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ABSTRACT

This document examines the effects of strength-development programs on the improvement of motor skills and sports competencies. Part one defines various terms used throughout the development studies. Part two discusses the mixed results of experiments involving speed of movement as the motor item indicative of strength development. Part three presents six experiments describing the effects of strength improvement on muscular power. Part four discusses two experiments testing the effect of strength training on circulatory-respiratory endurance. Part five illustrates the effects of strength improvement on various aspects of baseball, softball, swimming, football, basketball, and track. (Also included is a discussion on concentric-eccentric exercise and its effects on strength development, as well as a list of references.) (JS)

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STRENGTH DEVELOPMENT AND MOTOR-SPORTS IMPROVEMENT

This issue of the *Physical Fitness Research Digest* will be devoted to studies of the effects of strength development programs by various methods and procedures upon the improvement of motor skills and sports competencies. Muscular strength and muscular endurance, as two of the basic components of physical fitness, have been examined in depth in other issues of the *Digest*, as follows:

July 1971, "Isometric Versus Isotonic Exercises"

January 1973, "Toward a Better Understanding of Strength"

January 1974, "Development of Muscular Strength and Endurance"

In addition, the importance of strength to the athlete was shown in the April 1973 issue, "Characteristics of Athletes," and strength was an essential trait included in the October 1973 issue, "Individual Differences, Their Nature, Extent, and Significance." Other issues have included strength with other variables as a trait related to the individual's total effectiveness.

The importance of muscular strength and muscular endurance for the physical fitness and the overall competencies of boys and girls, and men and women, should now be reasonably well-established. However, still another strength-related area exists which has not been reviewed through the scientific literature. A sizeable number of experiments have been conducted on the effects of strength development and improvements in various motor traits and skills. Typically, in these experiments, a control and one or more experimental groups are formed; each experimental group is subjected to a specific strength development regimen, and the amounts of strength development and parallel improvements in motor traits are determined.

Some Definitions

Some of the terms that appear in this *Digest* have been used before in reporting strength development studies, while others have not. For purposes of clarification, several of these terms will be defined here.

Muscular strength: the contractive power of muscles as a result of a single maximum effort.

Muscular endurance: ability of the muscles to perform work by holding a maximum contraction for a given length of time or by continuing to move a submaximal load.

Isometric training: a held muscular contraction (sometimes called static training).

Isotonic training: raising and lowering a submaximal load, such as a weight, a given number of times (sometimes called dynamic training).

Concentric training: muscles shorten, as in lifting a weight.

Eccentric training: muscles lengthen, as in lowering a weight.

RM: repetitions maximum, or the weight that can just be lifted a set number of times through the full range of a given movement. For example, 10-RM is the weight that can be lifted only 10 times through the full range.

Significance: As has been true for all reports in the *Digest* series, the word "significant" is used in a statistical sense, which has to do with the elimination of sampling error. By way of explanation: differences may be expected from sample to sample as a consequence of randomly drawing repeated samples from the same population. Thus, it does not follow that a difference between means is due to an actual difference, but may simply be the result of sampling. Statistically, differences can be identified that are not the result of sampling; when this occurs, the difference is considered significant. In the *Digest* reports, minimum significance is generally at the .05 level, which means, exactly at this level, there are only five chances in 100 that a given difference can be attributed to sampling. When differences are indicated throughout, reference is to the difference between mean scores.

Speed of Movement

The largest number of studies on the effects of strength development on motor and sports improvement involved speed of movement as the motor item. The speed tests were of short duration, mostly involving the movement of an arm or a leg. The results of experiments related to this trait are presented here, with the exception of studies related to sports. Some conflicting results did occur, as will be seen.

Significant Improvements

A study to test the hypothesis that training with heavy weights leads to slower muscle contractions and, hence, will retard the athlete, was conducted by Zorbas and Karpovich (30). Two groups of 300 men each, 18 to 30 years of age, were contrasted: weightlifters, men who had participated in weightlifting for a minimum of six months and were still engaged in the activity, varying from little known weightlifters to world champions; nonweightlifters, men who had never indulged in weightlifting. For speed of muscle contraction, an apparatus was devised to record the number of rotary movements made in a clockwise direction; each subject completed 24 revolutions. The mean of the weightlifters was .174 sec. faster than for the nonweightlifters; this difference was significant at the .01 level. The investigators concluded that the findings of the study were contrary to the then (1951) common opinion of coaches, trainers and others associated with physical education who believed that weightlifting slowed the athlete's performances.

Masley, Hairabedian and Donaldson (18) compared the arm-cranking speed and coordination of an experimental weight training group with two control groups, one of which played volleyball and another which attended a sports lecture class. The weight training was progressive in nature, stressing overall body building; the exercise sessions were 30 minutes in length, three times per week for six weeks. Cranking speed was the time required to complete 24 rotary movements; the apparatus utilized was similar to that devised by Zorbas and Karpovich. Coordination was measured by accuracy of 50 thrusts with a fencing foil. The weight training group increased significantly more in strength and speed than did the volleyball group and more in coordination than did the sports lecture group.

Wilkens (29) tested the hypothesis that training by heavy resistance exercises causes an incipient muscle-bound condition, defined in part as impaired speed of movement. A control and two experimental groups of college men were established, as follows: nonweight trainers, subjects with no previous weight training experience; weight trainers, members of the university weightlifting team and others with at least a year of continuous, strenuous weight work; control, students from elementary swimming and golf classes. Both experimental groups participated in comprehensive and strenuous weight training programs. A rotary speed test was used, consisting of turning a mounted bicycle wheel with both hands for 90 seconds.

Among the conclusions of the investigator were: (a) weight training has no slowing effect of the speed of arm movement; (b) regular, long-term weightlifters are not "muscle bound" in the sense that their speed of movement is impaired; their speed is as great as that of other students and improves as much or more during a semester of training; (c) a semester of weight training does not increase speed of movement more than a semester of beginning swimming or golf; and, (d) individual differences in speed of arm movement are present, since the pre- and post-test correlations for all groups combined was .75; this correlation does not differ significantly between weightlifters and beginning swimmers and golfers.

Experimental and control groups of college men were formed by Clarke and Henry (11). Both groups were pre- and posttested on speed in a lateral adducted arm movement through an arc of 110 degrees. The experimental group participated in a progressive weight training program designed to increase the muscular strength of the upper and lower extremities, but which did not involve the movement under investigation; the training was conducted for 10 weeks, two times a week for 35 minutes each. The average of the training group improved significantly in speed, strength, and strength/mass ratio, whereas the average of the control group declined. A correlation of .405 was obtained between changes in the strength/mass ratio and movement speed.

In order to study the effect of weight training on speed of movement, Endres (13) formed a control and two experimental groups of boys 14 to 16 years of age; the groups were equated on the basis of speed of elbow flexion-extension while holding a 4-pound weight in the hand. The experimental groups underwent 16 training sessions over a period of four weeks. Each session consisted of performing as many elbow flexion-extension movements as possible in 10 seconds; one experimental group performed the movement with a 4-pound weight and the other with an 8-pound weight held in the hand. The two experimental groups showed daily increases in speed of movement, reaching a plateau after the fifth session, but improving again until the last three or four sessions. Speed of movement increased over 50 percent for both groups; the difference between the two groups, however, was not significant. The control group also improved (24 percent) on the speed test, which may demonstrate the effect of some learning in taking the test, as these subjects took the test three times during the experiment, each time with the 4-pound and the 8-pound weight in the hand.

Bergeron (5) formed four groups of college men in order to compare the effects of isometric and isotonic strength training over a 10-week period on the development of speed. The supine press was employed in training for strength development. The speed test consisted of the time required to extend the arms forward 18 inches from the chest while in a standing position. The regimens for the four groups were as follows: A, control group; B, trained isotonically through the full range of movement of the supine press, C, trained isometrically at the extended position of the supine press; D, trained isometrically at the flexed supine press position. The daily exercise for the isotonic group was 10 supine presses with a 10-RM load; the isometric groups held a single maximum contraction for six seconds. All experimental groups showed significant gains in speed of movement; the differences between the groups, however, were not significant.

Bates (3) forme six groups of 18 college men each in order to determine the effects of isometric and isotonic strength training over a period of five weeks, three times per week, on speed of movement, reaction time and muscular endurance, using the supine press as the training exercise. The groups participated as follows: A, B and C, isometric training at the beginning, mid-position and end of the supine press, respectively; D, E and F, isotonic training through the lower third, middle third and upper third of the range of motion of the supine press, respectively. The isometric contractions were maximum for eight seconds; the isotonic exercises were progressive and set for 8-RM. Speed was measured as the time required to perform a nonweighted supine press movement. Within the limited isometric and isotonic strength training programs, the investigator found that the six programs significantly improved strength, speed of movement, reaction time and muscular endurance, but the differences between the programs were not significant. The investigator concluded that significant gains in the elements studied are realized by exercising at any position within the range of movement or through any portion of the range of movement.

Mixed Results

Two studies of the effect of strength training on speed of movement produced mixed results, that is, some results were significant and others were not. One such study was by Macintosh (17). By random methods, he formed four groups of 21 to 24 college men each. One group served as a control; the other three groups exercised their elbow flexor muscles three days per week for eight weeks. The designated activities with training dosages each exercise day were: isometric group, five maximal contractions; isotonic group, one bout at 5-RM; speed group, five maximum speed movements of the forearm. For the speed test: the subject laid supine on a testing table, right arm along side of body; speed was measured as time for flexing forearm to a 90-degree angle, keeping the upper arm on the table. By analysis of covariance, which corrects postexperiment means for difference in preexperiment means, no significant difference in speed improvement between the four groups was found. However, the mean gain in speed by the isotonic group was significant at the .05 level; the isometric group showed a slight loss in speed (nonsignificant). This investigator obtained a correlation of -.372, significant at the .01 level, between preexperiment elbow flexion strength and speed of forearm movement; the postexperiment correlation, however, was not significant.

Larson (16) examined concentric and eccentric training regimens in the development of strength, muscular endurance and speed of movement over an 8-week period, thrice weekly. Three groups of 29 college men each were established: concentric, eccentric and control; the strength tests and movements were confined to four muscle groups, the elbow and hip flexors and extensors. Each exercise day the concentric group raised and the eccentric group lowered a weight eight to 10 times, using a 10-RM load. The control group participated in regular physical education classes, consisting of basketball, volleyball and softball. Speed of movement for elbow flexion and elbow extension was the time required to move the forearm through a 90-degree arc; for hip flexion and hip extension, the foot moved through a 36-inch arc. The results obtained from this study were not consistent for all muscle groups, so the conclusions are not clear-cut. Muscular strength, muscular endurance and speed of movement were significantly developed by some but not all muscle groups.

Nonsignificant Results

Mendryk (20) randomly assigned 18-19 college men to each of four groups in order to study the speed of the leg in performing a hip flexion movement. Three experimental groups underwent designated exercise regimens for six weeks, three times a week, while the fourth group was a control. The designated regimens with amount of exercise were: speed group, five maximum hip flexion speed of leg movements; isometric group, one set of maximum static contractions of the hip flexor muscles against a bar set at positions corresponding to 0, 17, 34, 51 and 70 degrees; isotonic group, weight training bout of 5-RM for hip flexion movement. The hip flexion speed test was performed from a standing position with the leg swinging in a pendulum motion through an arc of 70 degrees. All training regimens were performed from the same position and through the 70-degree arc. A significant increase in the speed of leg movement did not occur for any group as a result of this experiment. As can be seen, the workload for the study was minimal, single bouts of five efforts during each exercise session. It may be noted, however, that hip flexion strength of the isometric and isotonic groups did improve significantly, although the difference between the two groups was not significant; strength did not increase significantly for the speed and control groups.

Kerr (14) used 45 college men in a study of five weeks duration to determine the effects of isometric and isotonic knee extension exercises on the speed of knee extension movement. Isometric, isotonic and control groups of equal numbers were randomly formed. Both exercising groups significantly increased muscular strength. However, none of the three groups showed an improvement in speed of movement. In an experiment by Pierson and Rasch (23), 26 medical students participated in a 4-week weight training program consisting of four exercises designed to strengthen the muscles of the arms and shoulders. Significant increases in arm strength did not produce significant increases in the speed of elbow extension movement.

Negative Results

Only one study on the effect of strength development on speed of movement produced significant negative results, i.e., speed was slowed rather than increased. Two groups of college men participated three times a week for 10 weeks in an investigation by Swegan (26) to determine the effects of isometric and isotonic exercise on speed of movement. The exercises were confined to eight movements: right and left elbow and knee flexion and extension. The isotonic group trained on weights, based on 5- to 10-RM; the isometric group performed 6-second contractions at two-thirds maximum strength. Speed of movement was significantly slower on all eight tests for the isometric group and on six of the tests for the isotonic group.

Muscular Power

Six experiments on the effects of strength improvement upon muscular power will be reported. Muscular power was defined in the July 1971 *Physical Fitness Research Digest* as the ability to release muscular force in the shortest time. The most common power test used in the studies was the vertical jump. This test is usually performed by jumping vertically as high as possible from a crouch position, no step.

The only experiment that produced nonsignificant results was conducted by Ball, Rich and Wallis (1). The investigators formed control and experimental groups of college men in order to investigate the effects of isometric exercise on vertical jumping ability. The isometric training consisted of a single 10-second isometric effort, made in the starting position for the jump, three times a week for six weeks. The isometric group increased significantly in strength but not in vertical jump distance; the control group did not improve significantly on either test.

Four groups of college men were formed and trained three times a week in an experiment by Berger (4) to determine the effect of strength development on the vertical jump. The groups, with their daily exercise regimens, were as follows: A, isotonic, one set of 10-RM of deep knee bends with barbell resting on shoulders behind the neck; B, isometric, maximum contractions against an immovable bar from two positions within the range of motion of knee flexion, held for six to eight seconds; C, vertical jumping with weights, jumping squats for 10 repetitions with barbell weight across shoulders; D, vertical jumps, 10 maximum vertical jumps. The only groups that showed a significant increase in vertical jump distance were those using weights, the isotonic and the vertical jumps with weights (A and C). The investigator concluded that dynamic (isotonic) overload training is more effective for increasing vertical jump ability than is static (isometric) overload training.

Callahan (6) formed three groups of 14 college men each to study the effects of isometric strength development and rebound tumbling for eight weeks, five times per week on performance in the vertical jump. The three groups, with their daily participations, were: A, isometric group, isometric contractions, progressively from seven to 10 seconds, on six exercises related to the jump; B, rebound tumbling group, three 2-minute bouts on the trampoline, utilizing the bounce and seat drop; C, control group, regular physical education program, consisting of tumbling, parallel bars and softball. The vertical jump was performed in two ways, with and without a step, the score being the average of the two performances. Significant improvement in vertical jump distance was obtained by all groups. In comparing the three groups, the isometric group, but not the rebound trampoline group, performed significantly better than did the control group. As indicated, the control group was not physically inactive, but did participate in a physical education program, consisting mostly of gymnastics.

Chui (9) compared a weight training group of 23 college men with a nonweight training group of a similar number in the development of muscular power. The experimental group engaged in an extensive overall weight training program, utilizing barbells and dumbbells, two or three times a week over a period of three months. The other group participated in the service physical education program. Power was measured by the vertical jump, the standing broad jump and standing shot-put. The weight training group improved appreciably more on all tests than did the nonweight trainers; however, no level of significance was reported.

Two groups of college men were formed by Capen (8) in order to study the effects of weight training on muscular power. The training sessions were twice weekly for 10 weeks: Group A trained progressively on weights, consisting of 14 exercises; Group B participated in a strenuous conditioning course, consisting of tumbling, bag relays and running for two weeks; lifts and carries, hand combatives, and running for three weeks; and conditioning gymnastics for five weeks. The increase in standing broad jump distance was significantly greater ($t = 2.89$) for the weight trainers than for the nonweight trainers, in spite of the fact that this event was practiced in Group B but not in Group A.

In the experiment by Bergeron (5) reported in the preceding section, "Speed of Movement," improvement in muscular power was included. Two power tests of the arms and shoulders were utilized; these were basketball and medicine ball throws for distance. Four groups were utilized: control, isotonic and two isometric. The three experimental groups, but not the control group, improved significantly on both power tests; the differences between the means of these groups, however, were not significant. In this experiment, the daily muscular conditioning overload was not great: the isotonic, one bout of 10 weight lifts at 10-RM; the isometric, a single maximum contraction held for six seconds.

Morris (22) randomly formed four groups of 30 college men each in order to compare the effects of isometric and isotonic weight training when used as supplements to training for middle distance running. The groups participated two days a week for eight weeks, as follows: A, running and isotonic training; B, running and isometric training; C, running only; D, control. The running program was the same for the three experimental groups, consisting of interval training for the 880-yard run. The isotonic regimen was composed of three sets of supine leg presses with weights set at 8-RM. The isometric group performed three maximum contractions each at 90, 135 and 170 degrees through the range of motion of the leg press. The results showed that both isotonic and isometric strength training improved quadriceps strength and time for the 880-yard run more than did unsupplemented interval training for this middle distance run. Further, the isotonic weight training increased both quadriceps strength and running time more than did the isometric strength training.

Circulatory-Respiratory Endurance

In Swegan's experiment (26) reported in the section on "Speed of Movement," the effect of strength training on circulatory-respiratory endurance was included. The test of endurance was based on riding a bicycle ergometer at a predetermined rate and a predetermined resistance for as long a time as possible; the length of time for the ride and various pulse rate, blood pressure and blood analysis measures were obtained. Isometric and isotonic training groups exercised eight muscle groups, the right and left elbow and knee flexors and extensors. Significant results were as follows: the isometric group made a significant gain in bicycle riding time but the isotonic group did not; both groups had significant losses in red blood cell count and hemoglobin percentage; both groups made significant gains in reducing pre-exercise pulse rate, diastolic and systolic blood pressures, and blood lactate concentration; the differences between the two groups were not significant on all tests.

In the study by Capen (8) reported in the section on "Muscular Power," improvement in circulatory-respiratory endurance was included. The endurance test was time for a 300-yard shuttle run. In this experiment, as noted above, one group of college men trained on weights and another group participated in a vigorous diversified physical education program. The improvements in running times were approximately the same for both groups, 6.2 and 6.3 percentages.

Sports

High school and college coaches are faced with the problem of whether the time spent in training athletes for a given sport should be devoted entirely to the skills of the sport, the plays involved and strategy, or should some time be provided for weight training? This problem was discussed by Kusintz (15), who concluded with a rationale for the hypothesis that a "*running plus progressive weight training program results in greater running speed and endurance than a running program alone.*" For speed, he contended that, with greater strength, increased muscular tension is available at optimum speed for the performance of a task such as propelling the body forward as in sprinting. For endurance, he proposed that persons equal in cardiac and respiratory efficiency but unequal in the condition of their muscles will evidence differences in endurance performances due to limitations in strength of muscular endurance. Muscular endurance is related to strength, while circulatory-respiratory endurance is a combination of the factors of strength, muscular endurance and efficiency of the cardiac and respiratory apparatus. The effects of strength improvement on various aspects of several sports have been investigated.

Baseball

Three randomly formed groups each of 16 college freshmen and varsity baseball players were established by Swangard (25), in order to study the effects of isometric and isotonic exercises on speed of a baseball throw, swinging a bat and sprinting. The distances were 90 feet for sprinting and 50 feet for throwing; the bat swing was the normal batting movement of each player as measured with a Maroth velocity bat. All three groups participated in regular baseball practice and the same running program, which is all the control group did. Two experimental groups performed supplemental isometric and isotonic exercises, respectively, for eight weeks, three times a week. The exercises were the same for both groups, consisting of 10 resistance movements. For each exercise, the isometric groups performed five maximum contractions of six seconds; the isotonic group executed as many lifts as possible in 30 seconds, the weight being increased progressively as the number of repetitions increased. All three groups significantly improved in throwing speed, the experimental groups at the .01 level and the control group at the .05 level. The isometric and isotonic groups increased significantly in the 90-foot sprint, while the control group did not. In bat swinging, the isometric and isotonic groups improved, but not significantly (t's = 1.64 and 1.82, respectively). The differences between the means of the groups on all tests were not significant.

Thompson and Martin (27) studied the effect of weight training on the throwing speed of college varsity baseball players. The throwing distance was 50 feet; the speed of the throw was measured electrically to .01 second. Two groups, control and experimental, were formed with 10 and 12 players on each. For a period of four weeks, three times a week, 20 to 30 minutes each day, the experimental group followed a progressive weight training program in addition to regular baseball practice; the control group participated in regular baseball workouts only. The experimental group trained progressively in four exercises selected to develop and strengthen the most important throwing muscles of the arm and shoulder; these weight training exercises were clean and press, straight-arm pullovers, supine press and alternate press. The experimental group significantly increased throwing speed (t = 4.61), while the control group did not (t = 1.16).

In a study of the effect of weight training on baseball throwing power, Minor (21) equated three groups of six "junior varsity" baseball players each on the basis of initial throwing power. Throwing power, or velocity, was determined trigonometrically from time of throwing a baseball 100 feet, the height of release of the ball, and the height the ball struck a wire backstop. All three groups participated in regular baseball practice, which was all a control group did. Two experimental groups did supplemental weight training each day for 14 sessions over a period of five weeks, as follows: Group A trained with a 2½-pound steel ball, with 15 speed throws for the first and 20 throws for the last seven sessions. Members of Group B simulated their throwing patterns while holding dumbbells in their hands for three bouts of 10 trials each; the dumbbell weighed four and eight pounds for the first and last seven days respectively. The gains in throwing power of the three groups were: weighted baseball, 7.1 percent; dumbbell throwing motion, 4.5 percent; control 2.4 percent.

Softball

In order to study the effects of isometric exercises on softball underhand throwing distance and endurance, Bass (2) formed four groups of 20 college men each. The groups trained for the underhand throw, three times a week for six weeks, as follows: A, isometric exercises only; B, 80 maximum distance softball throws; C, isometric exercises and 80 maximum throws; D, control group. The isometric strength training program for Groups A and C consisted of five maximum contractions of 10 seconds each of the throwing arm and both legs; the exercises were functional in the sense that they were related to underhand throwing performance. Throwing distance, of course, was the distance the softball could be thrown underhand; throwing endurance was determined as maintaining the throw for distance throughout 80 such attempts. The conclusions reached by the investigator include the following; (a) functional isometric exercises will improve the endurance to maintain the maximum distance throw; (b) the addition of functional isometric exercises to a distance throwing program will produce positive gains beyond those of a throwing program only; and (c) both isometric and throwing programs will result in improved strength of the arm and leg muscles primarily involved in the underhand throw.

Swimming

Davis (12) studied the effects of a weight training program on speed in swimming the crawl stroke for 25- and 50-yard distances. The subjects were 17 college men with swimming experience, who trained for eight weeks, three times a week, with a comprehensive program of eight weight training exercises, based mostly on 8- to 11-RM. The subjects were not allowed to swim more than once a week. All but one subject improved their times on both swims. The mean decreases in time at the end of the experiment were .57 and 1.08 seconds for the 25- and 50-yard swims, respectively; significance was well beyond the .01 level. The investigator concluded that the popular belief (1955) held by many swimming coaches and swimmers that weight training is detrimental to swimming is not substantiated by fact.

Thirty-two college men from intermediate swimming classes were divided into a control and an experimental group by Clark (10). The purpose of this experiment was to compare the effects of an isometric strength training program upon thrust in the water and speed and endurance in swimming a short distance. Both groups participated in the same swimming program for eight weeks. In addition, the experimental group practiced isometric exercises for 10 minutes, five days a week. The isometric exercises were from various positions assumed in the front crawl stroke. Thrust was measured from a bracket harness with the subject attempting a crawl stroke; for these intermediate swimmers, 25- and 50-yard distances were used to test speed and endurance swimming, respectively. Both groups improved significantly on all tests. The experimental group was significantly superior to the control group on the swimming thrust test and on sprint swimming time.

Thompson and Stull (28) divided college men into six groups in order to determine the effects of various training programs on speed of swimming 30 yards. The groups consisted of a control, three swimming regimens, weight training and a combination of swimming and weight training. The greatest improvements in swimming time were for the three swimming groups during a 6-week training period. The swimming and weight training group improved, but not as much. Neither the control nor the weight training group significantly increased their swimming times.

Football

Freshman and varsity college football players were studied by Meadows (19) to determine the effects of isometric and isotonic strength training on the speed and force of the offensive football charge. The charge was for a 6-foot distance from a 3-point stance; force was measured as the impact against a blocking pad on the Crowther blocking sled. Three groups of 28 men each were employed: isotonic, isometric and control. The strength training sessions were held three times a week for 10 weeks, as follows: isotonic group, six progressive weightlifting exercises based on 10-RM; isometric group, two maximum 6-second contractions of hip, knee, shoulder and elbow movements. Most of the control group participated in regular physical education. Both experimental groups improved significantly on both the speed and the force of the offensive football charge, while the control group did not change significantly on either test. The differences between the isotonic and isometric groups on the tests were not significant.

Football, Basketball, Track

Campbell (7) studied the effects of weight training on the motor fitness of college football, basketball, and track and field squads during their competitive seasons. To measure motor fitness, the composite T score for the following seven tests was used: right grip, jump and reach, squat thrusts, pullups, situps, 300-yard shuttle run and 50-yard dash. Each of the three sports squads was divided into two groups, matched by motor fitness composites, at the beginning of the respective seasons, known as A and B groups for each sport. From the opening day of the season until midseason, each A group took regular training for its sport and also followed, twice a week, a progressive weight training program designed for the respective sports; the B groups took regular training for the sport only. At midseason, the A groups dropped and the B groups added weight training. In all instances, motor fitness improved significantly, beyond the regular sports training, as a result of strength conditioning with weights. When weight training was dropped, motor fitness declined. The investigator concluded that weight training should be started well before the competitive season and continued throughout the season. The study did not investigate improvements in playing the various sports as a consequence of strength development through supplemental weight training activity.

Concentric-Eccentric Exercise

This section is not directly related to the main topic of this issue of the *Physical Fitness Research Digest*, but is included more as an update item. An update section has appeared before: "Isometric Versus Isotonic Exercise," was the main topic for the July 1971 *Digest*; an updating of this topic occurred in the January 1974 issue devoted to "Development of Muscular Strength and Endurance."

In former *Digests*, including the present issue, considerable attention has been given to strength development through isometric and isotonic muscular exercise. Recently, some attention has been given to still other exercise forms, known as eccentric and concentric exercise. In these types, a given weight is lowered only in the eccentric (negative) type and raised only in the concentric (positive) type. Rasch (24) has just published an excellent review of research related to the eccentric form of exercise as utilized in strength development. In this section, his article is summarized without references to the specific studies reported by him.

a. Using oxygen consumption as a criterion, muscles produce tension three to nine times more cheaply when they are doing eccentric exercise than when they are doing concentric work. The exact ratio is dependent upon the type of work and the speed of the activity. Thus, it is shown (also, a matter of common observation), that more energy is required to raise than to lower a given load.

b. Electromyographical studies have shown that more muscle fibers are active during concentric contractions when the same weight is used. The explanation of this finding appears to involve two physiological phenomenon, the chemical reactions within the muscles and the development of muscle tension, which are supported in subsequent sections of the report.

c. Thermodynamic observations show that the chemical reactions involved in muscular contractions play a greater part in concentric than in eccentric work. Thus, if the muscle is required to shorten, it gives out an additional amount of heat. A parallel was drawn from the known fact that when tension is applied to a rod or a wire, the temperature rises.

d. Tension exerted by a muscle is the product of fibers activated and the frequency of the neural stimulation of these fibers. The numbers of fibers involved in muscular contractions applied to a given load seem to differ in the following order from least to highest: eccentric, isometric, concentric.

e. A limited number of studies have been done on the relative merits of concentric, eccentric and isometric forms of exercises in the development of muscular strength. The results have been conflicting, with nonsignificant results most frequently reported.

f. A number of side effects were discussed: (1) muscle soreness was reported more often from eccentric exercise than from concentric exercise and (2) two investigators observed that eccentric contractions are usually performed with less discomfort than are concentric contractions; consequently, their use was advocated in therapy and rehabilitation.

A conclusion by the author was: *"Eccentric movements with a given resistance may be used to lessen the load during rehabilitation regimens, but in developing strength in the normal individual, it is necessary to employ greater resistance in order to obtain the same amount of stress on the muscles."*

Summary and Observations

The following conclusions and observations on the improvement of motor skills and competencies in sports through strength development may be drawn from the research evidence available so far.

a. Speed of Movement

(1) Early speed of movement studies were conducted to check on the then held belief that muscular development and heavy resistance exercises may lead to a condition commonly referred to as muscle-bound; the presence of a bulky musculature was thought to interfere with speedy movement. This myth was exploded when it was shown that consistent weightlifters, including those who were little known and world champions, had greater speed in rotary movements of the arms and shoulders than had nonweightlifters.

(2) The experiments designed to study the effects of strength development upon speed of movement produced some conflicting results. However, a predominant number of studies showed speed improvement. Such improvement was most evident when the strength training programs provided considerable overload in regard to the strenuousness of and the length of time devoted to resistive exercises.

(3) Most speed tests measured limited movements of an arm or a leg, such as forearm through 90 degrees, leg through 70 degrees, lateral arm adduction through 110 degrees, and distance of a supine press. Still, despite these very minimal movements with minute time lapses, significant improvements in speed did occur as a consequence of strength training.

(4) In speed of movement experiments, isotonic exercises through progressive weight training regimens were used in all but one study. Significant decreases in speed time were obtained in six of 10 such studies. Comparable figures for isometric contractions were two significant and four nonsignificant improvements in speed. Only one study showed a significant slowing of speed; both isotonic and isometric exercise programs were utilized in that study.

(5) Usually, in the studies reported, isometric exercises were given at only one point in the range of movement and isotonic exercises were performed through the full range of movement of the involved joint. In one study, comparable gains were obtained when isometric exercises were performed at three points in the range of motion and when isotonic exercises were given through the lower, middle and upper thirds of such movement.

(6) In studies where significant gains in speed did not occur, the workload proved to be minimal, both for isometric and isotonic training regimens.

(7) In one study, an experimental group training with isotonic exercise increased significantly in speed, while a comparable group training with a speed movement did not; the difference in speed improvement between the two groups, however, was not significant. In another study, none of three groups training with isotonic, isometric and speed programs, respectively, produced significant gains in speed.

(8) In one study, participants in volleyball did not improve their speed of movement, while those in weight training did. In another study, however, weight training did not increase speed of movement more than did a semester of beginning swimming and golf.

(9) In the only study reported utilizing concentric and eccentric forms of strength training, speed improvement results were mixed. Muscular strength, muscular endurance and speed of movement were significantly improved by one but not by both experimental groups.

b. Muscular Power

(1) Only one of six experiments failed to show significant improvement in muscular power as a consequence of participation in strength development programs. In this study, isometric exercise was minimal, consisting of a single maximum 10-second contraction three days a week for six weeks. In another study, strength development through isometric exercise did result in significantly greater vertical jump distance; the isometric exercise, however, was greater, consisting of 7- to 10-second maximum contractions each for six movements related to the jump.

(2) In all experiments where isotonic exercises were used for strength development, significant increases in muscular power followed. The power events were vertical jump, standing broad jump, standing shot-put, and basketball and medicine ball throws for distance. The daily weight training regimens ranged between a single set of 10-RM to a comprehensive coverage of the total musculature.

(3) A weight training program in one study produced as much increase in vertical jump distance as did rebound tumbling on a trampoline. Further, the isotonic group significantly exceeded a "control" group, whose members participated in a physical education program consisting of tumbling, gymnastics and softball. In another study, weight trainers improved standing broad jump distance significantly more than did a group participating in a strenuous conditioning course, consisting of lifts, carries, combatives, gymnastics and running.

(4) Further, a study showed that college men training with weights improved significantly more in the vertical jump than did those who trained by performing the jump itself.

c. Circulatory-Respiratory Endurance

Three studies were reported showing the effects of strength development programs on circulatory-respiratory endurance. Each study employed a different endurance criterion: 880-yard run, 300-yard shuttle run and bicycle ergometer ride. Some differences in results were obtained in accordance with the criterion used.

(1) For the 880-yard run, three groups trained alike for running the distance, but two had supplemental strength development routines, isotonic and isometric. The isotonic group significantly exceeded the isometric group in 880-yard time improvement, while both groups were better than the group that trained by running only. For the 300-yard shuttle run, the decreases in running time were approximately the same for groups training with isometric and isotonic exercises.

(2) For the bicycle ergometer, circulatory-respiratory endurance was measured by length of time a set ride could be continued and by various physiological measures. The isometric group made a significant gain in riding time, while the isotonic group did not; both groups had significant losses in red blood cell count and hemoglobin percentage and gains in reducing pre-exercise pulse rate. diastolic and systolic blood pressures, and blood lactate concentration.

d. Baseball

Three experiments on the effects of strength development programs upon baseball skills were reported. In all instances, the strengthening activities were supplemental to regular baseball practice and the subjects were members of college baseball squads.

(1) In all studies, speed or velocity in throwing a baseball was included and weight training was the strength development medium. In all instances, significant improvement in throwing speed occurred; in two studies, the improvement was greater than for those who participated only in regular baseball practice sessions. In one study, practice throwing with a 2½-pound steel ball proved effective in increasing throwing speed.

(2) In one study, speed in swinging a bat and in time for sprinting 90 feet were included. Decreases in sprint time for isometric and isotonic groups were significantly greater than for the group practicing baseball only. Both experimental groups also decreased bat swinging time, but not enough to be significant.

e. Softball

One investigator studied the effects of isometric exercise and throwing training regimens upon softball underhand throwing distance and endurance. The results showed that the addition of functional isometric exercises to a throwing program produced significant gains in throwing distance beyond that of the throwing program only; further, isometric exercises improved the endurance to maintain maximum distance for 80 underhand throws.

f. Swimming

(1) One investigator showed decreased times in 25- and 50-yard swims as a consequence of an intensive overall weight training regimen; he concluded that the belief once held by many swimming coaches that weight training is detrimental to swimming is not substantiated by fact. Another investigator found that the greatest improvements in swim time for 30 yards were by groups training by swimming only; a combination of swimming and weight training did show improved time but not as much.

(2) In one study, an isometric strength training program was employed to study thrust in the water and speed in swimming 25 and 50 yards; both the isometric and a control group participated in the same swimming program. Both groups improved on all tests; however, the isometric group showed significant superiority over the control group.

g. Football

Both isometric and isotonic strength training produced significant improvements in the speed and the force of the football offensive charge for six feet from a 3-point stance; the difference between the two training forms was not significant.

h. Football, Basketball and Track

The motor fitness of college football, basketball, and track and field squads, as measured by muscular strength, power, and endurance and times in short and long runs, were significantly improved beyond their respective types of sports training as a result of progressive strength conditioning with weights. When strength training was discontinued at midseason for each sport, motor fitness declined. The investigator concluded that weight training should be started well before the competitive season and continued throughout the season.

i. Concentric-Eccentric Exercise

(1) In a research review by another author, the relative merits of concentric and eccentric strength training programs were presented. The functional worth of these exercises favors the concentric form, which requires lifting rather than lowering a given load. Eccentric contractions produce less heat and involve fewer muscle fibers than do concentric contractions.

(2) Thus, greater loads are required for equivalent work when eccentric exercises are used as contrasted with concentric exercises. However, eccentric movements with a given resistance may be used to lessen the load during rehabilitation regimens.

Implications

The implications presented are limited to general functional applications drawn from the research findings.

a. Both isometric and isotonic forms of strength training can produce improvements in many motor and sports performances. While the evidence is at times conflicting, progressive weight training programs are superior.

b. Some studies did not provide adequate overload in applying both isometric and isotonic strength training. Mostly, exercises confined to single static contractions of short duration or isotonic efforts limited to a single bout were not effective in developing either strength or motor skills. Strenuous resistance exercises of either form are needed for best results.

c. Fear of muscle-bound effects from weight training may be laid to rest. The studies predominantly show that speed of movement may be enhanced rather than retarded as a consequence of strength development.

d. Exercise programs designed to strengthen muscles primarily involved in a particular sport can be used as supplements to regular practice in effectively improving the athlete's skills and motor fitness.

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