THE EFFECTS OF ISOTONIC AND ISOMETRIC STRENGTH TRAINING ON PULL-UP ACHIEVEMENT

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THESIS

THE EFFECTS OF ISOTONIC AND ISOMETRIC STRENGTH TRAINING ON PULL-UP ACHIEVEMENT

By

Donald Thomas Thornton

AN ABSTRACT

Submitted to the College of Education of Michigan State
University of Agriculture and Applied Science in
partial fulfillment of the requirements for the
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The physical fitness of the American youth is of major concern to educators. Pull-up capability is one of the better measuring devices for evaluating the physical fitness of the upper torso of children. Another measuring device used for this same purpose is an isometric training apparatus with the isotonic horizontal bar training method.

Sixteen sixth-grade boys exercised five times weekly for six weeks on both training devices. The boys in each group were divided into four initial achievement level subgroups. The pull-up capability of each subject was tested three times during the course of the study and the results compared with the pull-up data of a controlled group. Analysis of variance and the Duncan multiple range test were employed in the analysis.

Only the highest initial achievement level group had a significant increase of pull-up capacity after the isotonic as well as for the isometric training period. There was no significant difference between the two training methods.

Three reasons for failure of a significant increase of pull-up strength in the subjects of the three lower initial achievement level groups were presented: the training methods may have been too advanced, the testing technique too stringent and the motivation control too weak.

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I. INTRODUCTION

1.1 General

The rapid technological developments during the last decade are the main cause of the greatly reduced muscular efforts required of the average child. Public school physical education programs offer the best means to improve the physical fitness of American youth. The President's Council on Youth Fitness has published a booklet in which a number of recommended physical education programs are described. In addition the booklet contains physical fitness evaluation data for children of different ages for different exercises.

For the past two years the Birmingham School System in Michigan has administered to the fifth and sixth grade students a series of six physical fitness tests. The tests are: (1) squat thrust; (2) standing broad jump; (3) sit-ups; (4) shuttle run; (5) push-ups; and (6) pull-ups. When the preliminary non-published scores of these tests were compared with the evaluation data sheets published by the President's Council on Youth Fitness it became evident that the Birmingham school children rated well above the national average in all but one of the fitness tests; only in their capability of performing pull-ups do these children rank below the national average.

Although during the last year some pull-up exercises have been incorporated in the regular physical education program of the Birmingham School System, no improvement of the pull-up capability of the school children has resulted. Consequently this study was initiated to develop training methods for increasing the pull-up achievement of these school children.

At the present time there is no agreement among experts which is the best training method, the static or the dynamic, for developing strength. Both of these methods will be tested in the form of isometric and isotonic exercises, on six grade male students.

1.2 Objectives

The main objective of this study is to compare the effects of static and dynamic training programs on pull-up achievement of six grade school boys.

The specific objectives are:

(a) To determine if pull-up ability can be significantly increased by maximum isometric contraction of the upper torso on a specifically designed training apparatus.

(b) To determine if pull-up ability can be significantly increased by a daily free isotonic pull-up exercise on a horizontal bar.

(c) To compare the two methods.

1.3 Basic Assumptions

Pull-up achievement can be significantly increased by the use of one of the following training programs;

(a) a thirty second daily free isotonic exercise period using a horizontal bar for a period of six weeks.

(b) a six second isometric exercise repeated three times daily with a specially designed pull-up apparatus for a period of six weeks.

1.4 Limitations of the Study

(a) The motivation of the individual subjects could not be controlled.

(b) The physical education programs at the two experimental schools were administered by the same physical education instructor. The control group received the same type of physical education program. However, this group had a different instructor.

(c) Any improvement detected by either training method was solely based upon the improvement made by individuals attaining complete pull-ups. Fractional improvement or partial attempts were not recorded.

1.5 Definition of Terms

(a) <u>Isometric exercise:</u> A muscular contraction held in a static state.

(b) <u>Isotonic exercise:</u> A muscular contraction involving a range of motion.

II. REVIEW OF LITERATURE

2.1 Roux-Lange Theory

In 1917 Lange published the now well-known Roux-Lange Theory on hypertrophy. He argues that only when a muscle performs with the greatest power, i.e., by overcoming a greater resistence per unit time than before, it will increase its functional cross section. He further hypothized that no increase in the contractible substance would result if the muscle performance is increased by working against the same resistance for a longer period of time. This means that hypertrophy will be observed only in muscles that perform a special feat in a short period of time. Examples would be an athlete who in a few seconds generates great power by lifting a weight, by making a fast running start or by jumping a wide distance. Consequently, distance runners, walkers or swimmers who generate the same power over an extended period of time would not experience hypertrophy.

The Roux-Lange Theories were restated more precisely by Petow and Siebert (1925) as follows: "Hypertrophy results from an increase in the intensity of work done (increase of work per unit of time) and not from the total amount of performed work." These authors also provided first experimental evidence for this overload theory. They showed that skeletal muscles hypertrophied in proportion to the intensity of the work demanded of them; that the greater the intensity, the greater the hypertrophy, and that only when the intensity was increased hypertrophy followed.

Karpovich (1953) and Steinhaus (1954) studying muscle strength and its development also tested Roux and Lange's theory. They concluded that a muscle only develops in size and strength when it is required to exert a force against a greater than normal resistance and that the muscle development is caused by an increase in the cross section of the individual muscle fibers.

2.2 Training for Strength

Erich A. Muller (1941) and coworkers at the Max Plant Institute for Arbeitsphysiologie in Dortmund, Germany, studied for ten years to determine methods for increasing muscle strength at the highest possible rate. The vital factors necessary to produce hypertrophy were finally determined by Hettinger _et al._ (1953) in intensity and duration studies of static contractions. Exercises were performed by nine male subjects in a series of 71 tests lasting over a period of 18 months. The exercises consisted of pulling and holding a predetermined weight against a dynamometer. For five days each week, Monday through Friday, training sessions were conducted in which the intensity of contractions, the length of hold-time and the number of practices per day were varied. On Saturday the maximal strength of each subject was measured. No training was held on Sundays. On the average, the increase of maximal muscle strength per week was 5 per cent of that which was recorded at the start of the training sessions. The study showed that muscle strength increased more rapidly with increased intensity of training up to a certain limit. Increasing the training load above that of two-thirds of maximum strength did not show any increased muscle strength.

Hettinger further found that one practice period per day in which the muscle tension was held for six seconds resulted in as much increase in strength as longer periods or more frequent practices. He concluded that the stimulus to hypertrophy is caused by a state of oxygen deficit within the muscle fibers. This means that the contracting of a muscle to one-third to two-thirds of its maximal strength for a period of six seconds a day is sufficient to cause an oxygen deficit in all of the fibers resulting in the maximum speed of hypertrophy of this muscle. This study therefore indicates that static exercises will permit a rapid muscle development without spending much total energy.

Kruse _et al._ (1957) made a study on the effects of isotonic and isometric exercises on elbow flexor muscles of one hundred and seventy college students.

The sixty subjects in the isotonic unit exercised to exhaustion on a Kelso Hellebrandt ergometer with a weight load equal to 3/16 of their maximum strength. The subjects in the isometric unit exercised by exerting minimum effort in three consecuitve six-second pulls on a strap. The two exercise units were divided into four groups, each group containing fifteen subjects. The groups exercised two, three, four and five times a week over a period of four weeks. No common regression line was found in the eight groups, indicating that the strength changes were peculiar to the individual groups. The isometric type exercise of the five day a week group caused the greatest number of subjects to significantly gain in strength.

Rarick et al. (1958) compared the effectiveness of a single daily six-second exercise bout using two-thirds maximum tension with an exercise program involving more frequent exercise bouts at 80 per cent maximum tension. The study lasted four weeks. The results generally supported the finding of Hettinger et al. (1953) in that brief periods of isometric tension (one six-second bout daily at two-thirds maximum tension) proved to be as effective for strength development as more frequently repeated exercise bouts at higher levels of tension. He found that in the isometric exercises the tension produced by a muscle decreased as the speed of shortening increased and that the greatest tension was produced at the zero-velocity shortening. However, the greatest total muscle development results from the isotonic exercises.

Salter (1955) in comparing isotonic and isometric exercises divided her subjects into groups of four. Each group trained for four weeks by supination of the left hand at one of the following rates:

(a) Isometrically at the rate of 15 per minute.
(b) Isometrically at the rate of 2 per minute.
(c) Isotonically at the rate of 15 per minute.
(d) Isotonically at the rate of 2 per minute.

She found no significant difference between the four training methods in their effect on muscle strength development.

After an experiment involving thirty maximum exertions at one minute intervals, Darcus *et al.* (1955) found:

(a) Static training caused a significant improvement in maximum isometric force.

(b) Dynamic training caused a significant improvement in the maximum isotonic work.

(c) Static training had a variable effect on muscle strength measured isotonically.

(d) Dynamic training produced an improvement in maximum isometric force.

Peterson (1960) compared different exercises with five groups of subjects:

(a) Group I trained the right elbow flexors and right extensors for 36 days with one maximum isometric contraction. No increase in isometric strength resulted.

(b) Group II trained the same muscles with 10 maximum isometric contractions per day for 36 days. The males increased their isometric strength significantly, but the females did not.

(c) Group III trained the right elbow flexors with 10 eccentric contractions per day for 36 days. No increase in strength resulted.

(d) Group IV trained for 15 minutes on an ergocycle for 20 days. A significant increase in strength resulted.

Peterson's results contradict the theories of Hettinger et al. (1953). Peterson theorized that a measured increase in strength due to certain exercises should be attributed to an improvement in skill rather than in strength.

A similar explanation has been given earlier by Rasch et al. (1957) who reported that male subjects performing isotonic exercises showed greater gains in strength and hypertrophy than did subjects who exercised isometrically. They demonstrated that in either case very little of these observed gains in strength were transferred over into unfamiliar situations. From this it was hypothesized that in many cases gains in strength are largely gains in skill. This same opinion was expressed almost simultaneously by Rose et al. (1957) after a study of very brief isotonic exercises. They stated that it is "almost inconceivable that a brief training period represents muscular exercise in the sense in which it is traditionally regarded especially since the persistence of strength as a learned act does not appear to be an impossible concept".

Hettinger et al. (1953) had postulated that a training effect resulted whenever the oxygen demands of a muscle were not satisfied during the exercise, and that static exercise was so effective because it created particularly unfavorable vascularization conditions. Experiments designed by Morehouse et al. (1959) in which some of the subjects submitted to pressure occlusions of the upper arm, led them to conclude that this explanation was untenable. In their opinion, the key lies in the development of tension, an argument which was earlier advanced by Buchthal et al. (1949). However, Royce (1958) has presented a study which appears to lend support to the Hettinger interpretation.

Summarizing it can be said with certainty that muscle strength can be increased by the use of either isotonic or isometric exercise. The reasons for the development of increased strength are in dispute. It appears that strength gains are greatest when tension is developed frequently during the course of the training program.

III. METHODOLOGY

3.1 Choice of Subjects

Forty-eight sixth grade boys of three schools in the Birmingham School System were selected as subjects. The physical education programs of the three schools are similar in content. The socio-economic backgrounds of the subjects were approximately the same.

The forty-eight subjects were divided into three groups of sixteen each. The first group represented the control, the second the isotonic and the third the isometric group. Individuals within each group were matched with individuals in the other two groups into four subgroups by the number of complete pull-ups they could do successfully at the beginning of the study. The four achievement levels were:

Level I - students that could do six or more pull-ups.
Level II - students that could do three to five pull-ups.
Level III - students that could do one or two pull-ups.
Level IV - students that were unable to complete one pull-up.

3.2 Training Apparatus and Procedure

The subjects of Group A, the control group, did not receive any additional exercise or training outside of their normal physical education activities administered as part of their regular education program. Their pull-up ability was tested at the start, at the midpoint and at the closing of the six-week training period.

Groups B and C, the experimental groups, trained five days a week for six weeks. Their pull-up ability was tested at the same times as was done for Group A.

Group B, the free pull-up exercise group, was offered in addition to their regular physical education exercises the opportunity to practice each day on a pull-up horizontal bar. The subjects were restricted to a daily 30 second time limit but no restriction was placed upon the method they used while practicing. Since each subject trained five times a week for six weeks, each exercised a total of 15 minutes on the horizontal bar.

Group C, the isometric group, was given in addition to their regular physical education exercises a program of isometric pull-up exercises on a pull-up apparatus designed by the author. This apparatus is pictured in Figures 1 and 2. It consists of a horizontal bar welded between two adjustable automobile bumper jacks which in turn are fixed to two angle iron uprights. The bumper jacks make it possible to move the horizontal bar up and down. The uprights are braced to the base. A set of heel plates are bolted to a plywood platform secured to the base.

The isometric training procedure was as follows: Each subject stepped onto the base of the apparatus facing the adjustable horizontal bar. After the bar was adjusted 4 inches above the chin of the subject and his feet were secured against a heel plate by means of straps, he gripped the horizontal bar with both hands using an overhand grip with fingers pointing away from the body. On the command "ready pull" the subject pulled for six seconds as if to attempt a regular pull-up. The feet of the subject were strapped to the base preventing him from lifting as he pulled. Each subject also trained for six seconds with the bar adjusted eight and twelve inches above the chin. The exercise times were controlled by using a stop watch.

All the testing and training procedures were administered by the investigator in the multipurpose room of the three schools. The room temperatures were constant between 68 and 70 degrees F. The training and testing of the subjects required in this study was done after school hours, between three and three-thirty on week days.

3.3 Testing Apparatus and Procedure

The same apparatus was used to test all groups. It consisted on a one and three-quarters inch galvanized bar five feet long suspended horizontally seven

Figure 1

Training Apparatus (Front View)

Figure 2

Training Apparatus (Side View)

feet above floor level. This height prevented the subjects from pushing off the floor when they were attempting a pull-up.

The following procedure was required to score a complete pull-up (Carter, 1958). The subject had to assume a hanging position on a horizontal bar with the arms and legs fully extended. Using the forward grip in which the fingers pointed away from the body, the subject had to flex his arms, keep his knees straight, and raise his body until his chin was above the bar. The subject then had to lower his body to the hanging position again before attempting the next pull-up. As stated before only complete pull-ups were recorded.

3.4 Statistical Analysis

The Duncan multiple range test was utilized for the statistical analysis of the data as described by Steel, et al. (1960).

IV. RESULTS AND DISCUSSION

4.1 Results

In Table I the numbers of pull-ups performed during the course of the study by each of the 48 subjects are presented. The four achievement levels are called I, II, III and IV, the three treatments A (control), B (isotonic) and C (isometric) and the time of testing 1 (at the beginning) 2 (midway) and 3 (after six weeks). Subgroup AI is therefore the control group with an initial achievement level of 6 or more pull-ups. Group A on the other hand stands for the complete control group, that is achievement levels AI, AII, AIII and AIV combined.

Table II gives the error mean squares, along with the degrees of freedom and error sum of squares used in the Duncan calculations.

In Table III the test data required to perform the Duncan Test are presented for the sources of variation listed in Table II. The significant studentized range (SSR) values for the 5% level and the appropriate number of degrees of freedom for p equal to 2 and 3 (two and three means, respectively) are listed in Table III along with the least significant range (LSR). In comparing the subgroups AII, BII and CII the values for $p = 2$ of the SSR and the LSR are 2.88 and 0.89, respectively.

Finally, the results of the Duncan Test for this study are presented in Table IV. The means of the compared groups or subgroups were first ranked and the differences among them compared. If we consider again the AII vs. BII vs. CII subgroups it will be noted from Table IV that not one of the three subgroup means is significantly different from one of the other two; the largest different between two means is namely 0.84 which is smaller than the corresponding LSR values of 0.89 and 0.94.

TABLE I

NUMBER OF PULL-UPS FOR THE THREE TREATMENTS AT FOUR ACHIEVEMENT LEVELS

Sub-Group	Achievement Level	Group A Control			Group B Free Exercise			Group C Isometric		
		Test			Test			Test		
		1	2	3	1	2	3	1	2	3
		6	6	6	6	10	11	7	8	9
I	6 and	6	6	6	8	10	10	7	7	9
	above	7	7	7	8	7	8	7	7	8
		7	7	7	6	5	7	7	8	8
		4	5	3	4	1	5	3	4	4
II	3-5	3	4	4	3	2	5	3	3	3
		3	3	3	3	3	5	4	5	6
		3	3	3	3	3	4	4	6	6
		2	2	2	1	1	1	2	4	4
III	1-2	1	1	1	2	5	4	1	3	3
		2	2	2	1	1	2	1	0	2
		1	1	1	2	0	3	2	1	3
		0	0	0	0	0	0	0	0	2
IV	0	0	0	0	0	0	0	0	1	2
		0	0	0	0	0	2	0	0	1
		0	0	0	0	1	2	0	0	0

TABLE II

ERROR SUM OF SQUARES, ERROR MEAN SQUARES AND $S_{\overline{x}}$ VALUES AMONG GROUPS AND TREATMENTS

Source of Variation	df	Error Sum of Squares	Error Mean Square	$S_{\overline{x}}$
A vs. B vs. C	141	1158.77	8.22	0.41
AI vs. BI vs. CI	33	49.7	1.50	0.35
AII vs. BII vs. CII	33	38.1	1.15	0.31
AIII vs. BIII vs. CIII	33	43.6	1.32	0.33
AIV vs. BIV vs. CIV	33	13.9	0.42	0.19

TABLE III

DUNCAN MULTIPLE RANGE TEST VALUES(p=.05)

A vs. B vs. C

Value of p	2	3
SSR	2.80	2.95
LSR	1.16	1.21

AI vs. BI vs. CI

Value of p	2	3
SSR	2.88	3.03
LSR	1.02	1.07

AII vs. BII vs. CII

Value of p	2	3
SSR	2.88	3.03
LSR	0.89	0.94

AIII vs. BIII vs. CIII

Value of p	2	3
SSR	2.88	3.03
LSR	0.96	1.01

AIV vs. BIV vs. CIV

Value of p	2	3
SSR	2.88	3.03
LSR	0.54	0.57

TABLE IV

DUNCAN'S NEW MULTIPLE RANGE TEST RESULTS FOR THE 5% CONFIDENCE LEVEL WITH MEANS RANKED

A vs. B vs. C

A	B	C
2.85	3.43	3.65

C-A	=	$0.80 \angle 1.21$	NS
C-B	=	$0.22 \angle 1.16$	NS
B-A	=	$0.58 \angle 1.16$	NS

AI vs. BI vs. CI

AI	CI	BI
6.5	7.7	8.0

BI-AI	=	$1.50 \geq 1.07$	S
BI-CI	=	$0.30 \angle 1.02$	NS
CI-AI	=	$1.20 \geq 1.02$	S

AII vs. BII vs. CII

AII	BII	CII
3.41	3.41	4.25

CII-AII	=	$0.84 \angle 0.94$	NS
CII-BII	=	$0.84 \angle 0.89$	NS
BII-AII	=	$0.00 \angle 0.89$	NS

AIII vs. BIII vs. CIII

AIII	BIII	CIII
1.50	1.91	2.16

CIII-AIII	=	$0.66 \angle 1.01$	NS
CIII-BIII	=	$0.25 \angle 0.96$	NS
BIII-AIII	=	$0.41 \angle 0.96$	NS

AIV vs. BIV vs. CIV

AIV	BIV	CIV
.00	.42	.50

CIV-AIV	=	$0.50 \angle 0.57$	NS
CIV-BIV	=	$0.08 \angle 0.54$	NS
BIV-AIV	=	$0.42 \angle 0.54$	NS

In Figures 3 through 6 some of the results of this study are graphically illustrated. In Figure 3 the average number of pull-ups is plotted versus time for each of the three treatments. All four achievement levels were combined in calculating the average values used in this figure.

Figures 4, 5 and 6 are bar graffs illustrating the average pull-up improvement of the four achievement levels during the first three weeks, the second three weeks and the total six week duration of this study. Figures 4, 5 and 6 give this information for the control, the isotonic and isometric groups, respectively.

4.2 Discussion of Results

It can be seen from Table IV that except for the AI vs. BI vs. CI subgroups, none of the compared group or subgroup means were significantly different at the 5% confidence level. This is a surprising result because it means that all but the highest achievement level group failed to increase their pull-up capacity significantly during the course of this study. The possible reasons for this result will be explored in the remainder of this section.

If we look at the number of students that have increased their pull-up capacity due to the six week isotonic or isometric training period, we notice that twenty-six out of thirty-two or almost 81.5% have. On the other hand only one student out of the control group of sixteen or 6.4% increased his pull-up strength. Comparing the values 81.5 and 6.4 it is clear that relatively large mean differences resulted. However, the variability was large, thus statistically significant differences were not obtained.

It was previously pointed out that a significant increase of pull-up capacity was observed after the six week isotonic as well as isometric training period for the highest achievement group. This means that the specifically for this study designed isometric apparatus as well as the horizontal bar can be used successfully to increase the pull-up strength of physically well-developed sixth grade boys. No significant difference resulted from training on the two

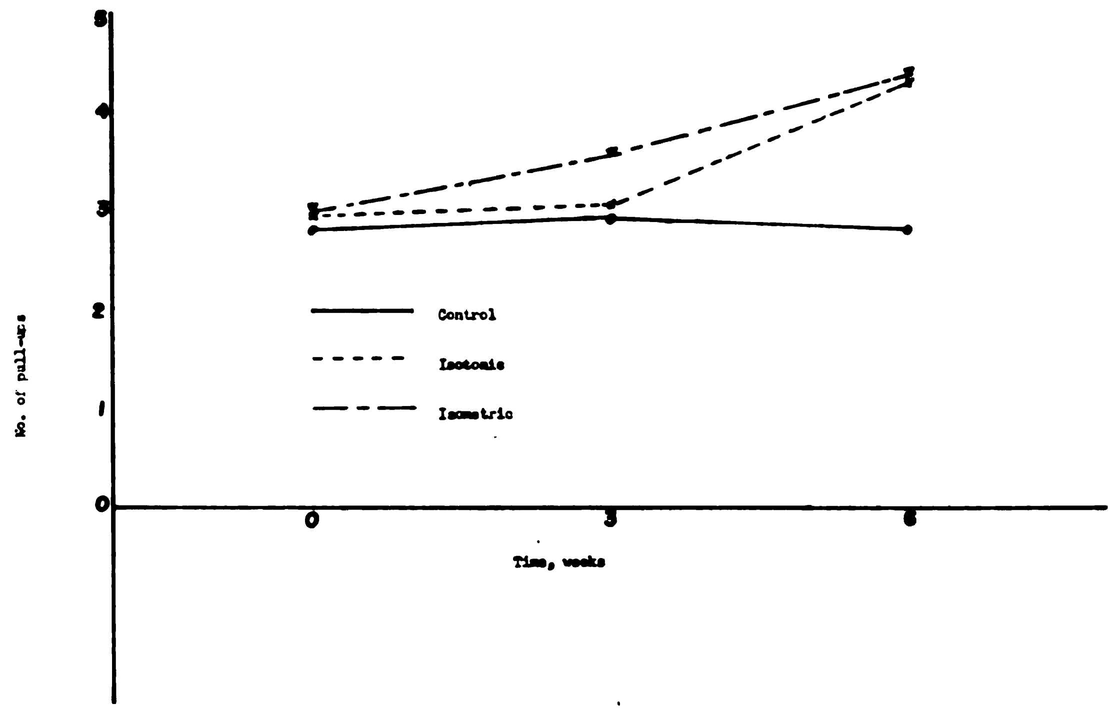

Figure 3. Average Number of Pull-ups for Three Treatments Versus Time.

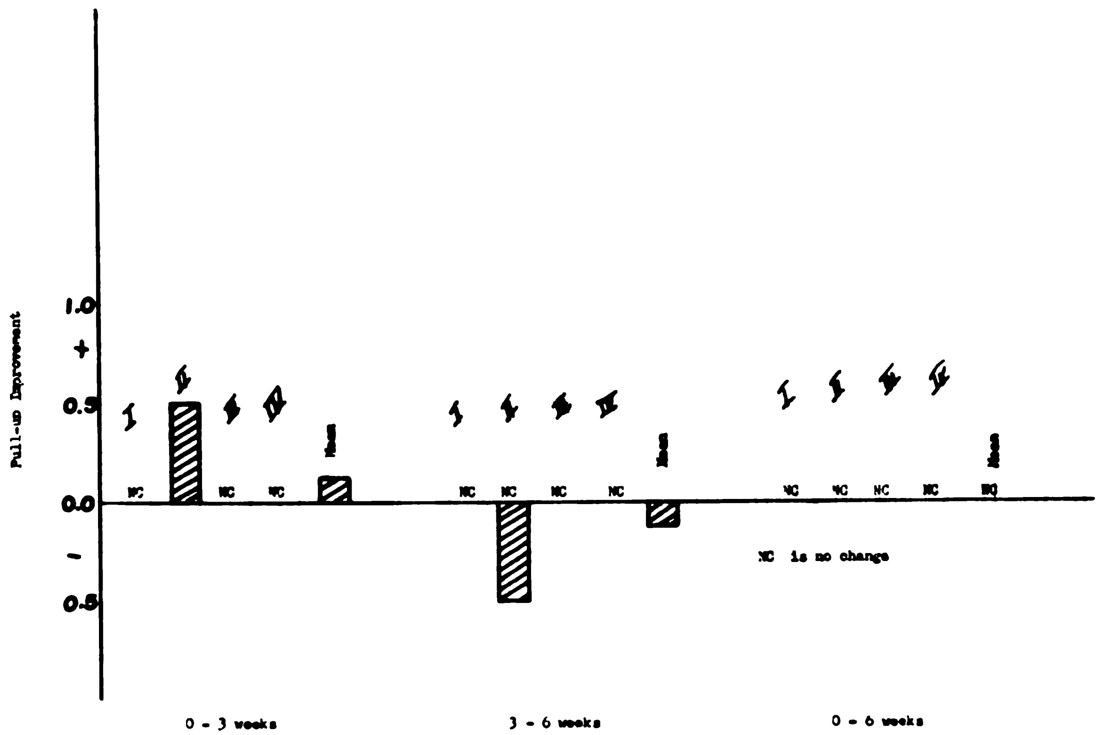

Figure 4. Increase in the Average Number of Pull-ups Versus Time for Four Achievement Level Groups (Control Group).

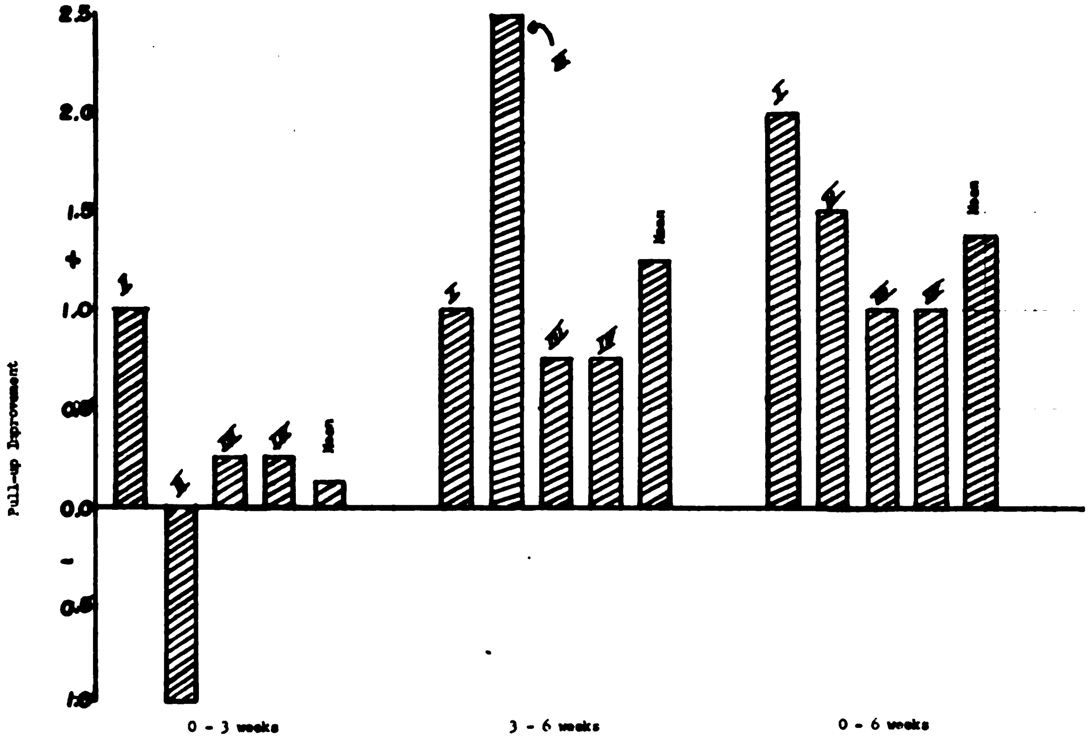

Figure 5. Increase in the Average Number of Pull-ups Versus Time for Four Achievement Level Groups (Isotonic Group).

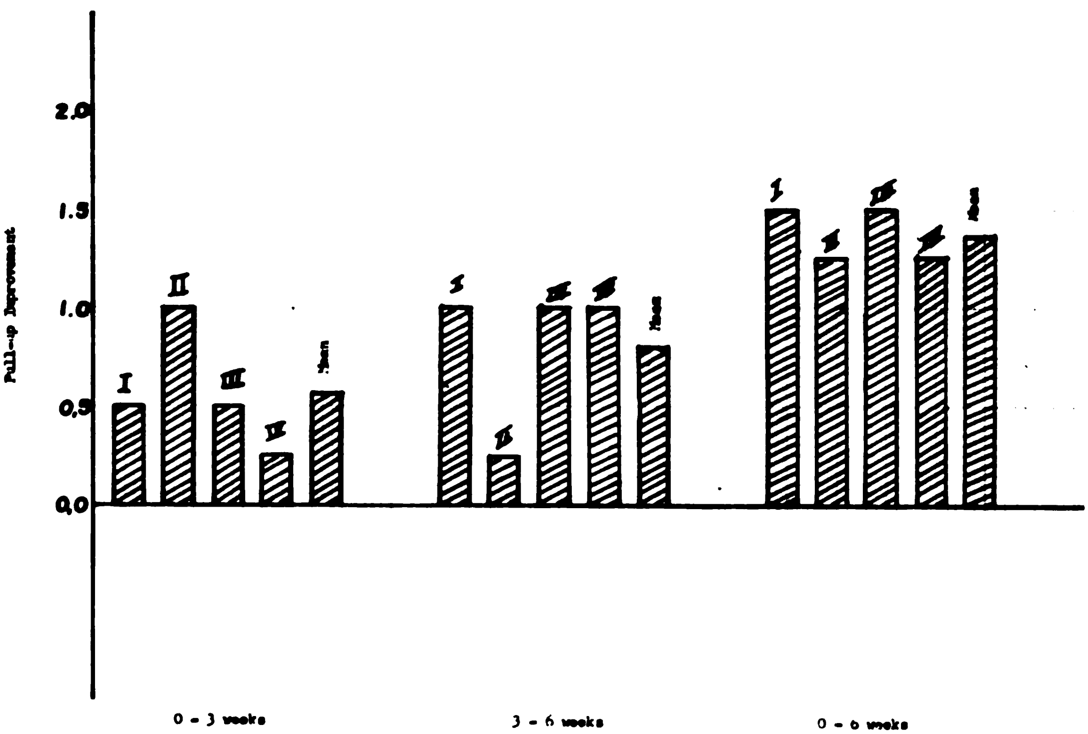

Figure 6. Increase in the Average Number of Pull-ups Versus Time for Four Achievement Level Groups (Isometric Groups).

types of exercise apparatus for this highest achievement group or for that matter for any of the four achievement groups.

There may be three reasons why the two training exercises tested in this study did increase the pull-up capacity of the highest achievement group but not of any of the three lower achievement groups. First the training methods may have been too advanced for all but the strongest boys. Secondly the testing technique may have favored the strongest boys and finally the highest achievement level boys may have been motivated more strongly.

It is very conceivable that training methods chosen for this study favored the stronger over the physically less developed subjects. This was especially observed during the isotonic training exercises on the horizontal bar. While the highest achievement level boys would practice pull-ups the weaker boys often hung on the bar. Although the isometric exercises seem to be adaptable for all strength levels the weaker boys may not have grasped the proper use of their own muscles.

The testing technique employed in this study definitely favored the stronger boys. Since only complete pull-ups were counted a partial pull-up made by a subject who could before the training period only hang limp on the bar, was not counted, although it constituted for him a tremendous advance in strength. On the other hand an increase in the number of pull-ups from 8 to 10 for a stronger boy was counted even though this increase was less significant than that of the weaker boy.

Motivation is a difficult variable to control. The author feels that lack of control over this variable did influence the results of this study. The stronger boys enjoyed the training exercises much more than their weaker peers. A strong boy was eager to increase his strength while the weaker boys often did not care.

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The physical fitness of American youth has been a matter of national concern for the last five years. The President's Council On Youth Fitness has published physical evaluation data for children performing different exercises. When the data on pull-ups were compared with pull-up scores of six grade boys in the Birmingham, Michigan school system, it became clear that the pull-up capability of these children ranked only on a par with the national average.

A study was conducted with 48 randomly chosen six grade boys to determine if the pull-up capability of these subjects could be improved by isotonic or isometric training exercise. The subjects were divided into three groups. Each subject was then placed in one of four achievement level subgroups depending on the number of complete pull-ups he could do at the beginning of the study. The isotonic training method consisted of free exercising for 30 seconds daily on a horizontal bar. A specially designed pull-up apparatus was used 18 seconds daily by the subjects in the isometric group. The study was continued for six weeks. The pull-up capacity of each subject in the control, the isotonic and isometric groups was tested at the beginning, at the midpoint and at the closing of the six week training period.

The Duncan multiple range test was employed to statistically analyze the pull-up data. A significant increase of pull-up capacity resulted for the highest initial achievement level group for the six week isotonic as well as the isometric training period. There was no significant difference between the two training methods. The three lowest initial achievement groups did not increase their pull-up capability during the course of this study.

Three reasons for failure of a significant increase of pull-up strength in the subjects of the three lower initial achievement level groups were advanced.

Recommendations for further study should be conducted on the following questions:

1. Training Methods. Should different training methods be employed for boys of different physical achievement level?

2. Testing Techniques. Should different testing methods be employed for boys of different physical achievement levels?

3. Motivation. How can the variable motivation be controled during physical exercises for boys of different physical achievement levels?

4. Length of Training. Is a training period of six weeks sufficient to show up increases in pull-up capability of the children in the three lower achievement level groups?

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