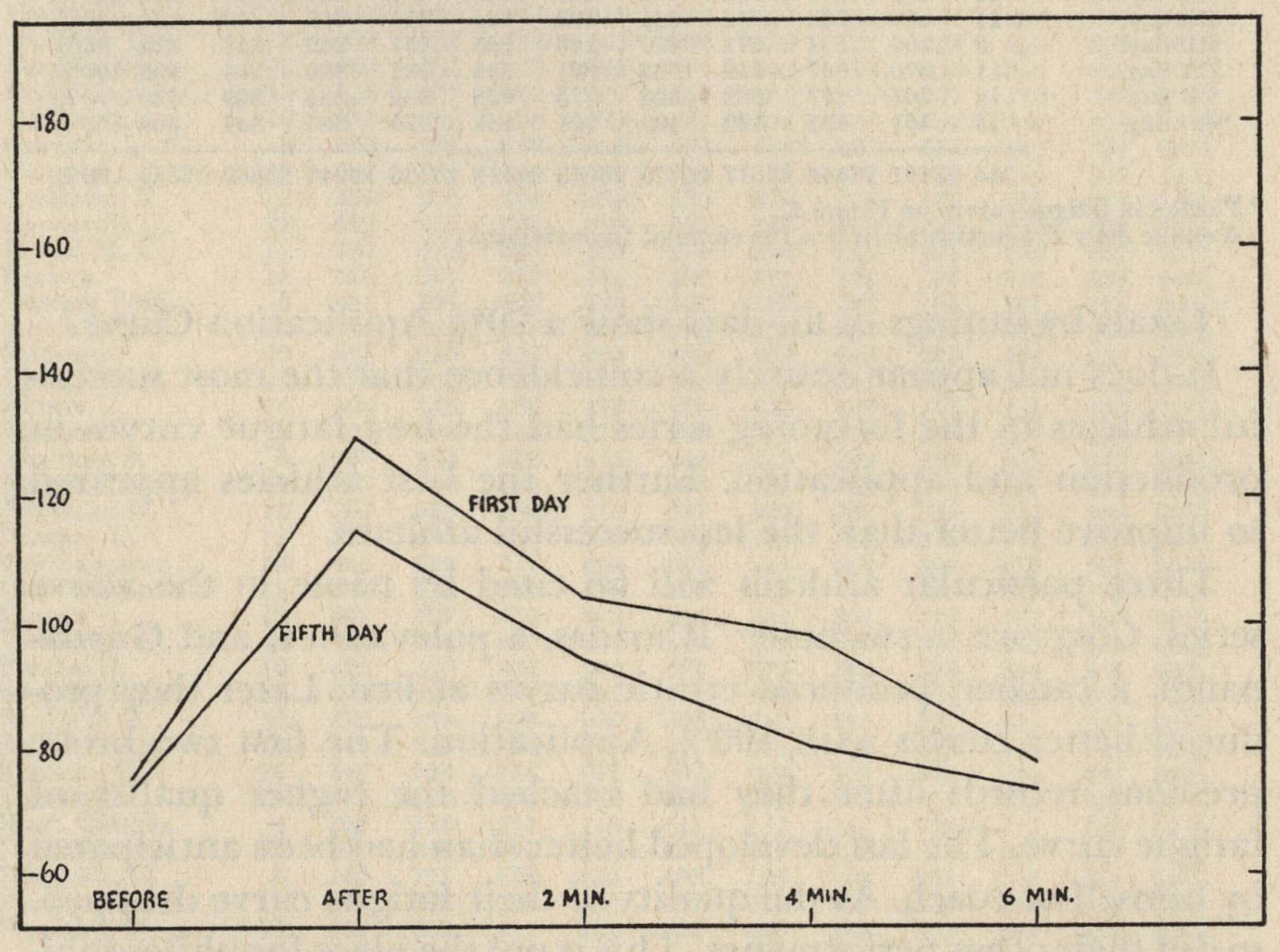

Figure 4. Costs in Heartbeats in Curves of Condition for Measured Efforts Shown in Figure 3.

participants actually did improve concurrently with the improvement of their fatigue curve. Edgar Jones, a great athlete in high school, college, and later in the Army, consistently ran good application curves with some at 100% in this series.

Condition in Costs and Recovery from Measured Efforts

The fatigue curve has been established as a medium to measure efforts and Application. The Costs of those efforts and the time and degree of recovery can be evaluated by heartbeats as determined by pulse rates.

A series of fatigue curves for measured Production and Application and the accompanying Costs was run in different age groups over varying periods of time. There was a continuity of progressive Production in each of the series. The results of each day and the effects upon successive days may be noted in the various occasions of operation.

1. Junior High School Series—Training and Conditioning

A series of fatigue curves produced by Munhall, Pennsylvania, Junior High School under Robert Baierl. Fifteen students each produced a fatigue curve daily for five successive days. Their pulse rates were recorded before and after each curve to evaluate condition.

The fatigue curves followed the usual pattern of less returns with increasing fatigue. Below are the figures of the first and fifth days which are plotted into a typical graph in Figure 3. The averages of all participants are listed by innings to record Production and Application.

Innings	1	2	3	4	5	6	7	8	9	10	Production	Application
First Day	33	29	28	27	*28*	*28*	*27*	26	25	24	278	70%
Fifth Day	35	34	33	32	31	30	29	27	26	25	301	100%

The first day's average Production was 278 with Application of the group at 70%. After four days of training, conditioning, and practice, there was a greater average Production of 301 and better Application to 100%.

The pulse rates, indicative of heart and circulatory action, were taken before the production of the fatigue curve, immediately

afterward, after two, four, and six minutes of rest in order to determine CONDITION.

Pulse Rates	Before	Immediately after	After 2 Min.	4 Min.	6 Min.	Sum or Index
1st day's average	78	131	105	98	82	494
5th day's average	75	113	90	80	75	433

The lessened number of heartbeats to do more work in a standardized pattern indicates that it costs less to do more when training and conditioning have increased Production. When the five pulse rates add up to less than 450 it is a sign of good conditioning. The factor of less heart beats is generally a sign of better condition. The time of complete recovery of the original pulse rate is more indicative of good condition. As will be noted in Figure 4, there is comparatively more recovery in the first two minutes of rest than there will be in the next half hour. This indicates the need of frequent short rest periods with spurt periods of work leading to greater development and improved function.

The average Production of each day paralleled with the average pulse index of that day can be plotted into a curve of improvement. The Production or the number of foot contacts go up. The costs in heartbeats go down. At the end of the fifth day Production is up 8.27% and the Costs are down 12.34%.

	1/5/43	1/6/43	1/7/43	1/8 A.M.	1/8 P.M.	
Production	278	283	297	298	301	up 8.27%
Costs in Pulse Rate	494	475	455	448	433	down 12.34%

2. *Senior High School Series of Fatigue Curves 1943—Training and Conditioning*

Twenty athletes of the Wilmerding, Pennsylvania, High School, under Walter West each produced a fatigue curve daily for ten days to aggregate 200 fatigue curves. The average figures, inning by inning, for the entire period offer further support to prove the fatigue curve an instrument of measuring effort to demonstrate declining returns. The average Production of 200 different curves 1/20 to 2/2/43 by innings is given below and results in a perfect fatigue curve.

Innings	1	2	3	4	5	6	7	8	9	10	Production	Application
Average Repetitions	45	44	43	42	41	38	37	36	34	27	387	100%

This series of fatigue curves of twenty Wilmerding High School basketball players are again reviewed to go further than to merely

confirm the fatigue curve as a measure of Production and Application. Average Production has been noted in sequence by innings above. Pulse rates as an index of condition were taken before the production of the fatigue curves, immediately afterwards, after two, four, and six minutes rest. The average sum of pulse rates per curve are listed below with the average Production of each day. They could be plotted into a curve of improvement with Production up 62.72% and Costs down 5.52%.

	1/20	1/21	1/22	1/23	1/26	1/27	1/28	1/29	2/1	2/2
Production up	279	339	366	372	380	410	426	433	438	454—62.72%
Costs—Pulse rate down	471	473	498	500	481	494	489	493	464	445— 5.52%

3. *Graduate Students Series of Fatigue Curves*
June 15 to June 24, 1942

Thirty individuals, male and female, seventeen up to sixty years of age, each one curve daily for ten days—300 curves demonstrate

1. Decline of efforts because of fatigue.
2. Increased Production with better training.
3. Better conditioning with fewer heart beats and shorter recovery time.

Below is found listed the average repetitions of 300 curves inning by inning.

Inning	1	2	3	4	5	6	7	8	9	10	Average	Curve
1. Average	30.3	28.9	27.5	26.0	24.9	24.2	23.3	22.4	21.4	20.5	249.4	100%

	June 15	16	17	18	19	22	23	24	25	26		
2. Production up	220	235	238	252	246	250	254	263	258	271	up	23.36%
3. Heartbeats down	562	555	553	541	538	540	535	545	548	526	down	6.41%

4. *University of Pittsburgh Engineers—*
Tested Weekly—Ten Weeks

The tests in the physical conditioning course for 570 Pitt Engineers during the summer session followed the established patterns. After the first two weeks the students were enthusiastic about the benefits. To get actual figures, the Tuesday afternoon group, with fifty four participants, was given the fatigue curve tests for ten different weeks. This could be considered a good cross section of all participants. Two factors, Production and Costs, were plotted into the curves of improvement shown in Figures 5 and 6. Each student produced his fatigue curve in each test for Production.

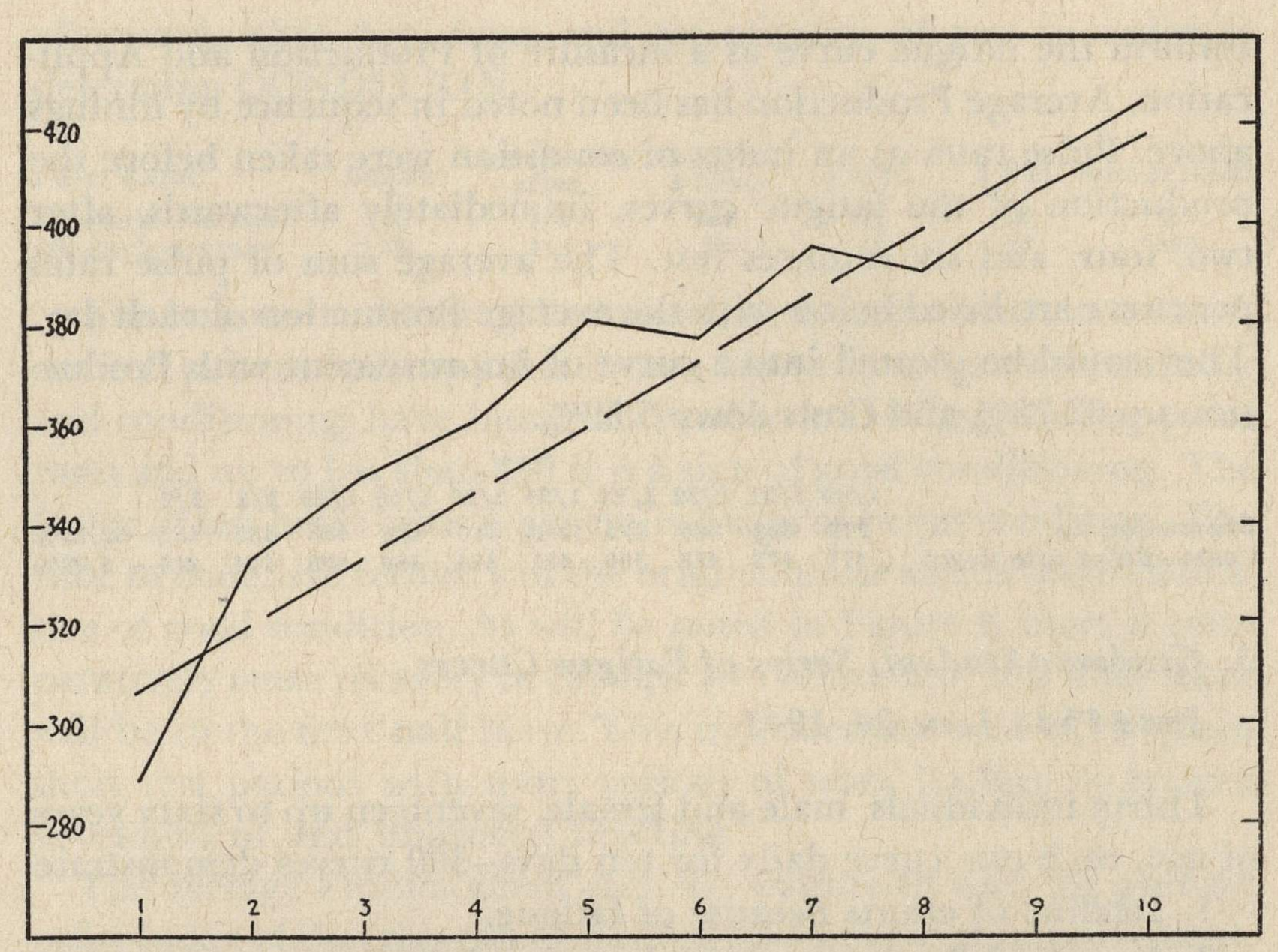

Figure 5. (Engineers Series) Composite Curve of Improvement Over a Period of Ten Weeks. The average of production is the average of measured efforts produced in the fatigue curves of each day.

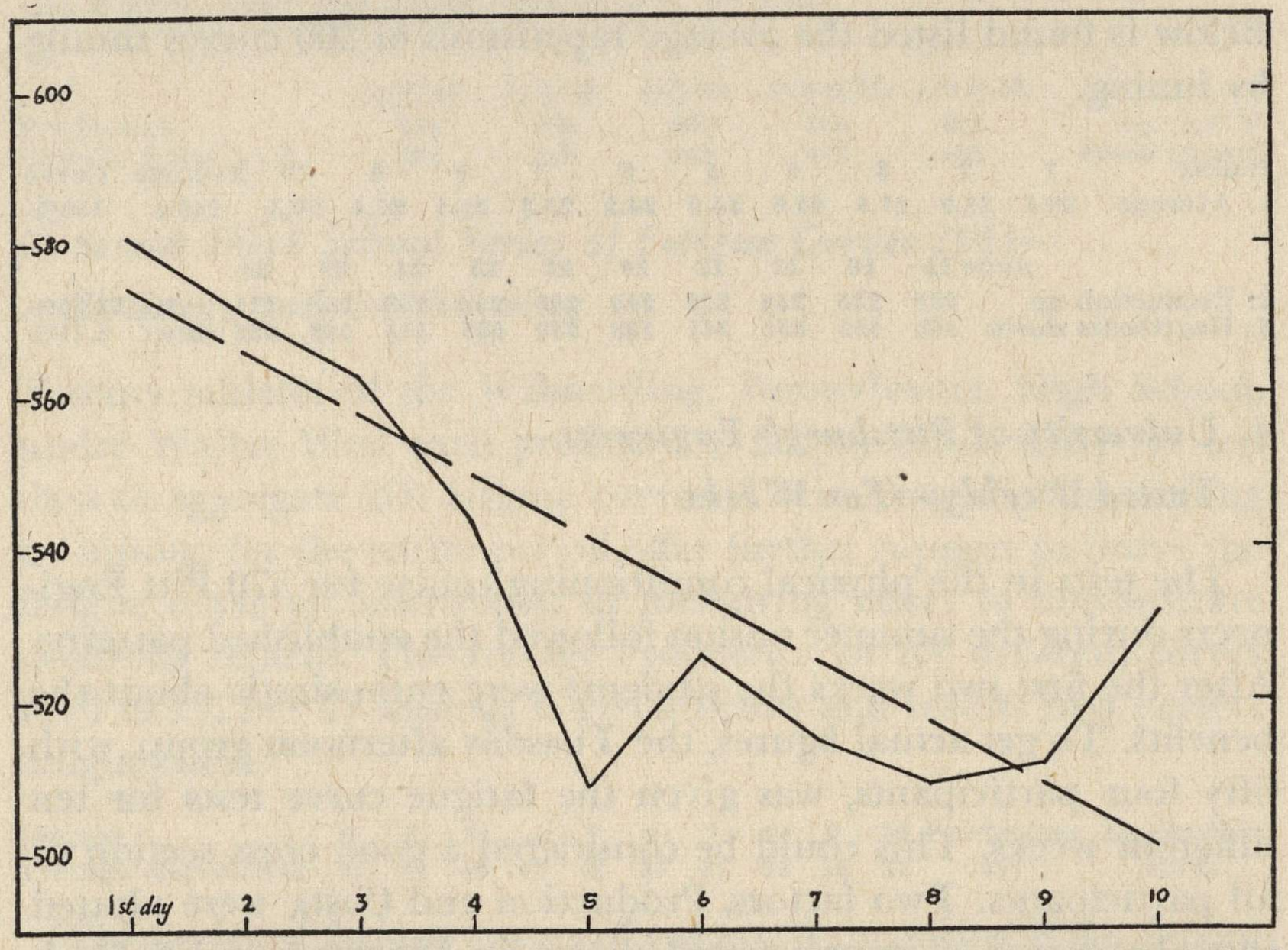

Figure 6. Declining Composite Curve of Costs in Heartbeats Over the Period of Ten Weeks Shown in Figure 5. The averages are taken from the curves of condition which are plotted from five different pulse rates, taken immediately before the production of the fatigue curve, immediately afterward, after two, four, and six minutes rest.

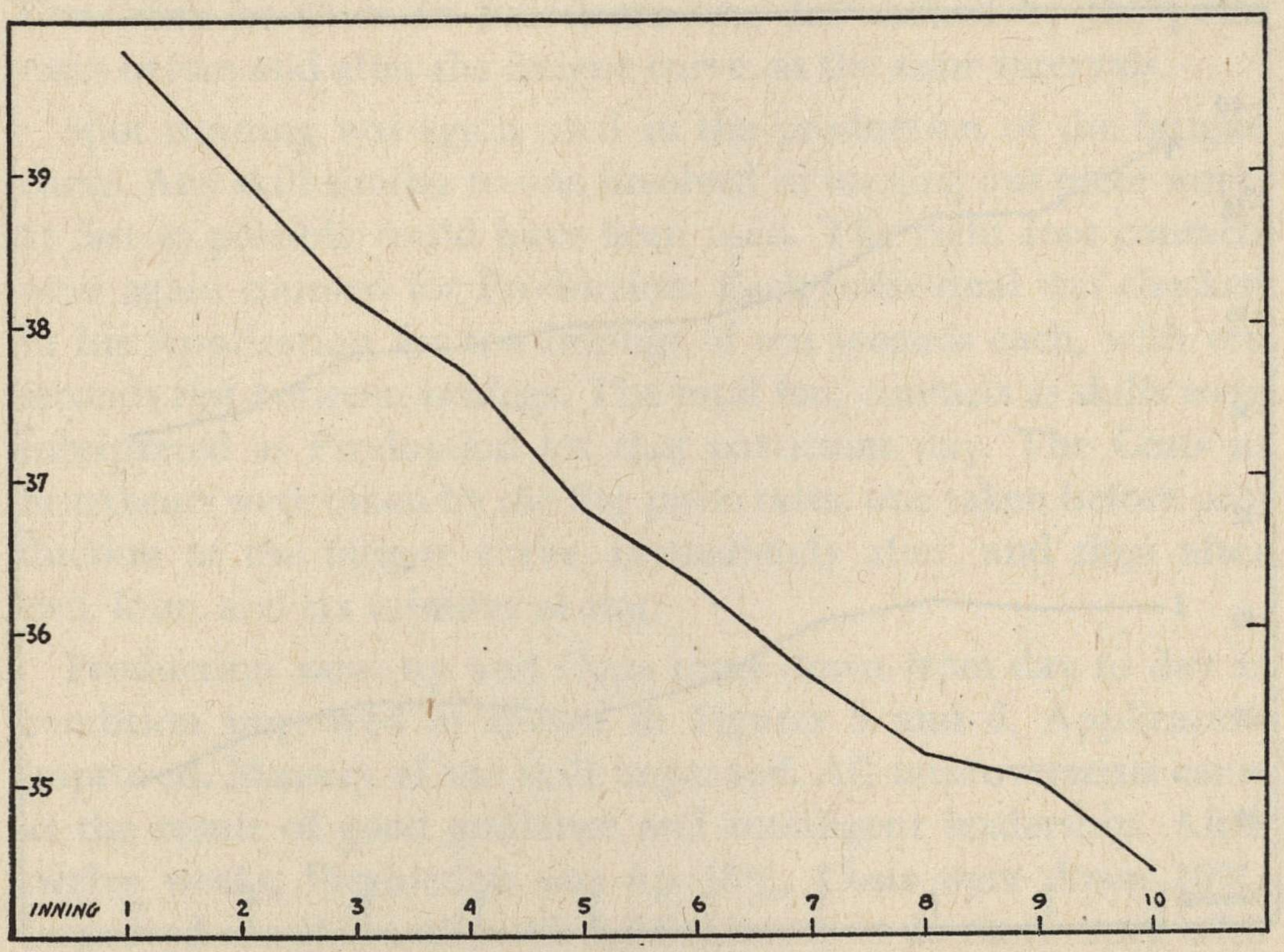

Figure 7. (Engineers Series) Composite Fatigue Curve of Engineers for Ten Weeks. The fatigue curves of each day in ten weeks efforts are plotted inning by inning for ten innings.

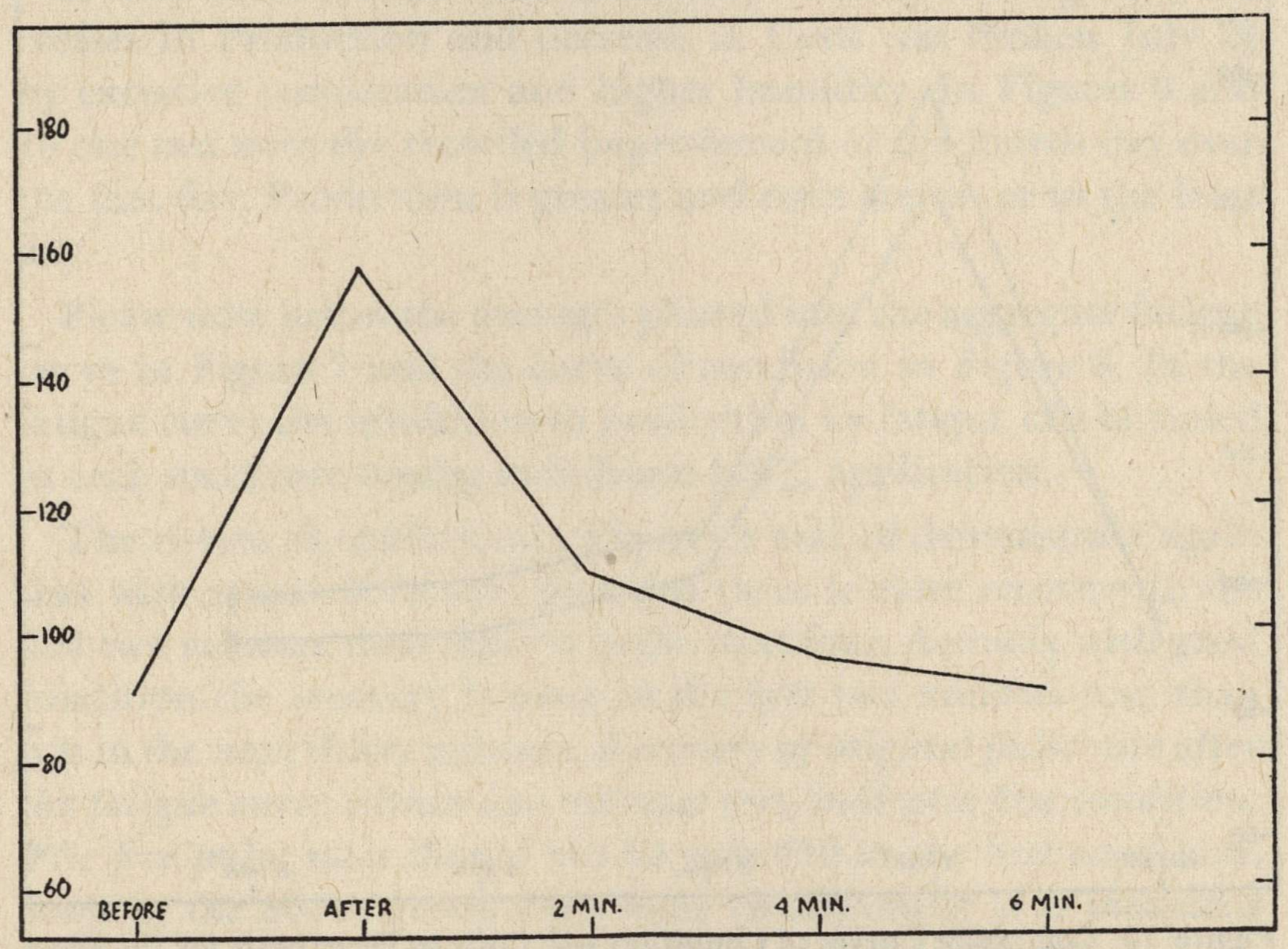

Figure 8. Composite Curve of Condition for the Period shown in Figure 7.

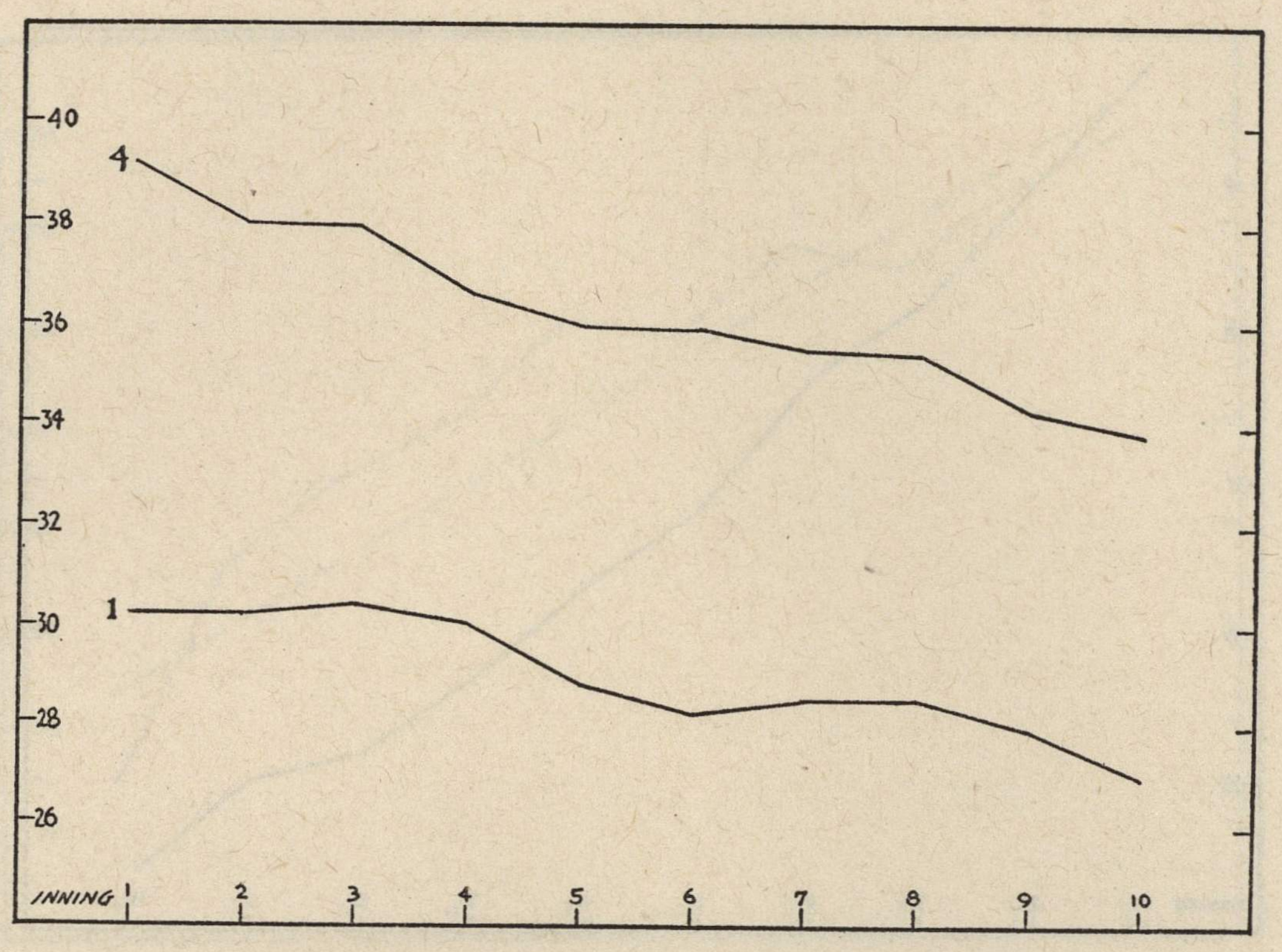

Figure 9. (Engineers Series) Composite Fatigue Curves of First and Fourth Days Showing Increasing Production.

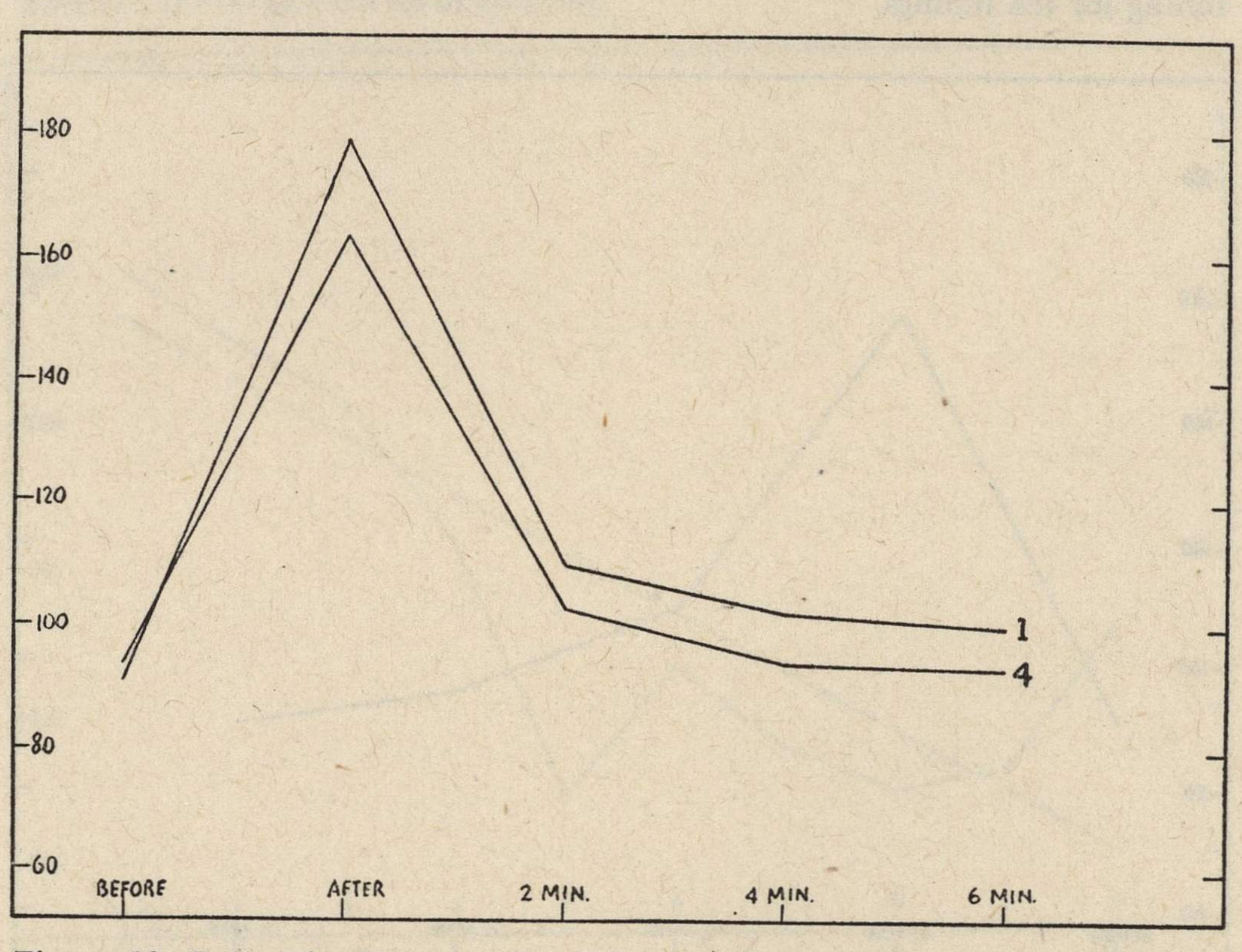

Figure 10. Composite Curves of Condition and Costs in Heartbeats for the Days Shown in Figure 9.

Condition or Costs in heartbeats was determined by the pulse rates before and after the fatigue curve, at the same intervals.

Spot running was again used in the production of the fatigue curve. Any skill similar to one involved in turning out piece work, as fast as possible could have been used. The right foot contacts were again counted for Production. Each individual was checked in his Application for ten innings of ten seconds each, with ten seconds rest between innings. The total foot contacts as skills were interpreted as Production for that particular day. The Costs in heartbeats were taken by the five pulse rates, one taken before production of the fatigue curve, immediately after, and then after two, four, and six minutes of rest.

Production went up and Costs came down from day to day as condition improved as shown in Figures 5 and 6. Application improved. Mastery of the skill improved. All improvements came as the result of good guidance and intelligent leadership. After twelve weeks, Production was up 45%, Costs were down 10%. Improved condition allowed the Engineers to do more work with less discomfort. If it isn't necessary to be physically fit it is certainly worthy of attention and some efforts.

It may be noted that the continuity of progressive greater increases in Production and decrease in Costs was broken July 28 by excessive temperature and higher humidity. In Figures 9 and 10 one can note the recorded improvement of the fourth day over the first day. Production is greater and costs are lower in the later day.

Please note below the averages plotted into the aggregate fatigue curve in Figure 7 and the curve of condition in Figure 8. In the fatigue curve the inhibition to production by fatigue can be noted in each successive inning to indicate 100% application.

The curves of condition in Figures 8 and 10 demonstrate again that with spurt efforts and then rest there is more recovery in the first two minutes than there is in the next four. Actually with good condition the recovery is more in the first two minutes rest, than it is in the next thirty minutes. *Recovery of original pulse rate after the fatigue curve within two minutes rest, indicates fine condition. The five pulse rates should not be over 450 in the best condition. Some of the above group need more conditioning as is indicated by the curve of condition.*

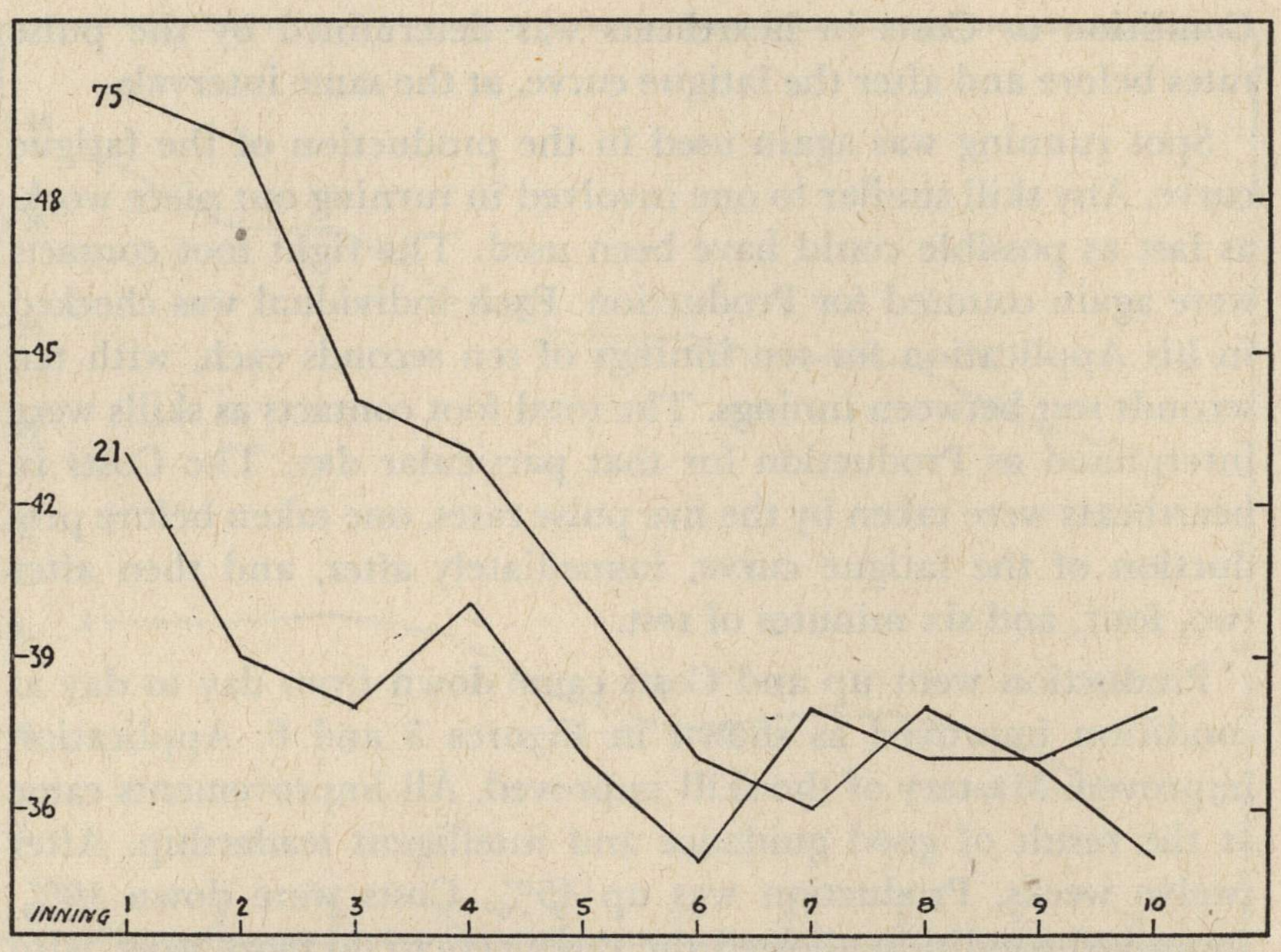

Figure 11. (Series of Older Individual) Twenty-first and Seventy-fifth Fatigue Curves. These fatigue curves illustrate that an older person may train to increase his production.

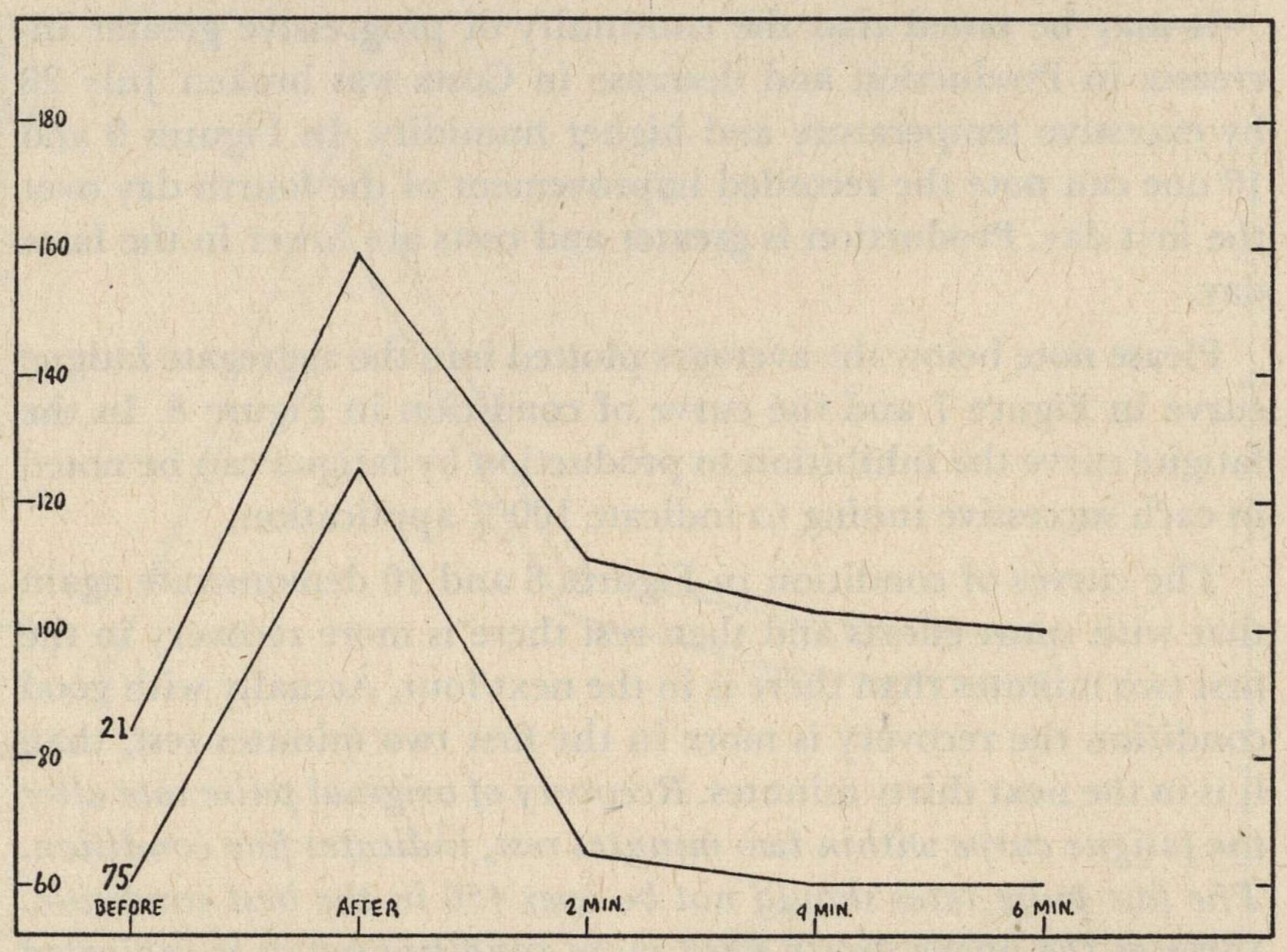

Figure 12. Curves of Condition for the Production Curves Shown in Figure 11. These curves illustrate the lowered costs in heartbeats for greater production in the presence of improving condition.

5. *Individual Series of Fatigue Curves*

One individual, aged 47, three curves daily for thirty one days, ninety three curves. This series, in retrospect, in addition to the research angle proved a conditioning course. The writer was taken by all stairways prior to these workouts. Afterwards the writer took all stairways. It is no myth that a good conditioning course will cause good effects continuously for six months after the course is discontinued—for many people anyway.

Some of the personal feelings of increased physical reserves included the legs insisting on running when the opportunity offered itself. This desire to run may be readily imagined when one recalls how the legs have been trained and conditioned in spot running. It is one of those things where the muscles want to carry on as a result of habit.

The following arrangement of numbers in this series illustrates improved production and conditioning. Figure 11 illustrates the improved Production and Figure 12 illustrates the lowered Costs in the seventy-fifth test as compared with the twenty-first test.

First Curve—First of each week

	5/14/42	5/21	5/28	6/4	6/13	
Production	262	382	380	361	379 —	up 44.65%
Application	30%	50%	90%	60%	60%	
Pulse Rates	576	558	468	400	352 —	down 37.15%

Three Curves daily—Twenty-one per week

	5/14 to 5/20	5/21 to 5/27	5/28 to 6/3	6/4 to 6/10	
Production	6679	7435	7848	7543 —	up 12.94%
Heartbeats	15432	14056	12452	11570 —	down 25.02%

The improvements in Production and in Costs are recorded and apparent as shown in Figures 11 and 12.

The improved conditioning as indicated by less heart beats with greater production stands out. Less heartbeats are accounted for by a slower heart rate in the better conditioned, and quicker return to the original pulse rate. The slower rate and the aggregate of the five pulse rates are noted above.

A schedule of recoveries in sequence as listed below illustrates improving condition. In the first week recovery of the original heart rate within twenty-eight minutes came only four times in the production of the twenty-one curves. In the second week recovery within twenty-eight minutes came nine times in twenty-one attempts. In the third week recovery within twenty-eight minutes

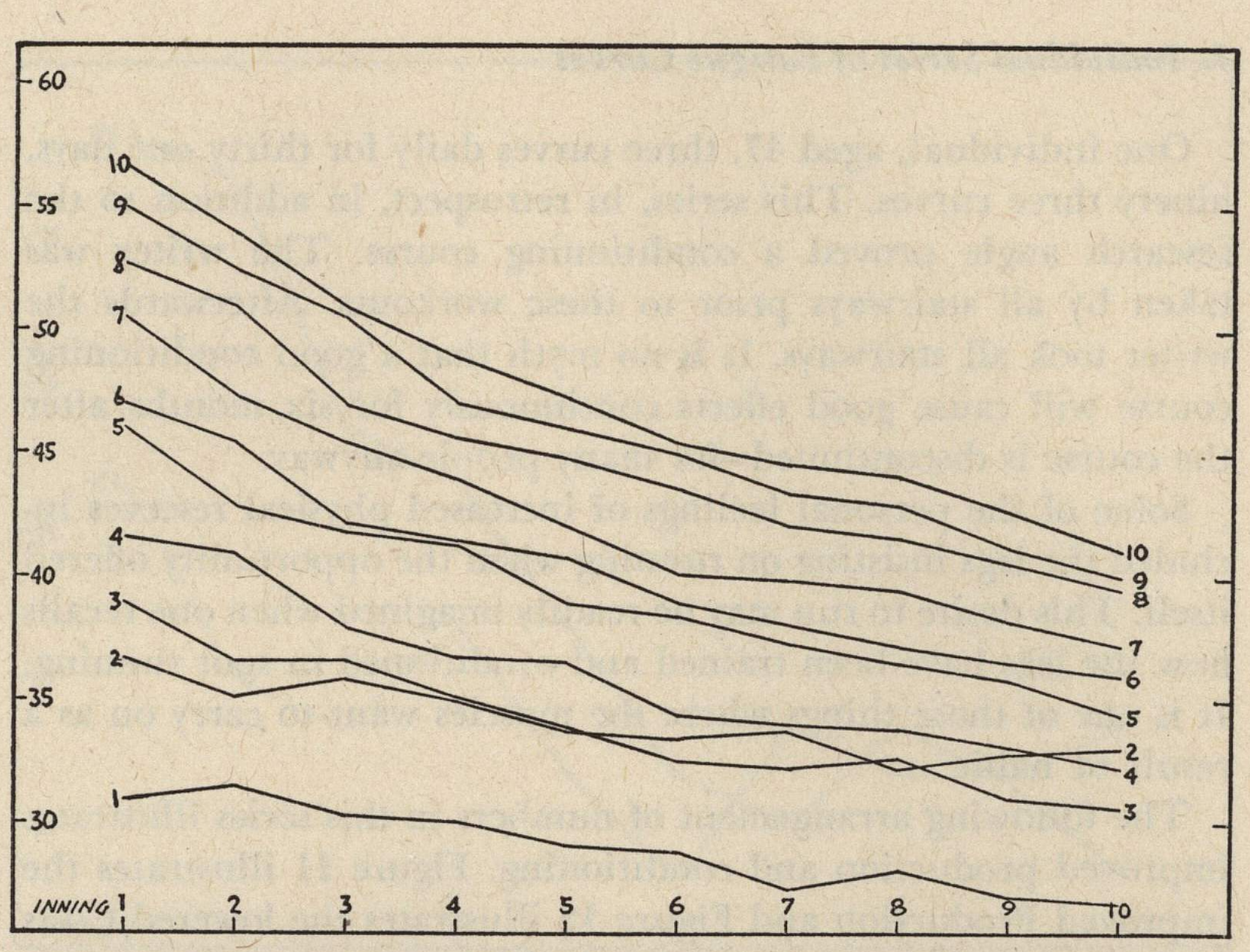

Figure 13. (Aircrew Series—Legs) Composite Fatigue Curves Improving for Ten Consecutive Days. Each day they said they did their absolute best and each subsequent day they found they could do more through improved training.

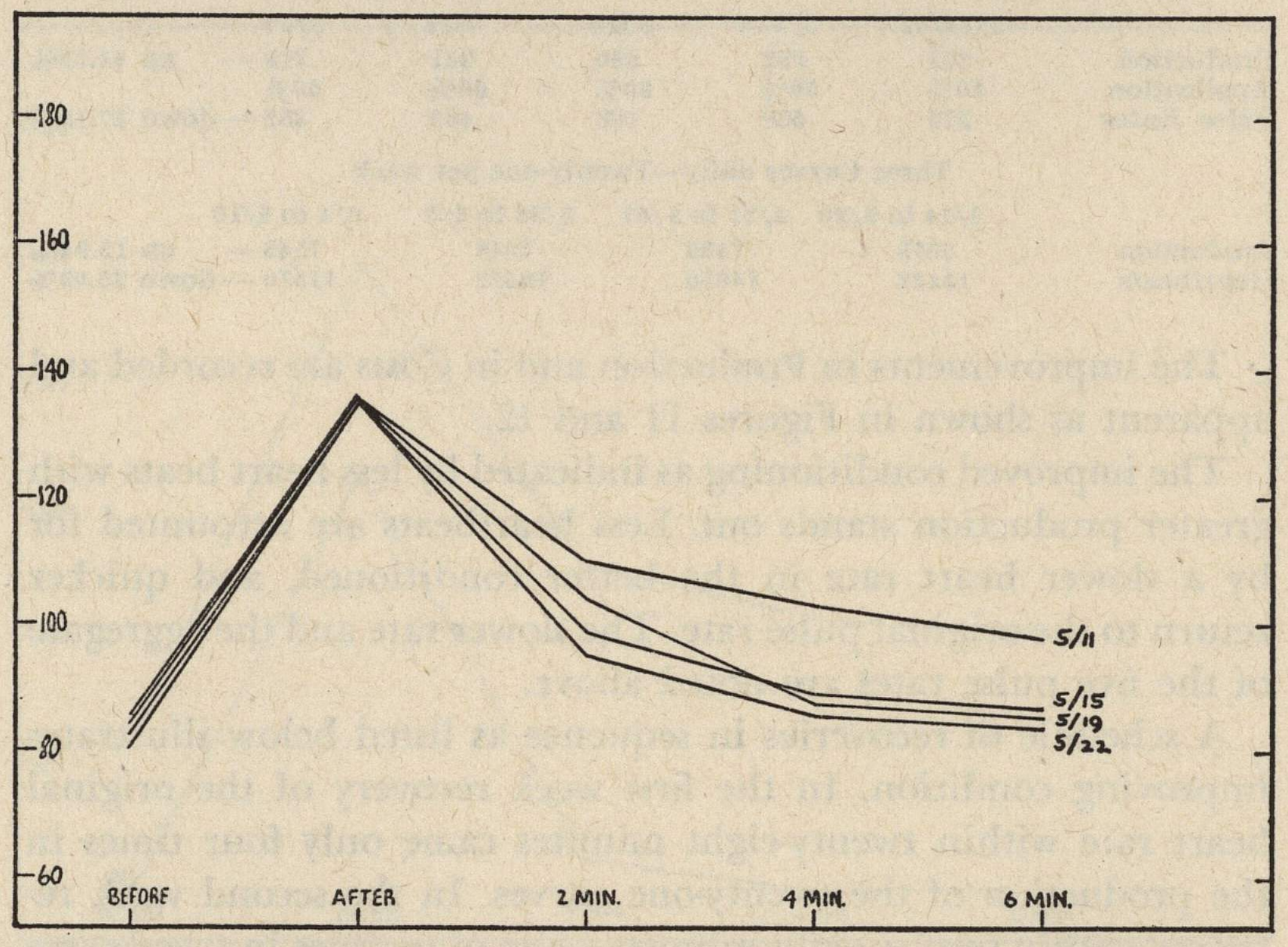

Figure 14. Composite Curves of Condition Corresponding to Four of the Days Shown in Figure 13. These curves show the improvement in condition through hard work.

came in seventeen of twenty-one times. In the fourth week complete recovery of the original pulse rate within twenty-eight minutes occurred in every one of the twenty-one tests.

Another way of noting improved condition in conjunction with fatigue production is the increasing number of quicker recoveries. In the first and second weeks there were no complete recoveries of the original pulse rates within two minutes. In the third week there were eight recoveries within the first two minutes of rest after the completion of twenty-one curves. In the third week there were nine trials of the twenty-one, in which there was a recovery of the original pulse rate with the first two minutes of rest. In the first week there were only four recoveries in twenty-eight minutes. In the second week there were nine recoveries within eight minutes rest. The third week showed ten recoveries within four minutes. The fourth week showed twelve recoveries within four minutes rest.

Production, recovery, and improvement varied within the same person with improved training, condition, and application. Production and recovery vary with foods, rest, sunshine, heat, and other fundamentals of physical and functional fitness. Production and recovery vary with thoughts, with surroundings, and with association.

6. Aircrew Series—Leg Muscles

Four hundred Aircrew Students worked in nearly 6000 fatigue curves on successive days. The fatigue and condition curves followed the regularly established patterns. In addition to spot running, the curves were made with two other similar skills of right and left arm jabbing and flexion-extension at the hips. The inhibitions of fatigue were apparent either in good or bad condition. The improved Production through ten days training is graphically shown in Figure 13. The improved condition is shown through quicker recovery and slower pulse rates in Figure 14.

Each day they said they did their utmost. The work of each day showed its good effects the following day.

Improved training promotes greater Production as shown in Figure 13, greater condition is illustrated by lowered cost in heartbeats in Figure 14 and better Application through regularly declining foot contacts, inning by inning, are graphically illustrated in the graphs of Figure 13.

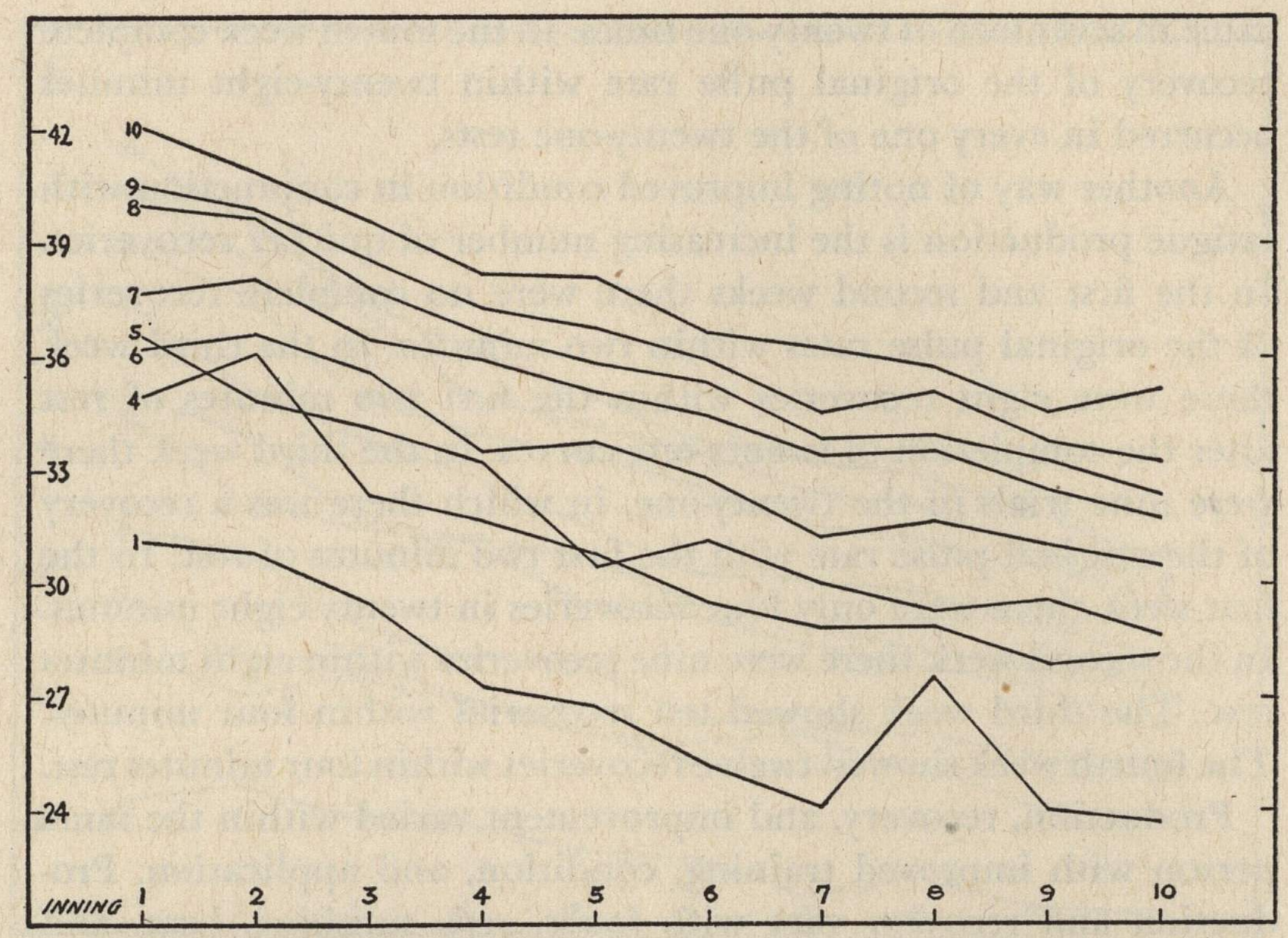

Figure 15. (Aircrew Series—Arms) Eight Composite Fatigue Curves Illustrating Progressively Improved Production. Arms fatigue in the usual pattern of declining returns from efforts. The approximately 200 Aircrew soldiers discovered they could use their arms much better with improved training.

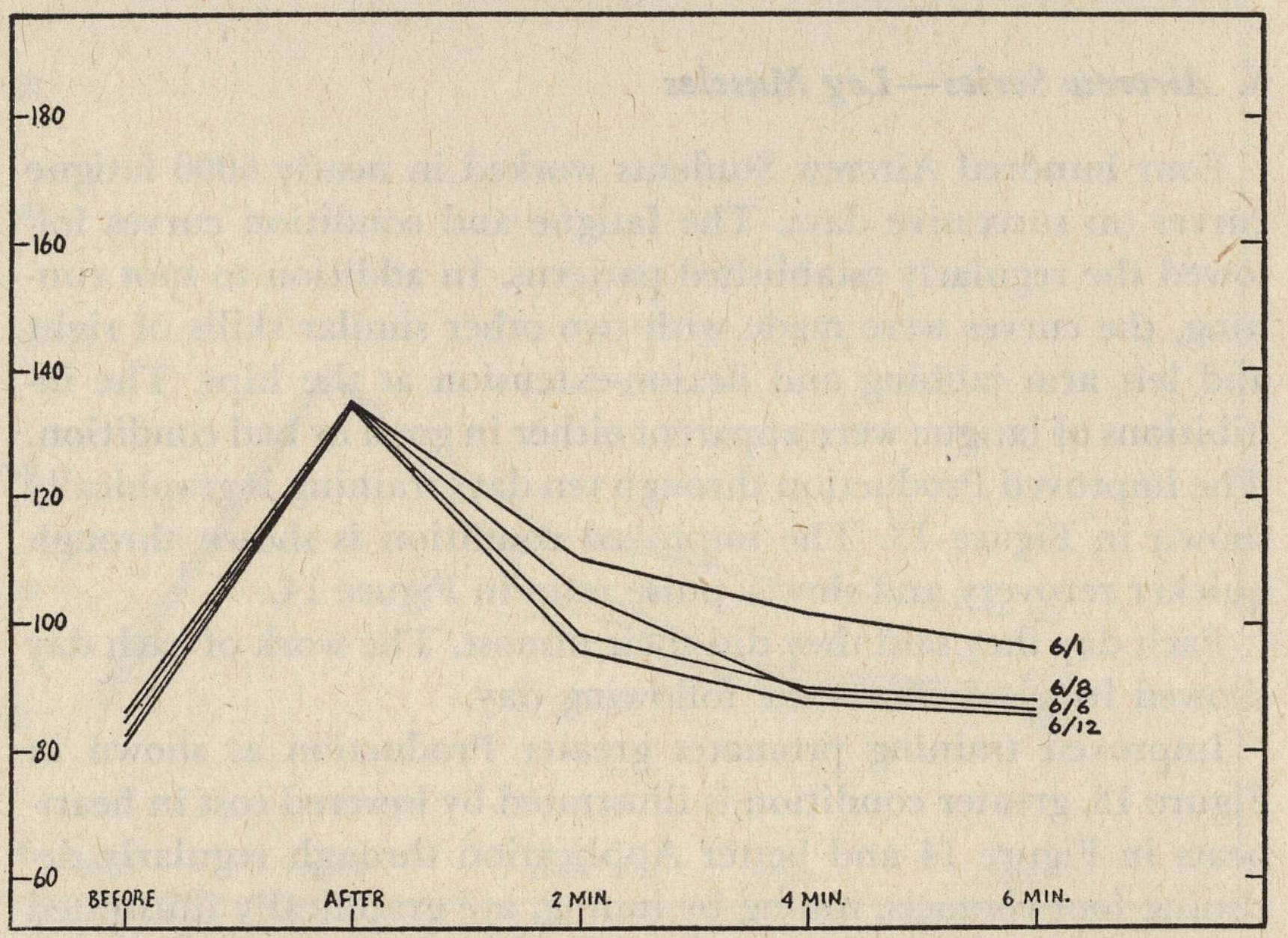

Figure 16. Composite Curves of Condition Corresponding to Four of the Days Shown in Figure 15. The subsequent curves of condition show less cost in heartbeats as condition improves. Greater work with less cost in heartbeats is the sign of improving condition.

A curve of improvement could be plotted to show how this Aircrew Squadron justified the procedure in one of their requisites of physical training and conditioning.

I. Physical Skill—Spot Running to improve 300 yard Shuttle Run.

Date	5/11	5/12	5/13	5/15	5/16	5/17	5/18	5/19	5/20	5/22	Results
Participants	178	177	198	172	115	197	201	199	198	203	
Average Production	286	335	341	362	389	404	424	446	463	486	up 69.9%
Cost Index (P.R.)	532	523	505	508	500	484	498	487	492	480	down 9 %

They cut approximately three seconds on the average for the run.

7. *Aircrew Series—Other Muscles*

The fatigue curve pattern and the pattern of the curve of condition apply to the work of any muscles.

Figures 15 and 16 illustrate Production and Costs as acquired by the use of the arms rather than the legs. The cost in heartbeats for the use of the arms does not come as high as it does for the use of the legs.

Curves of improvement in greater production at lowered costs could be plotted from the Aircrew statistics given below in the use of muscles of the arms and the abdomen by different squadrons.

II. Physical Skill—Flexion and extension at elbows to improve pull ups and push ups. The arms are less dextrous than legs.

Date	6/1	6/2	6/3	6/5	6/6	6/7	6/8	6/9	6/12	6/13	Results
Participants	197	171	171	132	179	178	160	156	148	147	
Average Production	268	282	295	306	317	333	345	359	367	380	up 41.5%
Cost Index (P.R.)	512	501	487	484	486	460	469	473	476	463	down 7 %

Improved jabbing speed 41.5% Improved pull ups 22%

III. Physical Skill—Extension backward at hips and flexion forward with hands clasped on back of head while standing to improve sit ups. Least dextrous.

Date	6/1	6/2	6/3	6/5	6/6	6/7	6/8	6/9	6/10	6/12	Results
Participants	178	147	198	120	131	115	145	123	144	116	
Average Production	146	150	166	171	178	191	201	207	210	219	up 49.7%
Cost Index (P.R.)	404	388	386	377	372	390	386	399	402	381	down 5.5%

Average sit ups went from 48.9 to 69.9 with 1000 seconds supplementary work.

8. *Army Specialized Training Reservists Series*

This group of 137 approximately seventeen year olds was given pencils and cards on short notice and directed into the regular procedures of spot running and pulse taking by Director Olenn.

The figures for the composite fatigue curve and the composite

curve of condition for their first experience are given below. They will be seen to conform to the established patterns.

Innings	1	2	3	4	5	6	7	8	9	10
Average Production	38.7	37.7	34.8	32.8	31.2	30.1	28.8	28.1	*28.3*	27.7

	Before	Immediately after	After 2 Min. Rest	4 Min.	6 Min.
Average Pulse Rates	91.3	145.6	113.2	100.4	96.4

9. Shadyside Academy Basketball Team Series

This series in spot running under the direction of Coach Walter Jones was done by eighteen different members of the squad daily for ten days.

The figures for the composite fatigue curve and the composite curve of condition are given below. In contrast to the one day's work in Series 8 of the A. S. T. R. P. these figures are the average for ten days.

Innings	1	2	3	4	5	6	7	8	9	10
Average Production	31.8	31.1	29.2	28.5	27.8	26.0	25.7	*25.7*	24.4	24.0

	Before	Immediately after	After 2 Min. Rest	4 Min.	6 Min.
Average Pulse Rate	82.2	156.0	102.2	88.2	84.0

10. University of Pittsburgh Basketball Team

The production of a fatigue curve by flexion and extension of the elbows is a good procedure to train and condition shooting muscles.

The figures given below demonstrate the pattern of the fatigue curve, and give evidence of why there is more inaccurate shooting with fatigue. Any coach can have his squad produce a fatigue curve any day to further both his knowledge of the physiology of action and the condition of his players.

The figures below could be plotted into an 80% fatigue curve. There were fourteen participants and the work was done in a "rest period" of a practice period.

Average Production by innings.					Elbow extensions and flexions.				
1	2	3	4	5	6	7	8	9	10
50.8	47.0	44.4	43.3	40.7	38.2	*39.8*	38.0	37.0	*37.4*

PART III. INTERPRETATIONS OF FINDINGS

THE term "Physical Fitness" commonly denotes an ability to execute many complex movements skillfully. This limitation of the criteria to skill, though, is too narrow to be adequate. In its broader sense, Physical Fitness also includes many other qualities among which are endurance, or ability to perform over relatively long periods of time; will power and determination, or mental spurs driving one to apply maximum effort in face of opposition from within or without; and organic power which permits rapid recovery from the effects of fatigue. Actually, therefore, use of the adjective "physical" often causes misconception since true fitness involves mental as well as physical aspects.

Physical Fitness is developed by *training,* by *conditioning,* and by *application.* While for the purposes of analysis these factors are considered separately, it must be remembered that they operate simultaneously; are overlapping and interlocking; and work stressing one has some influences upon the other two.

Training consists of practice, analysis of errors, and repetition of movements with the view of mastering skills. The result is efficient and comparatively effortless performance in which speed and accuracy are added.

Conditioning involves strenuous and numerous repetitions of movements planned to develop endurance. The result is ability to perform over longer periods with less time needed for rest.

Application refers to the mental and emotional drives necessary for maximum expenditure of controlled energy. Development of these urges results in ability to complete the task at hand in the best possible manner; to give one's most; or to "go all out."

Whether they plan it or not, all coaches of basketball utilize one or more of these factors in their teaching of team candidates. Some are known to emphasize skill aspects, and to pay little attention to conditioning or inspiration. Some are demons on endurance and seemingly forget that skills and application require attention. Others offer only inspiration and do little teaching of skills or developing of condition. The ideal, of course, is represented

by a balanced program in which the coach is a trainer, a conditioner, and a stimulator.

Some of the detailed elements of the three factors are listed:

TRAINING	CONDITION	APPLICATION
Aided by:	Aided by:	Aided by:
Teaching	Learning	Practice
Vision	Courage	Enthusiasm
Interests	Faith	Inspiration
Desires	Perserverance	Incentive
Quality work	Quantity work	Rhythmic work
Initiative	Ambition	Tenacity
Habits	Reserve	Motivation
Experience	Reliability	Adventurous spirit
Specializations	Versatility	Adaptation
Morale	Achievement	Expression
Humility	Capability	Discipline
Imagination	Dependability	Good manners

Good and Bad Days

A study of the Curves of Improvement in these tests shows a general tendency to swing upwards, but variations occur so that improvement is not uniform. In other words, each subject experienced times when performance was good, and other days when it was poor. This fluctuation is commonly noted by all athletes who refer to such performances as being "hot" or "cold".

Many times these variations may be charged to changes in the surroundings such as temperature, ventilation, lighting or equipment. Often, though, external conditions may not be altered and yet the performance is above or below the expected level. In these fatigue experiments, for instance, variations occur despite the fact that conditions remained practically identical at all times. If conditions remain uniform it is obvious that the search for causes of good and bad days most often must concern itself with the performer himself. That sets up the necessity for a complex analysis of the emotional drive or application possessed or developed by the subject. The three factors, training, conditioning, and application and the elements of which each is composed serve as a basis for this analysis of causes of fluctuations in performance.

Spurters and Pacers

The consideration of good and bad days introduces the controversy over methods of reaching maximum production. Is it

best to spurt, or should one pace himself? Should the performer put forth all possible energy right at the start in an explosive effort and continue the drive until fatigue enforces rest; or should he operate at "three-quarter" capacity while maintaining some energy reserves for emergencies or for longer continuous work?

The spurter always is in competition with his own upward curve of improvement. As long as he spurts he has a chance of raising his place on that curve. But fatigue causes him to stop and rest. On the other hand, the pacer may misjudge his capacity and thus penalize his chances of improvement. In fact, only the wise, consistent, and experienced athlete or worker can prevent lowering his ability when he is not making effort to improve it. Tests made in many activities such as typing, ticket selling, changing money, and other skills indicate that the spurter, or fast worker, accomplishes more in the end than does the pacer, or slow worker.

The spurter will run out of his endurance on the fatigue curve base line of condition before the pacer. That is the reason the spurter must rest more frequently and then produce more than the pacer before decline sets in again. The pacer declines less perceptibly in production but just as surely. In the process of physical development the spurter may fall behind in the earlier days, but by employment of maximum effort he heightens his line of training, lengthens his line of condition, and performs his best always within the limits of his fatigue curve. The spurter, by going all out, always has the chance of full development while the pacer is playing a game within himself in guessing his limits and may possibly curtail his development.

Training, conditioning, and application play the greatest part in determining whether or not one reaches a high stage of Physical Fitness. The athlete with a high degree of ability but who does not develop endurance and emotional drive will lose some or most of his ability in time. One with a short vertical line representing lesser ability, but with a long horizontal line denoting endurance, and a fine graph of application will increase his ability. The type of athlete who possesses ability and endurance, but who lacks the emotional drive to apply himself soon finds the up and base lines of training and conditioning becoming shorter, and has less on which to work even when he desires to do so. Physical Fitness may be developed only when one tries to lengthen every line of his fatigue curve; when he gives equal emphasis to the

factors of training, conditioning and application; when he gives his best at all times in every work period until stopped by inevitable fatigue. A letdown in any one of the three factors affects the other two and leaves its scars in spite of subsequent effort.

A close study of the fatigue and improvement curves plotted in this research series leads to the unmistakable conclusion that the practice of spurting and resting leads to higher development, and to an increase of consistency in performance. The spurter's record climbs the vertical line of ability in Figure 17, page 47 because of training. The horizontal base line is lengthened showing greater endurance and quicker recovery. The diagonal line of performance indicating application derived from healthy emotional drive is improved by consistently putting forth maximum effort.

Tiredness from True or False Fatigue

Tiredness may come from true or false fatigue.
The cure for tiredness from true fatigue is rest.
The cure for tiredness from false fatigue is work.

The pattern of the fatigue curve shows a decline in return from efforts as fatigue inhibits efforts. If a man uses his abilities at their best, as fast and as long as possible, he becomes truly fatigued and should rest. The idea of the Spartan and the "show must go on" may be fallacious if the returns are erratic, confused, and unpredictable. When the tensions of fatigue make us awkward in skills and in learning, then both the coach and player are wasting time and efforts. The cure for tiredness from true fatigue is rest.

The fatigue curve illustrates the factors of production to be ability, endurance, and emotional drive. A weakness in any one of these three factors induces tiredness too quickly. The weakness causes false fatigue and the answer is the correction of that weakness through work. This is in contrast to the true fatigue which comes when all factors are strong and operating at their best. If we lack ability we should work at training in the improvement and acquisition of skills. If we lack endurance we should find if we have healthy structures and if so we should work to condition ourselves. If we lack emotional drive, we should work in the application of our abilities and endurance to like our game and to play it better.

We have noted the tiredness of a novice in our game and often the anxiety and tension that come from misunderstanding and lack of ability. We need to train him. We can recall the cold sweats and the tiredness which overwhelmed us when we were first trying to learn to drive an automobile.

We have noted the boy who quickly tired, seemed unable to get his breath, and was awkward because he was not conditioned to carry on in the demands of early season or after a prolonged layoff.

We have noticed the boy who tired quickly because he was not interested nor enthusiastic, who may have disliked the game and had no desire to play. He may have been tired from lack of motivation or incentive, from physical hunger or some mental or social difficulties.

The player who is master of the skills, is perfectly conditioned, has lots of emotional drive and does his best becomes tired from true fatigue. He needs rest.

The player who has little ability, less endurance of healthy structures, and no emotional drive gets tired from false fatigue. He needs work. He should be trained, conditioned, and helped to apply himself and that requires a coach with training, condition, and patience.

We have seen people accused of lacking courage and fight. Maybe they didn't have the skills. Maybe they weren't conditioned. Maybe they weren't inspired. Of course they were tired from false fatigue. They needed intelligent work.

The person who studies or works one hour and does well, will not accomplish twice or four times as much if he studies two or four hours. This will help the coach who may think he can teach four times as much in four hours as he can in one hour. After the first hour his emphasis must of necessity swing from the factor of training into the factor of conditioning. If the skills are carelessly practiced with poorer application, the gain in endurance may be neutralized by sloppy skills, inefficiently executed. There is a happy balance of practice and perfection not always achieved. We can learn to partially distinguish true from false fatigue and to decide when work or rest is indicated.

In athletics we lean to the overwork idea with the value of rest being assured. In many activities the tendency is toward overrest and the loss of ability, endurance, and application.

Work toward true fatigue and rest.
Don't rest with false fatigue and fail to improve.

Physical Fitness a Division of Functional Fitness

Basketball, and other branches of athletics, is justified in the school program not alone because it aids in the development of Physical Fitness, but because it also contributes to the total educational effort. The purposes and aims of education have been outlined in numerous ways, but all of them stress that it is a process which presents experiences to the individual with the view of perfecting his skills and extending his capacities while at the same time he learns to adapt himself to his social environment. In other words, the coach of basketball uses the game as a tool to teach his players to become better and more valuable citizens. He has failed as a coach if, in concentrating on superior performance, he neglects the behavior phases and does not emphasize approved conduct. Whether the idea is pleasing to him or not, every coach is teaching "character" as well as basketball skills. Ultimately his work will be judged as much on how well his players behave on and off the court as on how many games his teams win.

Physical Fitness, thus, cannot stand alone. It must be combined with mental poise, self control, and approved social conduct. The term used here to denote this total of developed attributes is "Functional Fitness". Good coaching may be claimed when one has utilized training, conditioning, and application to produce skill, endurance, and maximum effort while at the same time he has taught by precept and example the necessities of healthful living and social adaptation.

The National Association of Basketball Coaches recognized that their members must use the physical approach as a means to social ends when that organization adopted "The Basketball Coaches' Creed" some years ago. The Creed states, in part:

"I BELIEVE that the proper administration of this sport offers an effective laboratory method to develop in its adherents high ideals of sportsmanship; qualities of co-operation, courage, unselfishness and self control; desires for clean, healthful living; and respect for wise discipline and authority.

"I BELIEVE that these admirable characteristics, properly instilled by me through teaching and demonstration, will have a long

carryover and will aid each one connected with the sport to become a better citizen."

The broader aspects of Functional Fitness have been stated previously to include training, conditioning, and application to develop the physical; and explanation, inspiration, and demonstration to improve the mental and social. The magnitude of the coach's job may better be grasped by further consideration of a longer list of fundamentals to be stressed if Functional Fitness is to be the outcome.

FUNDAMENTALS OF FUNCTIONAL FITNESS

Physical	*Mental*	*Social*
Action	Action	Action
Rest	Rest	Recreation
Diet	Face Reality	Spiritual Sustenance
Elimination	Eliminate Negative	Eliminate Negative
Water	Difficult Competition	Economics
Air	Emotional Response	Politics
Heat	Personality	Human Relationships
Light	Understanding	Education
Growth	Development	Progress
Reserves	Reserves	Reserves
Cleanliness	Self Control	Morals and Ethics
Posture	Attitude	Philosophy

The exact amount of carryover of these fundamentals from athletics to other activities often has been debated, but it is agreed that some transfer does take place. The amount is dictated by methods of teaching combined with the vividness of the impressions made upon the student. Properly taught, the lessons in school athletics develop physiques which can do more physical work and do it longer before fatigue inhibitions arise; stimulate mental processes and stabilize emotions; and inculcate worthwhile social traits. These transfer with an enjoyable spontaneity and pleasing efficiency to many other fields.

The primary approach, it is seen, is through the physical and the method involves action. Psychologists insist that a human being learns best by doing—that there is no teaching substitute for physical action. Evasion of action, especially in the young, plants the seed of an unhealthy pattern with subsequent disastrous repercussions. There can be no separation in any learning process of the physical, mental, and social phases, in the accomplishment of improved training, greater conditioning, and better application.

Player Application and Uses of the Fatigue Curve

Coaches of individual sports such as track and field, boxing, golf, wrestling, or tennis, have little difficulty in selecting their best performers or in predicting with relative accuracy what these performers will do in competition. In these activities numerous tests have been conducted and objective records are at hand to show exactly who, for instance, is a track team's best sprinter or shot putter, and to indicate with what degree of success he may compete against another sprinter or shot putter whose record is known.

However, in team games such as basketball and football accurate ratings of players are much more difficult since the factors involved are so numerous and complex that they are not easily measured. In fact, coaches of these sports usually admit their inability to tell just how good a player is; how much he has improved; or how well he will perform in a forthcoming contest. Notoriously they often predict defeat while hoping for victory. The track coach can make positive ratings because he has statistics to back his statements; the basketball coach cannot be positive because he is prone to rely upon judgment which, at best, is sometimes inaccurate.

Probably every basketball coach has tinkered with methods by which he may be certain that his judgment is sound. He has kept charts and records dealing with goal shooting, freethrow accuracy, passing and dribbling errors, and other elements of game performance; then pored over this mass of material only to discard most of it and guess that player "A" is better than player "B". Often he discovers that his judgment is disputed by the players themselves, by spectators, and by fellow coaches. Note, for instance, the wide variety of opinions expressed by coaches who try to select All-Star teams. Recognition of the need for objective grading of players has resulted in a number of tests claiming to supply the coach with accurate ratings of ability and condition. With few exceptions these tests are complicated, difficult to administer, and consume so much time that little energy is left to practice the skills of the game.

It is contended here, and not without considerable experimentation, that the compilation of production efforts, and the plotting of fatigue curves will provide coaches with significant information

leading to more accurate estimates of player ability. Periodical conduct of the spot running fatigue test, as done in this research, supplies data as to the state of Physical Fitness for each team candidate; indicates the degree to which a player has developed emotional drive; and permits rather definite prediction as to the type of response an individual will show when faced by an emergency or a difficult situation.

Furthermore, the fatigue test can be done easily and quickly thus avoiding serious hindrance with the practice of game skills and team maneuvers. The individual and aggregate curves are graphic and precise. The story they tell is a true one which makes possible interpretations that correct faulty impressionable ratings or substantiate sound judgment. Coaches who doubt these claims are challenged to conduct fatigue tests as described in Part I and see for themselves how precisely and conveniently they can solve some of their problems.

The problem of endurance is difficult to solve by judgment alone but since most methods of measuring this capacity are complicated coaches try to mold all team candidates into players who

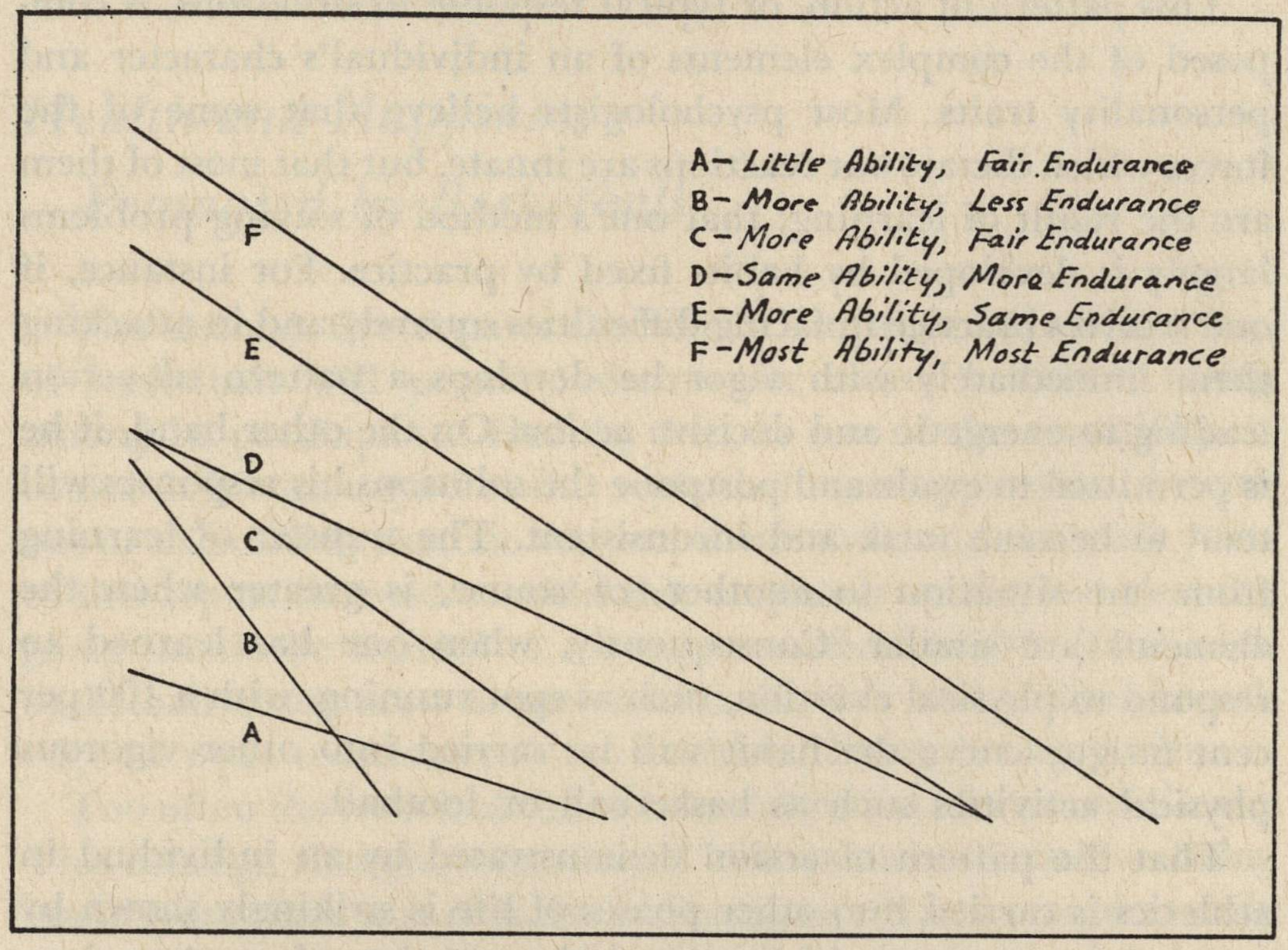

Figure 17. Sample Fatigue Curves Showing Variation in Ability and Endurance. These curves may represent different individuals or the same individual on different days with fluctuation in ability and endurance. If one tries to acquire more ability and endurance, the lines lengthen. If maximum effort is not applied, these assets regress.

can perform at high efficiency throughout an entire game, and usually guess as to the amount of work which will produce such results. In doing so they ignore the important factor of individual differences which vary as widely with respect to endurance as in the execution of skilled movements. Thus, some players can give their best in relatively short periods while others can operate for longer periods. The fatigue curves permit accurate rating of condition, or endurance, so that individuals may be removed from competition at pre-determined intervals with the knowledge that the maximum has been given, and that further effort without rest would result in inefficient performance.

Fatigue curves also may be used to predict the type of performance to be expected. In fact, it is possible to determine with astonishing accuracy whether or not an athlete is "hot" or "cold" for a contest that is about to start by his reactions to a single ten second spot running fatigue test providing enough previous tests have been given him to know his pattern of action. With such knowledge at hand a coach may choose his starting line-up with greater accuracy and make substitutions with fewer mistakes.

This pattern of action, or typical response to situations, is composed of the complex elements of an individual's character and personality traits. Most psychologists believe that some of the forces which dictate our reactions are innate, but that most of them are the result of learning; that one's method of solving problems largely is developed by habits fixed by practice. For instance, if one receives practice in facing difficulties squarely and in attacking them immediately with vigor he develops a pattern of action leading to energetic and decisive action. On the other hand, if he is permitted to evade and postpone the solutions his responses will tend to become weak and inconsistent. The transfer of learning from one situation to another, of course, is greater when the elements are similar. Consequently, when one has learned to respond to physical exertion, such as spot running, with a 100 per cent fatigue curve the habit will be carried into other vigorous physical activities such as basketball or football.

That the pattern of action demonstrated by an individual in athletics is carried into other phases of life is strikingly shown by a recent news story which related the reaction of an American soldier to a combat situation. The soldier had developed his pattern of action in high school and college football where he

learned to appraise situations quickly and act promptly. In an attack upon the enemy he threw a hand grenade which struck some vines and rebounded among a group of comrades. The habits of speedy response and desire for team welfare were so firmly fixed that the soldier threw himself on the ground and covered the missile with his body. The explosion killed him but saved all of his comrades. He had developed ability, was conditioned to act in emergencies, and had learned to give his best at all times. His sacrifice was dramatic proof that the training imparted by his coaches had transferred to another problem.

A series of fatigue curves for each team candidate, then, gives accurate pictures of the relative ability, condition, and application of each player. These measurements are objective and easily obtained. Careful study of the curves will tell the individual how he stands with respect to his teammates; will inform the coach accurately of the stage of Physical Fitness of any player or of the squad as a whole; and makes possible accurate predictions as to type of future performance by graphically showing the pattern of action.

Health and Happiness

Promoted by Basketball

The Coaches Creed states the belief that proper administration of basketball will promote desires for clean, healthful living among its participants. Health, then, is one of the essential outcomes. It is with regard to this topic that most opponents of vigorous or exhausting exercise concern themselves, and the early parts of this report devoted considerable emphasis on the fact that the game should be limited to those possessed of health. That each basketball coach must acquaint himself with, and utilize, knowledge of what constitutes clean, healthful living is imperative.

Too often the term health has been defined as absence of disease. This concept, though, is considered by experts in the field as being inadequate since it is negative in its approach and considers only the physical aspects. Expressions of more acceptable definitions vary in the words used, but all insist that health, though difficult to measure accurately, involves the mental, emotional, and social

factors of one's life as well as his physical qualities. One authority defines health as "that quality of life which enables one to live most and to serve best". To live most and to serve best results in happiness, and happiness is listed by leading philosophers as the ultimate aim of human existence.

Health, thus, is the product of exercise, rest, attention to body needs, maintenance of mental balance and emotional control, favorable environmental forces, and pleasant social contacts. The basketball coach is not expected to be a technician in every science concerned with the promotion and maintenance of health; neither can he be ignorant of the principal facts contributed by physiology, anatomy, hygiene, sociology, and psychology. His contribution to health centers in his technical knowledge of the use of exercise, but he must have more than a mere speaking acquaintance with the other fields in order to fit his specialty into its proper place.

Health and happiness are by-products of a mode of life which adheres to the Fundamentals of Functional Fitness outlined previously. Basketball coaches, in order to be successful, must know the steps leading to Functional Fitness; must be living examples of their use; and must apply them in their teaching. Their place in the educational scheme is a positive one in that they train and condition students to give their best against stiff opposition out in the open where public observation requires them to perform within a straightforward pattern. Of course, only the most highly trained and expert players are exhibited to the public and many think, erroneously, that these few receive all of the values of a coach's efforts. Not many realize that behind the scenes hundreds and thousands of boys in intramural competition and Physical Education classes benefit, directly or indirectly, from the training and conditioning provided by the game and its teachers.

Any educational endeavor which fails to stress the training, conditioning, and application common to basketball becomes negative in type, and teaches evasion of physical, mental, and social obligations. The results range all the way from minor functional psycho-neuroses to advanced structural defects. An important part of the coach's contribution to individual and group health, thus, is his responsibility to keep the values of strenuous physical exercise before his students, and to see that the public obtains similar information.

Physical Trauma vs Emotional Trauma

Many of the early investigators in fatigue were shocked to find that the pulse rates and blood pressures were extremely high a short time after the subjects ceased strenuous work or play. Many of these observations were made after about two minutes of rest, and the records were compared with the rates and pressures established as normal for the individuals. The differences often were wide enough to lead to some critical interpretations concerning the effects of strenuous exercise. Statistical studies connected with this research work does not dispute the findings of these other investigators, but there is no question that the methods and interpretations were in error.

First, the pulse rate just preceding a contest is increased by emotional disturbances and in the few minutes before a game is already higher than during normal rest periods even though activity has not yet taken place. Second, few of the investigators checked the pulse immediately upon cessation of work. Had they done so, and then repeated the check after two minutes, they would have found, as did this investigator, that the rate slowed considerably in even this short period. Also, it is in this first two minute interval that those in best physical condition show the most rapid return towards their normal rates. By disregarding the increases caused by emotional strains, and by waiting for several minutes after work had stopped it is obvious that wide variations from the normal resting heart rates and blood pressures would be found. Use of these differences to conclude that the activity was harmful is erroneous as compared to method used here in which the comparisons are made at the start and immediately at the close of the activity period.

Checks on the pulse rates of basketball players and coaches when a game is about to start show their hearts beating faster than normal due to emotional disturbances. If, then, by two minutes after the close of the effort the pulse rates have returned to the same count as at the start it must be concluded that the activity has put no strain on the vital organs that could be considered harmful.

In connection with the topic of the effects of emotions upon the pulse rate some results of personal and restricted observations are worthy of comment. Pulse rates of both players and coaches

go up just before a game. Another increase for both has been noted at the close of the first half. This would be expected for the players because of their exertion, but for the coaches it can be blamed only on greater mental strain since they have done little or no physical work. A similar jump again has been found at the close of the game. Thus, the heart rates of the coaches keep pace with those of the players despite the fact that one group works strenuously and the other just "sweats blood".

After the game the heart rates of the players return to normal quickly while the recovery of the normal rate for the coaches is much slower. This might be explained by the observation that expenditure of physical energy when one is also under an emotional strain leads to a type of fatigue which nature takes care of readily and easily in a comparatively brief rest period. However, if the higher pulse rate is caused solely by emotional trauma the recovery is much slower.

This observation is not intended to conclude that the coach should add physical exertion to his emotional disturbance in hopes that the combination would react on him as it does on the players. Unless conditioned to such activity he might increase his already rising emotional tension. It is possible that players recover quickly because they unconsciously divorce themselves from emotional trauma while the coaches are unable to remove game situations from their thoughts.

The tendency of coaches to keep their troubles constantly in mind does violence to emotional control and may result tragically, as is shown by the terrific price paid by some. Listed among prominent men in football coaching circles whose deaths at comparatively early ages have been attributed, at least partially, to emotional trauma are: Percy Haughton of Harvard, Enoc Bagshaw of Washington, Herman Stegeman of University of Georgia and Howard Jones of Southern California. George Keogan of Notre Dame, Leonard Sachs of Loyola, Ollie Seelbach of Canisius College and James Usilton of Temple University are late members of the National Association of Basketball Coaches. They too, are men who suffered the shocks of emotional trauma of coaching.

The evidence and suggestions outlined seem to indicate that damage from strenuous physical exertion is prevented by inhibitions induced by fatigue; that recovery is rapid when one is Physically Fit; but that rampant and uninhibited emotions con-

tinue to cause disturbance after the effort is completed. In other words, emotional trauma is more severe upon the health of coaches than exhausting play is upon the bodies of the competitors.

Summary of Interpretations of the Fatigue Curve Studies

1. The general form of more than 20,000 fatigue curves plotted in this series of tests convincingly demonstrates that nature employs fatigue as a protective mechanism against harmful overwork under healthful conditions for all age levels, and that fatigue inhibits activity before damage to the individual occurs.

2. The arguments of superficial critics regarding the effects of basketball and other strenuous types of athletics are found to be false in the light of this carefully conducted research which proves that sound bodies become structurally stronger and functionally more efficient by participation in properly conducted programs of vigorous exercise.

3. Study of the fatigue curves crystallizes graphically the three guiding factors in improvement of physical performance and shows them to be important objectives in coaching. The three factors are: Training or ability; Condition or endurance; Application or emotional stability and drive.

4. Training increases performance ability by perfecting or mastering the skills involved. Conditioning increases endurance by developing the capacity to work harder and longer while recovering more rapidly in shorter rest periods. Application enhances performance by adding motivation which uses training and conditioning to reach the highest possible peak of production.

5. Use of this test as organized and administered offers a convenient and scientifically sound method of evaluating effort for different subjects, anywhere, and at any time.

6. The fatigue curve is an accurately drawn and complete picture which permits evaluation of Training in specific skills by recording the number of movement repetitions accomplished. It indicates the extent of Application by showing the rate of decrease of the number in succeeding work periods; and determines Condition through pulse readings taken before and after measurable effort.

7. Results of repeated tests for a single subject permit the plotting of a curve of Improvement. Comparison between Improvement curves for several subjects shows that those who produce 100 per cent fatigue curves reach a higher level of performance and improve more rapidly than those whose fatigue curve patterns are less efficient.

8. The curves of Condition indicate the need for and value of frequent short rest periods since there is more and faster recovery from strenuous work during the first two minutes of rest than there is during the next ten minutes.

9. Functional Fitness with its associated physical, mental and social elements may be evaluated by examination of Fatigue curves developed by an individual.

10. This series of Fatigue curves proves conclusively that vigorous and strenuous physical activity develops sound bodies which can accomplish more work; can work better, faster and longer; recover better and more quickly; and can be ready for additional work with less rest.

NATIONAL ASSOCIATION OF BASKETBALL COACHES OF THE UNITED STATES

OFFICERS

EDWARD J. HICKOX, *President*
Springfield College, Springfield, Massachusetts

W. H. BROWNE, *First Vice-President*
University of Nebraska, Lincoln, Nebraska

MARSHALL DIEBOLD, *Second Vice-President*
Carleton College, Northfield, Minnesota

VAL. LENTZ, *Third Vice-President*
United States Military Academy, West Point, New York

HOWARD HOBSON, *Secretary-Treasurer*
University of Oregon, Eugene, Oregon

WILLIAM CHANDLER, *Bulletin Editor*
Marquette University, Milwaukee, Wisconsin

BOARD OF DIRECTORS

E. A. KELLEHER, U. S. Military Academy, West Point, New York
EVERETT DEAN, Stanford University, Stanford University, California
FORREST COX, University of Colorado, Boulder, Colorado
BLAIR GULLION, Cornell University, Ithaca, New York
HERBERT W. READ, Western Michigan College, Kalamazoo, Michigan

COMMITTEE CHAIRMEN

Membership
C. S. EDMUNDSON, University of Washington

Rules
J. D. LAWTHER, Penn State College

Convention
E. A. KELLEHER, U. S. Military Academy

Coaching Ethics
DON WHITE, University of Connecticut

Tournament
H. A. OLSEN, Ohio State University

Research
BRUCE DRAKE, University of Oklahoma

Visual Interpretation
H. E. FOSTER, University of Wisconsin

High School
JOHN JACOBS, North High, Minneapolis

Officials
ADOLPH RUPP, University of Kentucky

Convention Displays
ELMER RIPLEY, Columbia University

PAST PRESIDENTS

DR. F. C. ALLEN, University of Kansas
J. CRAIG RUBY, University of Illinois
L. P. ANDREAS, Syracuse University
A. A. SCHABINGER, Creighton University
H. A. OLSEN, Ohio State University
ROY MUNDORF, Georgia Tech
HOWARD ORTNER, Cornell University
A. C. LONBERG, Northwestern University
DR. H. C. CARLSON, University of Pittsburgh
GEORGE R. EDWARDS, University of Missouri
W. S. CHANDLER, Marquette University
B. T. GROVER, Ohio University
NAT HOLMAN, City College of New York
NELSON NORGREN, University of Chicago
E. A. KELLEHER, U. S. Military Academy