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IN-SEASON WEIGHT TRAINING AND ITS EFFECTS
ON HIGH SCHOOL BASKETBALL PLAYERS

presented by

Steven Boyd Mather

has been accepted towards fulfillment
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M.A. degree in the School of
Health Education, Counseling Psychology
and Human Performance

William W. Heusner
Major professor

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IN-SEASON WEIGHT TRAINING AND ITS EFFECTS ON HIGH SCHOOL BASKETBALL PLAYERS

By

Steven Boyd Mather

A THESIS

Submitted to
Michigan State University
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ABSTRACT

IN-SEASON WEIGHT TRAINING AND ITS EFFECTS ON HIGH SCHOOL BASKETBALL PLAYERS

By

Steven Boyd Mather

Eleven male high school basketball players were tested for leg strength and power. They then were divided into control and experimental groups. The experimental group participated in a weight training program in addition to their regular practice and game schedule. The controls were not involved in a weight training program prior to the season.

Testing was conducted at the beginning, middle and end of the competitive season. Data were collected on peak torque and power. Peak torque was measured with a Cybex II dynamometer. Power was measured with a modified vertical jump test. Analyses showed no significant changes in peak torque or leg power throughout the season for either group. It was concluded that the weight training load was not enough to produce significant strength gains. A motor learning model was advanced as a tentative explanation for the non-significant increase observed in leg power within the control group.

DEDICATION

This thesis is dedicated to my parents, P. Boyd and Darlene Mather, whose love and concern have provided countless opportunities for me, and my brother David, whose companionship and opinions I value so highly.

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

THE PROBLEM

Weight training is currently a well-known and widely accepted component of athletics and physical education. Many studies that have been conducted on weight training show that it can be a great aid in building and maintaining strength, power, endurance, and speed.[6,7,8,9,10,11,12,16,19,30,21,28,29,30,70,77] Weight training also can be a great aid in the prevention of athletic injury.[14]

With this in mind, it would seem logical to want to extend these benefits to high school sports, which involve a great proportion of this country's active, competitive athletes. However, comparatively few studies have been performed with high school athletes as opposed to other populations, e.g. college athletes. Pitman[58] and Kusinitz and Keeney[46] have found that weight training can improve strength and motor performance in adolescents. Fisher,[32] however, found that no significant differences in strength or performance resulted from adolescents participating in a weight training program.

There also have been few studies done on how to maintain strength during a competitive sports season. Many coaches are hesitant to commit a great deal of time during a season for strength training due to time and fatigue considerations. Guess[37] and Coleman[22], however, have shown that strength training can be quite beneficial in maintaining strength levels. Again, few if any studies have been performed on high school subjects in this area.

Purpose

The purpose of this study was to provide information on the effects of in-season weight training on high school athletes. Eleven male high school athletes at East Lansing High School in East Lansing, Michigan, volunteered to serve as subjects. They were not involved in weight training programs prior to the season. Two comparison groups, weight training and non-weight training, were formed. Leg peak torque and power were analyzed.

Research Hypotheses

The following hypotheses were tested during the course of this investigation:

1. A decline in peak torque and power will occur in the control group as the season progresses.

2. The weight training group will maintain pre-season levels of peak torque and power, and may increase these levels somewhat as a result of weight training.

Research Plan

Two comparison groups were used in an ex post facto one-way design. The control group contained seven subjects and the experimental group four. Each subject underwent isokinetic testing of the knee joint of his dominant leg, at speeds of 60^{0}/second and 240^{0}/second. Each subject performed five repetitions at each speed.

Peak torque values for leg extension and flexion were analyzed. Total leg power and power/kilogram of body weight were analyzed from a vertical jump test.

Limitations of Research Plan

The results of this study can be generalized only to the age range and sport involvement of the subjects.

A given subject may not have been able to achieve 240^{o}/second angular velocity quickly enough for accurate peak torque values to be recorded.

Each subject was encouraged to put forth his best effort during both testing and weight training; however, there was no method available to ensure that they did so.

The necessarily small sample size may have limited the results of the study.

Significance

This study was designed to aid in the assessment of the value of weight training to high school age athletes, with an emphasis on the value of in-season weight training. The results of this study may help to determine training loads and methods of strength training during the season.

CHAPTER II

REVIEW OF RELATED LITERATURE

There are five areas of literature related to in-season strength training that shall be reviewed: 1) The effects of strength training, 2) methods of measuring and assessing strength and power, 3) previous studies in strength training during a competitive season, 4) methods of strength training, and 5) strength training in adolescents.

Effects of Strength Training

Cellular Level

One well-known and commonly documented effect of strength training is an increase in muscle size and girth. Two mechanisms have been suggested for this phenomenon: hypertrophy (enlargement of the muscle fiber) and hyperplasia (increase in the number of muscle fibers). The hypertrophy theory currently is believed to be the most accurate.[30] Hypertrophy was first explained by Morpugo in 1897. Morpugo found that there was no increase in the number of muscle fibers in dogs after two months of running exercise, although the muscle itself increased significantly in size.[68] A possible mechanism of hypertrophy has been proposed by Goldsberg et al,[34] with the increase being due to increased protein synthesis and increased amounts of noncontractile tissue (e.g., connective tissue) being formed. Goldsberg tends to rule out the endocrine system as being of great influence, and as another interesting finding states that the rate of protein synthesis does not appear to be increased. These conclusions were confirmed in part by Van Linge,[74] who noted in studies on albino rats that in trained muscle the muscle weight doubled and was able to generate three times its normal force. Van Linge also noted increased protein synthesis and increased amounts of connective tissue between the muscle fibers. However, Van Linge went further in noting an increase in muscle fibers as well. Gonyea et al, [35] also reported an increase in muscle fibers in cats after heavy resistance training. deVries[30] questions whether or not actual mitotic cell division has been found, so hyperplasia is still a controversial model for muscular size increase due to training.

Another cellular change that results from strength training is a selective increase in the size of Type II (fast twitch) fibers. Thorstensson[72] noted selective hypertrophy of Type II fibers, although he does not specify whether Type IIA or Type IIB fibers are selectively increased in size.

Still another cellular change that occurs due to strength training is an increase in the levels of activity of certain enzymes. Costill et al.[24] noted significant increases in glycolytic, ATP-PC, and Krebs' Cycle enzyme activity with a training program of repeated 30-second bouts of maximal isokinetic exercise. In six-second bouts, however, increases were only noted in muscle phosphofructokinase. This led Costill to postulate that levels of activity probably are more related to duration of exercise than to intensity of exercise.

In addition to having effects on the muscle fiber directly, strength training also appears to enhance neuromuscular control and electrical activity within the muscle. Moriteni and deVries[53] found that after eight weeks of progressive resistance exercise, both neural and hypertrophic factors combined to cause a strength increase. In this study, as the strength of the subjects increased, the slope coefficient of the electromyogram (EMG) was found to decrease, an indication of more efficient electrical activity. Cross-sectional area of the exercised muscle was found to increase. In addition, the contralateral limb also showed significant strength gain, although cross-sectional area and EMG slope coefficient did not change. It was concluded that the neural factors are most important in the early development of strength gain and that hypertrophic factors gradually take over. This finding is confirmed by Hakkinen and Komi,[38] who tested 14 male subjects during a 16-week weight training program and eight weeks of detraining afterwards. It was found that neural factors were affected first, then fiber diameter. The majority of the changes occurred in the first half of the training program.

Detraining is found to reverse the effects of the training program, again affecting neural factors first then fiber diameter. The majority of the changes occurred in the first half of the detraining process.

Other tissues are affected by strength training as well. Bones develop structural changes depending on where the bone is stressed most, with increased deposition of mineral and bone matrix in those areas. Ligaments and tendons develop more strength at their attachments. On the articular surface of joints, cartilage tends to thicken in proportion to the increased load.[12]

The results of weight training in terms of performance, particularly regarding strength, are well documented. Significant gains in strength have been reported in isometric, isotonic and isokinetic programs.[16,19,46,6,53,52,57,48,21,29,9,62,72,38,24,17]

The applicability of these various programs to sports is still open to question. Isotonic and isokinetic programs seem to improve athletic power,[19,26,47] whereas isometric training programs do not.[3,8] These power improvements seem to be specific to joint speeds at or below the speed of training.[26,47]

One of the traditional arguments against weight training is that it tends to make an athlete "muscle-bound," thus decreasing the athlete's speed. This was disproved by Zorbas and Karpovich,[46] who showed that a group of weight lifters could perform a speed task faster than a control group of non-lifters. Clarke and Henry[20] also showed that speed is improved by strength training.

Measurement of Strength and Power

Several operational definitions of strength have been offered for various sport activities. Choodinov[18] defined absolute strength as maximum muscular strength without consideration of body weight.

This definition could be used in relation to events such as the shot put or hammer throw. Relative strength is expressed as the ratio of maximum muscular strength to body weight. Events using relative strength are running and jumping. Berger[12] expands these definitions. Absolute strength can be defined as strength in moving a heavy object other than body weight. It is measured by application of muscular force to an external object such as a strain gauge or dynamometer. Relative strength is strength used in moving body weight and can be measured by exercises such as chins and dips.

Absolute power is the strength or force involved in moving an external object quickly. An example is the shot put. Relative power is strength used in moving body weight rapidly. It is perhaps the measurement of power most pertinent to sports situations. Relative power is measured by such motor performance tests as the 50-yard dash and the vertical jump.

Absolute strength can be measured isometrically, isotonically, or isokinetically. An isometric contraction of muscle occurs when force is exerted but muscle length does not change. Common methods of isometric measurement use cable tensiometers and strain gauges. Kennedy[45] has found that the outputs of these devices correlate very well with each other and also with measures of maximum isotonic strength. He also found that the measurement results were dependent upon factors of subject selection and investigator experience. Bender and Kaplan[5] evaluated the Multiple-Angle Testing Method for isometric strength testing. In this procedure, the subject exerts maximum voluntary isometric contractions at several points in the range of motion. Bender and Kaplan found this method to be reliable in most isometric testing. The disadvantage of the method is that it does not give a strength value for the whole range of motion, only at preselected points.

Isotonic testing, which involves the application of muscular force against a constant resistance through a range of motion, is widely used in the coaching profession as a method of determining performance levels and improvements. For scientific purposes, however, the method is not reliable because the testing involves guessing the subject's repetition maximum (RM).[30] Generally, an attempt is made to predict the subject's 1-RM load, and testing begins slightly below that weight so that the subject can work up to maximum weight. This procedure can require a number of trials for the 1-RM load to be established and subject fatigue can greatly influence the final result. A further disadvantage to isotonic testing is that in most cases the test involves a sport-specific skill, e.g., the bench press. The subject's previous experience in such skills also will influence the results of the testing, with a less experienced subject not being able to lift as much as he/she might after motor learning has taken place.

The use of isokinetic exercise recently has become a very popular method of both testing and training. An isokinetic contraction occurs when a muscle exerts force, either concentrically or eccentrically, at a constant velocity.[30] The reliability of the isokinetic method has been established by Molnar.[50] Pilot tests of 46 children showed a very high test-retest reliability. In a later study, Molnar et al.[51] found that different behavioral and technical aspects of testing caused no significant variations in testing results. Other investigators, however, have found that procedural and physical errors can greatly bias results if not corrected. For example, Winter et al.[76] found that gravitational effects could produce significant errors in peak torque measurement. This effect can be corrected mathematically by taking into account the weight of the limb and the effect of gravity on it.[40,52]

Another error which can occur is more technical in nature. Sapega et al.[62] found that during isokinetic testing an "overshoot" phenomenon can occur at the end of the free acceleration period when the resistance mechanism engages. This effect was found to produce a spike on the recording graph immediately before formation of the torque curve. Investigators must be careful not to include the spike in their torque calculations, as the spike represents inertial forces and not muscular tension.[62] Sinacore et al.,[63] found that increasing the damp of the machine aids in reducing "overshoot" and in identifying peak torque. Increased damp also has the effect of shifting the torque curve to the right.[62] This can result in decreased measurement of peak torque because the torque curve seems to appear later in the range of motion. Sinacore emphasized the importance of keeping the damp settings constant during testing, recording the damp settings for future reference and reproducibility of results, and being familiar with the damping effects of available equipment.[63]

Other factors, both physical and psychological, are involved in the expression of a subject's strength, particularly in the case of adolescents. Tabin et al.[71] and Maughan et al.[48] both found that lean body mass correlates well with the maximum torque produced. These results appear to be confirmed by Watson and O'Donovan[75] who found that all anthropometric measurements, except skinfolds, have positive correlations with strength. Skinfolds produced negative relationships.

Ikai and Steinhaus[44] found that psychological inhibition tends to be the limiting factor in the expression of strength. It was shown that stimuli which cause the inhibition to be inhibited, such as a close proximity gunshot or a hypnotic suggestion of strength, all caused temporary increases in strength. The opposite effect also takes place. When a stimulus that increases the normal inhibition occurs, such as a hypnotic suggestion of weakness, then strength tends to decline.

Weight Training Programs

Isometric Training

An isometric contraction is the exertion of force by a muscle without change in muscle length. In early research on muscle strength and strength training, isometric training was studied most. Hettinger and Muller were the pioneers in this early research. Hettinger[41] found that one isometric contraction per day at 40-50% of maximal strength is sufficient to cause an increase in muscle strength. Earlier work by Hettinger and Muller indicated that one contraction per day at two-thirds maximum strength for six seconds is best for promoting strength gains. It was found that greater force, number of repetitions, or duration of contraction do not seem to change the rate of strength gain.[30] In later work, Muller[55] found that the rate of gain with maximum exercise increases at 12% of maximum strength per week up to approximately 75% of maximum strength. Thereafter, the rate of strength gain declines exponentially as the level of strength approaches 100% maximum. Muller also reported that a maximal muscle contraction causes a prolonged stimulus for the development of contractile tissue that lasts approximately seven days.[55] An additional finding was that detraining causes a strength decrease of approximately 5% per day.

Muller and Rohmert[30] suggest that five to ten daily repetitions of a maximal contraction held for five seconds provides the most effective protocol for isometric strength development. Muller[54] cited several advantages for isometric training. First, the method saves time and money by keeping equipment simple and by using only one contraction a day. Muller also stated that fatigue would not necessarily occur because only one contraction a day was needed to build strength and that the heart and circulatory systems were not stressed by isometric exercise. These latter suggestions, particularly those regarding the heart, have been disputed in recent literature.[30]

Without having comparisons to other types of training in their work, Hettinger and Muller have left themselves open to the criticism of other investigators. One of the major arguments is that isometric training has poor applicability to sports and athletics. Berger[8] and Ball et al.[3] found that static training causes increases in strength but not in vertical jumping ability. A possible reason for this is the specificity of isometric training which promotes increases in strength at zero velocity and only at the specific joint angle to which resistance is applied.[5,30]

Isotonic Training

An isotonic contraction involves a muscle producing force while its length changes. If the muscle shortens during the contraction, a concentric contraction occurs; if the muscle length increases while force is produced, an eccentric contraction is taking place. Isotonic methods of strength training probably are the most frequently used in sports and athletics.

DeLorme,[29] who was among the first to systematize isotonic strength training as a means of inducing muscular strength gain and hypertrophy, dubbed his program "progressive resistance exercise." Isotonic exercise has the advantage of being less specific to joint angles than is isometric exercise.[28] That is, the contraction may take place throughout the entire range of motion. With this advantage, however, comes the problem of finding optimum exercise loads and regimens for maximum strength gains. DeLorme[29] at first suggested 70-100 repetitions, but later reduced this number to 20-30.[4] This is now the accepted number of repetitions used in most isotonic rehabilitation programs. In terms of sports, Berger[10] found that a smaller number of repetitions, between three and nine per set with an average of three sets, is better for building strength.

In terms of exercise load, DeLorme[4] found that one set of 10 repetitions at 1/2 10 RM followed by two sets of 10 repetitions at 3/4 10 RM and 10 RM produced significant gains and muscular hypertrophy. Barney and Bangerter's findings[4] tend to support DeLorme. Berger[11] finds that maximum or near maximum loads for exercise programs are more effective for producing strength. The DeLorme procedure seems most effective for producing muscular hypertrophy.[4]

The optimum frequency of workouts also is open to question, but appears to be between three and five times per week.[33] Capen[17] suggests that when using high loads with few repetitions one should work out only three times per week to ensure better recovery.

Rasch and Morehouse[59] and Darcus and Salter[28] found that greater gains result from isotonic programs than from isometric programs. In contrast, Berger[6] found that isometric training produces more strength than does isotonic training. In later work, Rasch[60] concluded that strength may be gained by either isometric or isotonic exercise.

Isokinetic Training

An isokinetic contraction occurs when a muscle shortens or lengthens at a constant angular velocity.[43] If all factors causing variations of force are controlled, the muscle theoretically will contract at full capacity at all points in the range of motion.

One advantage of isokinetic training over isometric and isotonic training is its applicability to sports. Most sport movements take place at faster velocities than do weight training movements. It has been shown in studies utilizing isokinetic equipment that strength gains occur chiefly at velocities that are equal to or slower than the training velocity.[26,57,47] This would tend to make isokinetic training superior to isometric and isotonic training. The research of Hutinger,[42] Lesmes,[47] and Pipes and Wilmore,[57] tends to confirm this premise, although the latter study yielded controversial results. The chief disadvantage of isokinetic training is the cost of the equipment which tends to be prohibitive on a large scale for most institutions.

In-season Weight Training

In contrast to the work done on weight training programs and the physiological effects of weight training, comparatively few studies have been done to determine the effectiveness of weight training during a competitive sports season. However, almost all the serious scientific work suggests that weight training should be an essential part of the in-season conditioning program.

Campbell[15] was among the first to study the effects of weight training during the season. Sixty-two college athletes were divided into two groups. At the beginning of their respective seasons one group began weight training in addition to their normal sports program. The second group participated only in regular practice and games. At mid-season the roles of the two groups were reversed, and the nonlifting group began lifting. Campbell found that while the training procedures were more effective in the first half of the season, both groups had significantly higher performance on physical fitness tests while weight training.

Guess[37] studied the effects of in-season weight training on 60 college football players. It was found that those athletes who did not lift weights during the season sustained significant losses in strength compared to the lifting group. These findings were confirmed by Coleman[16] who studied 20 major league baseball players over the course of an 162-game season. At the end of the season, the training group was found to be significantly stronger and to have significant reductions in absolute body fat and relative body fat as well as increased lean body mass.

A point of uncertainty exists in the optimum number of workouts per week during the season. While most sources[22,15,2,39] advocate two sessions per week. Guess[37] maintains that one per week is sufficient.

Strength Training in Adolescents

Few studies have specifically been aimed at adolescent weight training. It has been speculated that adolescents cannot gain as much hypertrophy and muscular development as more mature subjects can.[30] The primary reason for this is a lower level of testosterone secretion before puberty. Questions also have been raised about the safety of weight training for adolescents.[13]

The studies done in this area vary in results. Kusinitz[46] demonstrated significant increases in scores of performance tests such as push-ups and pull-ups. Anthropometric gains, although small, were statistically significant. Pitman's[58] findings tend to confirm these results. Fisher,[32] however, found that while gains in strength and anthropometric measurements were made, they were not significantly different from control subjects who participated in an exercise program that did not include weight training. Of these studies, only one injury was reported in almost 200 participating subjects. This suggests that weight training can be safe for adolescents if they are properly supervised.

CHAPTER III

PROCEDURE

Sampling

Twelve male high school athletes volunteered to participate in this study. All had been medically cleared to participate in high school athletics. All subjects were in ninth and tenth grade and were participants on the high school basketball team corresponding to their levels in school. Informed consent was obtained from the athletes and their parents prior to the beginning of the study.

The subjects were divided into control and experimental groups with a stratified technique. The subjects were first classified by the position they played on the basketball team: guard or forward/center. The subjects then were divided further by their school grade so that there were four groups total: a) ninth-grade guards, b) ninth-grade forward/centers, c) tenth-grade guards, and d) tenth-grade forward/centers. The members of each group then were randomly assigned to the control and experimental groups. The physical characteristics and abilities of the subjects were assumed to be normally distributed within their respective populations. No attempts were made to match subjects by body weight or basketball skill level.

Weight-training Program

The control subjects participated only in regular team practices and games. Those subjects assigned to the experimental group trained with weights twice a week in addition to the regular practice routine. The weight workout was confined to the lower extremities and consisted of leg press, quadricep extension, and hamstring curl exercises. The subjects performed three sets of eight repetitions at the 8-RM load which was established in a testing session prior to beginning the weight training program. Weight training sessions were held after practice twice a week. Subjects were dropped from the study if they missed more than four consecutive training sessions. One subject who did miss all sessions of the weight program had data that were acceptable for use in the control group, so he was reassigned there to replace one subject who was forced to leave due to injury. The remaining subjects were able to successfully complete the study. Progress was noted on individual charts. Data were collected on the control subjects only at regular testing sessions.

Testing

The leg strength and power of the athletes were tested by a standard protocol on the Cybex II dynamometer and by a vertical jump test. A total of three testing sessions were held, one at the beginning, middle, and end of the competitive season. Testing sessions were conducted by the same personnel who fulfilled the same duties each time. The two tests will be dealt with separately here.

Cybex Testing

Testing was conducted within a week of the targeted date for each testing session. The equipment consisted of a Cybex II dynamometer with a Cybex data reduction computer. Before testing commenced, all equipment was calibrated to the manufacturer's standards. The subjects were required to warm-up prior to testing by riding an exercise bicycle for five minutes and by performing exercises for approximately the same amount of time. Each subject then was seated on the testing apparatus and secured to it by means of restraining straps placed on the chest, abdomen, upper thigh, and ankle. The straps served the purpose of isolating the appropriate muscle groups. Damping and torque scale settings were kept constant for all subjects. All apparatus settings, such as torque arm length, were noted at the initial testing session for each subject and were reproduced for later testing. Backboards were placed beneath the subject's lower back for additional comfort when necessary. Backboard conditions were reproduced at subsequent testing sessions as well. Each subject was required to perform five repetitions at 60^{o}/second and five repetitions at 240^{o}/second with their dominant leg. The peak torque was recorded for each speed. Gravitational effects were accounted for by weighing the limb prior to testing in accord with standard Cybex procedures.

Vertical Jump Testing

Testing was conducted within a week of the targeted date. The testing apparatus is a unit constructed by Smoak[66] which is designed to measure the distance through which the subject accelerates prior to take-off in a vertical jump and thus to give a true indication of the leg power generated during the jump. Two measurements are recorded: one measures the crouch of the subject prior to jumping, the second measures the actual jump height. The point of measurement is on the subject's back at the level of the center of gravity where two measuring tapes are attached. The subject is required to perform three jumps at each testing session with the best jump being used.

CHAPTER IV

RESULTS AND DISCUSSION

Body Weight

Subject body weight did not change significantly in either group. In the control group, weight decreased between the second and third test sessions, but increased slightly between the first and second, with a slight overall increase noted (see Table 1). In the experimental group, body weight again showed a slight overall increase, with an insignificant decrease between the first and second test sessions, and a slight increase between the second and third (see Table 2). No attempts were made to control subject body weight through diet or exercise.

Peak Torque

In leg extension and flexion at 60^{o}/second, gain score calculations and comparative t-tests revealed no significant gains or losses in peak torque when the groups were compared. No significant gains or losses were noted within either group. In the control group, an insignificant increase was noted in both extension and flexion between the first and second test sessions (see Tables 3-6), with insignificant gains being made between the second and third test sessions and over the length of the study (see Tables 7-22). In the experimental group, insignificant increases were noted in leg

Table 1. Control Group Body Weight

Test Session	$\bar{X}$	sum x^2	s^2	s
1	137.29	1431.4	238.57	15.45
2	139.57	1505.68	250.95	15.48
3	138.86	1098.86	183.14	13.53

Table 2. Experimental Group Body Weight

Test Session	$\bar{X}$	sum x^2	s^2	s
1	153.5	629	209.67	14.48
2	152.5	561	187	13.67
3	154.5	702.81	234.27	15.31

Table 3. Gain Score D1-D2 60^{o}/second Extension

Test Session	$\bar{X}$	sum x^2	s^2	s
Experimental	3	582	194	13.93
Control	-6.57	345.68	57.61	7.59

Table 4. Gain Score D1-D2 60^{o}/second Flexion

Test Session	$\bar{X}$	sum x^2	s^2	s
Experimental	3.75	504.74	168.25	12.97
Control	-0.14	310.86	51.81	7.20

Table 5. Gain Score D1-D2 240^{o}/second Extension

Test Session	$\bar{X}$	sum x^2	s^2	s
Experimental	-1	6	2	1.41
Control	0.14	130.86	21.81	4.67

Table 6. Gain Score D1-D2 240^{o}/second Flexion

Test Session	$\bar{X}$	sum x^2	s^2	s
Experimental	-0.5	125	41.67	6.46
Control	2	142	23.67	4.87

Table 7. Gain Score D2-D3 60°/second Extension

Test Session	$\bar{X}$	sum x^2	s^2	s
Control	9.42	410.74	68.48	8.27
Experimental	-0.75	168.74	56.25	7.50

Table 8. Gain Score D2-D3 60°/second Flexion

Test Session	$\bar{X}$	sum x^2	s^2	s
Control	3.71	359.40	59.9	7.24
Experimental	.25	314.74	104.91	10.24

Table 9. Gain Score D2-D3 240°/second Extension

Test Session	$\bar{X}$	sum x^2	s^2	s
Control	2.29	55.4	9.23	3.04
Experimental	5.25	46.74	15.58	3.95

Table 10. Gain Score D2-D3 240^{0}/second Flexion

Test Session	$\overline{X}$	sum x^2	s^2	s
Control	-4	292	48.67	6.98
Experimental	.25	109	36.33	6.03

Table 11. Gain Score D2-D3 Total Power

Test Session	$\overline{X}$	sum x^2	s^2	s
Control	-40.71	45477537	757959.55	870.61
Experimental	-20.67	1872010.4	936005.21	967.47

Table 12. Gain Score D2-D3 Power/kg Body Weight

Test Session	$\overline{X}$	sum x^2	s^2	s
Control	-0.79	919.93	153.32	12.38
Experimental	-3.5	226.02	113.01	10.63

Table 13. Gain Score D2-D3 Variance Testing

	60% Ext.	60% Flex.	240% Ext.	240% Flex.	Total Power	Power/kg
s_1^2	68.46	104.91	56.25	48.67	936,005.21	12.38
s_2^2	56.25	59.9	9.23	36.33	757,959.55	10.63
F	4.64	1.75	6.09	1.34	1.23	1.16
equal variance	yes	yes	yes	yes	yes	yes

Table 14. Gain Score D2-D3 t-tests

	60% Ext.	60% Flex.	240% Ext.	240% Flex.	Total Power	Power/kg
$\bar{D}_1$	9.42	3.71	2.29	-4	- 40.71	-0.79
$\bar{D}_2$	- .75	.25	5.25	- .25	-202.67	-3.53
t	-2.02	-0.64	1.41	0.36	- 0.26	-0.33
Significant Difference	no	no	no	no	no	no

Table 15. Gain Score D1-D3 60^{0}/second Extension

Test Session	$\bar{X}$	sum x^2	s^2	s
Control	2.86	454.86	75.81	8.71
Experimental	2.5	419.27	139.75	20.48

Table 16. Gain Score D1-D3 60^{0}/second Flexion

Test Session	$\bar{X}$	sum x^2	s^2	s
Control	3.57	793.68	132.28	11.50
Experimental	4	276	92	9.59

Table 17. Gain Score D1-D3 240^{0}/second Extension

Test Session	$\bar{X}$	sum x^2	s^2	s
Control	2.43	86.03	14.34	3.79
Experimental	4.25	21	7	2.65

Table 18. Gain Score D1-D3 240°/second Flexion

Test Session	$\bar{X}$	sum x^2	s^2	s
Control	-1	778	129.67	11.39
Experimental	-3	277	92.33	9.61

Table 19. Gain Score D1-D3 Total Power

Test Session	$\bar{X}$	sum x^2	s^2	s
Control	553.43	6597617.7	1099602.9	1048.62
Experimental	280.67	10488127	522406.33	724.16

Table 20. Gain Score D1-D3 Power/kg Body Weight

Test Session	$\bar{X}$	sum x^2	s^2	s
Control	8.2	1430.16	238.36	15.44
Experimental	3.83	300.72	150.36	12.26

Table 21. Gain Score D1-D3 Variance Testing

	60% Ext.	60% Flex.	240% Ext.	240% Flex.	Total Power	Power/kg
s_1^2	419.27	132.28	14.34	129.67	5224406.33	238.36
s_2^2	75.81	92	7	92.33	1099602.9	150.36
F	5.53	1.44	2.04	1.40	4.75	1.59
equal variance	yes	yes	yes	yes	yes	yes

Table 22. Gain Score D1-D3 t-tests

	60% Ext.	60% Flex.	240% Ext.	240% Flex.	Total Power	Power/kg
$\bar{D}_1$	82.86	3.57	2.43	-1	553.43	8.2
$\bar{D}_2$	2.5	4	4.25	-3	280.67	3.83
t	- 0.03	0.07	-0.13	-0.31	- 0.47	-0.48
Significant Difference	no	no	no	no	no	no

flexion during all phases of the study (see Tables 4, 7, and 16). In leg extension, insignificant increases were noted overall and between the first and second test sessions (see Table 3), with an insignificant decrease evident between the second and third test sessions (see Table 7). In leg extension and flexion at 240^{0}/second gain scores and comparative t-tests showed no significant increases or decreases when the two groups were compared. The experimental group showed a net decrease in peak torque at 240^{0}/second of leg flexion (see Tables 6, 10, and 18), both between testing sessions and for the study as a whole. In leg extension at 240^{0}/second, the experimental group showed an initial decrease in peak torque between the first and second test sessions, but showed gains between the second and third test sessions and for the duration of the study (see Tables 5, 9, and 17). The control group showed insignificant gains in peak torque at 240^{0}/second of leg extension, while insignificant decreases were noted for 240^{0}/second leg flexion overall and between the second and third test sessions, with an insignificant increase between the first two sessions.

Variance analysis and t-tests for gain scores D1-D2 are found in Tables 25 and 26. Means, variances, and standard deviations are found in Tables 27-38.

Power

Both groups showed insignificant increases in both total leg power and leg power/kg of body weight. The control group showed the greater increase, although the difference was found to be nonsignificant (see Tables 37, 38, 23, 24, 11, 12, 19, and 20).

Table 23. Gain Score D1-D2 Total Power

Test Session	$\bar{X}$	sum x^2	s^2	s
Experimental	567.5	1329945	443315	665.82
Control	462	1179088	196514.67	443.30

Table 24. Gain Score D1-D2 Power/kg Body Weight

Test Session	$\bar{X}$	sum x^2	s^2	s
Experimental	8.15	308.8	102.93	10.15
Control	9	385.68	64.28	8.02

Table 25. Gain Score D1-D2 Variance Analysis

	60% Ext.	60% Flex.	240% Ext.	240% Flex.	Total Power	Power/kg
s_1^2	194	168.25	21.81	41.67	443315	102.93
s_2^2	57.61	51.81	2	23.67	196514.67	64.24
F	3.37	3.24	10.91	1.76	2.26	1.60
equality	yes	yes	no	yes	yes	yes

Table 26. Gain Score D1-D2 t-tests

	60% Ext.	60% Flex.	240% Ext.*	240% Flex.	Total Power	Power/kg
$\overline{D}_1$	-6.57	-0.14	0.14	2	462	9
$\overline{D}_2$	3	3.75	-1	-0.5	567.5	8.15
t	1.51	0.51	-0.61	-0.74	0.32	-0.15
Significant Difference	no	no	no	no	no	no

*The t-test of 240% extension is a Cochrane-Cox t-test.

Table 27. Control Group 60^0/second Flexion

Test Session	$\bar{X}$	sum x^2	s^2	s
1	75	2180	363.33	19.06
2	74.86	1250.86	208.48	14.44
3	78.57	1483.68	247.28	15.72

Table 28. Control Group 240^0/second Extension

Test Session	$\bar{X}$	sum x^2	s^2	s
1	78	584	97.33	9.87
2	78.14	484.86	80.81	8.99
3	80.43	427.68	71.28	8.44

Table 29. Control Group 240^0/second Flexion

Test Session	$\bar{X}$	sum x^2	s^2	s
1	47.43	1255.68	209.28	14.47
2	49.43	697.68	116.28	10.78
3	46.43	337.68	56.28	7.50

Table 30. Control Group Total Power

Test Session	$\overline{X}$	sum x^2	s^2	s
1	3502.29	4191257.4	698542.9	8.82
2	4111.71	4614255.4	769042.56	876.95
3	4055.71	4008560.9	668093.44	817.37

Table 31. Control Group Power/kg Body Weight

Test Session	$\overline{X}$	sum x^2	s^2	s
1	55.44	466.92	77.82	8.82
2	64.44	592.1	98.68	9.93
3	63.66	1588.81	264.80	16.27

Table 32. Control Group 60^{0}/second Extension

Test Session	$\overline{X}$	sum x^2	s^2	s
1	118.56	1506.86	251.14	15.8
2	116.57	947.68	157.95	12.57
3	126.00	830.00	138.33	11.76

Table 33. Experimental Group 60^{o}/second Extension

Test Session	$\bar{X}$	sum x^2	s^2	s
1	152	576	192	13.86
2	155	1190	396.67	19.92
3	154.25	1598.74	532.91	23.08

Table 34. Experimental Group 60^{o}/second Flexion

Test Session	$\bar{X}$	sum x^2	s^2	s
1	86.5	153	51	7.14
2	90.25	882.74	294.25	17.15
3	90.5	261.00	87	9.33

Table 35. Experimental Group 240^{o}/second Extension

Test Session	$\bar{X}$	sum x^2	s^2	s
1	96	138	46	6.78
2	95	104	34.67	5.89
3	100.25	218.74	72.91	8.54

Table 36. Experimental Group 240°/second Flexion

Test Session	$\overline{X}$	sum x^2	s^2	s
1	57.5	41	13.67	3.70
2	57	90	30	5.48
3	54.5	141	47	6.86

Table 37. Experimental Group Total Power

Test Session	$\overline{X}$	sum x^2	s^2	s
1	4940.75	480498.74	160166.25	400.21
2	5508.25	2048814.7	682938.25	826.40
3	5393.67	1052788.7	526394.34	725.53

Table 38. Experimental Group Power/kg Body Weight

Test Session	$\overline{X}$	sum x^2	s^2	s
1	71.63	355.00	118.33	10.88
2	79.78	444.40	148.13	12.77
3	80.23	78.81	39.41	6.28

DISCUSSION OF RESULTS

The finding of no significant gains in peak torque for the experimental group makes it doubtful that two weight training sessions per week with three sets of eight repetitions at the 8-RM load are sufficient to build strength. This finding would tend to agree with those of others in the area. Berger[9] noted that while strength gains could be made in two weeks, training twice weekly with a load of 2/3 1-RM, at least one maximal effort had to be made at a third weekly training session for the effect to occur. Berger added that the increase in strength with this particular training program was due largely to that maximal effort. Berger's statement tends to support the earlier conclusion of Steinhaus[66] that no matter how much a muscle is worked, it must be overloaded in order for strength gains to occur. In some later work, Berger and Hardage[11] concluded that maximum or near maximum loads are necessary for optimal strength increases. This observation also was supported by Barney and Bangarter[4] who showed that with heavier loads, greater gains in strength and hypertrophy could be made.

While a strength loss in the control group was expected, that loss did not occur. Fisher[32] obtained similar results in that a weight training group of junior high school athletes had scores on a standardized physical education test that were not significantly different from those of a control group performing the same test. This is in contrast to the findings of Pitman[56] and Kusinitz and Keeney[45] who found significant improvements in both physical fitness tests and anthropometric measurements. However, it is questionable whether losses of strength reported in subjects who were not participating in weight training could be due to the attrition of the competitive season. The subjects in this study were not involved in a weight training program prior to the start of their season. Coleman[22] reported significant strength losses in major league baseball players who did not train as the season went on. These players did lift weights in their preseason training. This also was true in a study by Guess,[37] who reported significant strength loss in college football players who did not train with weights during the season. In this study, the players had again lifted during preseason practice, but stopped once the season began. The lack of strength loss in the control subjects of the present study tends to argue that the strength loss reported by Guess and Coleman probably is more from a detraining effect than the attrition of athletic competition. It should be remembered, however, particularly in the case of Coleman's study, that the competitive season of those athletes is longer, and competition tends to be more intense than in high school sports.

The weight training program in this study was designed to be a maintenance program. In view of this, nonsignificant or nonexistent losses of strength in the experimental group are not surprising. However, it should be noted that the control subjects did not suffer significant strength losses either. This tends to preclude the conclusion that the weight program maintained the strength level of the experimental group.

Both groups failed to increase peak torque at the 240°/second speed. This finding tends to confirm the theory of specificity of training speed reported in previous work. Coyle et al.[26] found that college men who trained isokinetically at fast speeds improved power at their training velocity and at all slower velocities, but those who trained at slow speeds only improved power at their training velocity. Lesmes et al.[47] also found that training velocity is an important factor in power improvement.

The lack of improvement in power by the experimental group was unusual in view of previous findings which showed weight training does improve power.[16,19,8] Again, however, since the weight program was designed to be a maintenance program and did not produce significant gains in peak torque for the experimental group, it is possible that the program was not intense enough to produce gains in power either.

An interesting observation is that the control group improved in leg power slightly (but nonsignificantly) more than did the experimental group. A possible explanation for this difference is to be found in the fact that the experimental subjects tended on the average to be physically more mature than the control subjects. The mean body weight of the control group was approximately 15 pounds less than that of the experimental group throughout the study. It is conceivable that during the season the smaller and less mature athletes gained power by a motor learning mechanism. This idea has support in the work of Moriteni and deVries[53] and Hakkinen and Komi[38] who showed that neural control tends to be one of the most important factors in early strength development due to training. Moriteni and deVries found that as strength increases the slope coefficient of the electromyogram decreases, indicating greater efficiency of electrical activity. This could be the result of a more efficient pattern of motor unit recruitment in the involved muscles. In a sport where jumping predominates, such as basketball, the athletes receive continual practice at the skill during the season and conceivably will improve as the neural recruitment pattern improves.

Another factor that could have influenced final results was the motivation of the subjects. During the latter half of the season, several subjects were heard to say that they were not as interested in basketball as they had once been. Ikai and Steinhaus[44] found that a key to the expression of human strength is the removal of inhibitions that prohibit this expression. Conversely, reinforcement of this inhibition would tend to further mask strength expression. It is possible that an unmotivated subject will be more inhibited than a motivated subject.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Eleven high school basketball players were tested for leg extension/flexion peak torque and leg power at the beginning, middle, and end of their competitive season. During the season, four of the athletes participated in a weight training program that consisted of two training sessions per week in addition to practice and games. The training load used was 8-RM for each subject, with an exercise regimen of three sets of eight repetitions. The other subjects participated only in regular practice and game activities. Peak torque and leg power were analyzed after all data were collected. Statistical analyses revealed no significant differences between groups in either peak torque or power. In addition, no significant changes were noted in peak torque or power within the comparison groups during the study. The athletes were not involved in weight training programs prior to the season. In an unusual finding, the control group experienced a nonsignificant gain in leg power during the season.

From these results the following conclusions were drawn:

1) Two weight training sessions per week with a regimen of three sets of eight repetitions with an 8-RM load is not sufficient to build significant amounts of strength.

2) A conclusion that the weight training program maintained prior strength levels is unjustified in this study because the control group maintained strength and power levels successfully without a weight training program.

3) Losses of strength noted in previous in-season weight training studies probably are due to a detraining effect rather than to the attrition of sports participation.

4) An insignificant increase in control group leg power was possibly due to a motor learning effect from repeated jumping practice as the season progressed.

For future research, the following recommendations are made:

1) The study should be repeated with a larger sample size and with two full, comparable teams being used as subjects. In this way, team unity can be preserved and better comparisons made.

2) A study comparing a group that had lifted weights prior to the season with a group that had not would be a revealing test of the detraining vs. attrition theory.

3) Studies with a variety of age groups and weight training programs are needed to determine the efficacy of exercise regimens for in-season weight training.

4) Testing should be conducted at medium speed Cybex setting, e.g. 180^{o}/second, rather than 240^{o}/second to avoid potentially misleading torque readouts due to the torque overshoot phenomena.

APPENDIX

Raw Data Tables

RAW DATA TABLES
Peak Torque is in ft./lbs.
Power is watts. Power/kg. is in watts/kg. body weight

CONTROL SUBJECT 1:

	60% ext.	60% flexion	240% ext.	240% flexion	Total Power	Power/kg.
1)	136	83	81	52	3687	54.9
2)	124	86	80	53	4623	68.3
3)	141	91	85	53	4642	69.1
D3-D1)	5	8	4	1	955	14.2
D2-D1)	-12	3	-1	1	936	13.4
D3-D2)	17	5	5	0	19	0.8

CONTROL SUBJECT 2:

	60% ext.	60% flexion	240% ext.	240% flexion	Total Power	Power/kg.
1)	117	87	83	61	3980	62.6
2)	104	74	77	58	4985	78.4
3)	113	76	83	46	3897	63.6
D3-D1)	-4	-11	0	-15	-83	1.0
D2-D1)	-13	-13	-6	-3	1005	15.8
D3-D2)	9	2	6	-12	-1088	-14.8

CONTROL SUBJECT 3:

	60% ext.	60% flexion	240% ext.	240% flexion	Total Power	Power/kg.
1)	147	92	84	62	3905	61.4
2)	138	91	85	57	4128	62.7
3)	138	96	88	56	4103	62.3
D3-D1)	-9	4	4	-6	198	0.9
D2-D1)	-9	-1	1	-5	223	1.3
D3-D2)	0	-5	3	-1	-25	-0.4

CONTROL SUBJECT 4:

	60% ext.	60% flexion	240% ext.	240% flexion	Total Power	Power/kg.
1)	100	36	56	19	1819	38.1
2)	104	47	61	26	2490	50.8
3)	110	55	64	38	2000	39.3
D3-D1)	10	19	8	19	181	1.2
D2-D1)	4	11	5	7	671	12.7
D3-D2)	6	8	3	12	-490	-11.5

CONTROL SUBJECT 5:

	60% ext.	60% flexion	240% ext.	240% flexion	Total Power	Power/kg.
1)	111	70	79	50	3167	51.7
2)	108	71	73	51	3413	55.3
3)	128	84	75	43	4195	68.4
D3-D1)	17	14	-4	-7	1028	16.7
D2-D1)	-3	1	-6	1	246	3.6
D3-D2)	20	13	2	-8	782	13.1

CONTROL SUBJECT 6:

	60% ext.	60% flexion	240% ext.	240% flexion	Total Power	Power/kg.
1)	121	71	80	44	3551	55.9
2)	123	72	84	50	4728	74.4
3)	122	60	81	37	5995	91.7
D3-D1)	1	-11	1	-7	2444	35.8
D2-D1)	2	1	4	6	1177	18.5
D3-D2)	-1	-12	-3	-13	1267	17.3

CONTROL SUBJECT 7:

	60% ext.	60% flexion	240% ext.	240% flexion	Total Power	Power/kg.
1)	130	86	83	44	4407	63.5
2)	115	83	87	51	4415	61.2
3)	130	88	87	52	3558	51.2
D3-D1)	0	2	4	8	-849	-12.3
D2-D1)	-15	-3	4	7	8	-2.3
D3-D2)	15	5	0	1	-857	-10.0

EXPERIMENTAL SUBJECT 1:

	60% ext.	60% flexion	240% ext.	240% flexion	Total Power	Power/kg.
1)	156	94	99	62	4424	57.3
2)	177	114	99	60	5235	67.8
3)	185	103	101	49	*	*
D3-D1)	29	9	2	-13	*	*
D2-D1)	21	20	0	-2	811	10.5
D3-D2)	8	-11	2	-11	*	*

* Areas marked with asterisk were not recorded or computed due to ankle injury subject suffered the day before the last testing session. This data was not included in final calculations.

EXPERIMENTAL SUBJECT 2:

	60% ext.	60% flexion	240% ext.	240% flexion	Total Power	Power/kg.
1)	156	82	92	59	4925	79.2
2)	143	73	91	54	4503	72.4
3)	136	85	95	55	4672	74.5
D3-D1)	-20	3	3	-4	-253	-4.6
D2-D1)	-7	-9	-1	-5	-422	-6.8
D3-D2)	-7	12	4	-4	169	2.2

EXPERIMENTAL SUBJECT 3:

	60% ext.	60% flexion	240% ext.	240% flexion	Total Power	Power/kg.
1)	164	79	104	54	5018	69.1
2)	166	87	101	63	5877	84.0
3)	159	92	112	64	6123	87.0
D3-D1)	-5	13	8	10	1105	17.9
D2-D1)	2	8	-3	9	859	14.9
D3-D2)	-7	5	11	1	246	3.0

EXPERIMENTAL SUBJECT 4:

	60% ext.	60% flexion	240% ext.	240% flexion	Total Power	Power/kg.
1)	132	91	89	55	5396	80.9
2)	134	87	89	51	6418	94.9
3)	137	82	93	50	5386	79.1
D3-D1)	5	-9	4	-5	-10	-1.8
D2-D1)	2	-4	0	-4	1022	14.0
D3-D2)	3	-5	4	-1	-1032	-15.8

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