Brief Review

Effects of General, Special, and Specific Resistance Training on Throwing Velocity in Baseball: A Brief Review

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ABSTRACT
Throwing velocity is a necessary requirement for success in baseball. All position players, including pitchers, may increase their defensive performance if their throwing velocity is improved. A review of the literature suggests that throwing velocity can be increased by resistance training and/or biomechanical improvement of the throwing motion. This paper reviews the 3 broad categories of resistance-training methods by which throwing velocity is increased. The results of research using general, special, and specific throwing resistance-training exercises are presented. The role and applications of these different exercises for baseball players of different ages are discussed.

Key Words: ballistic training, isotonic, specificity


Introduction
Throwing velocity is an important performance variable in baseball. The ability of throwing the ball faster is not only important for baseball pitchers, but is also important for position players to execute successful defense. In pitching in particular, the ball is delivered at extremely fast speeds. It is not uncommon for a pitcher to deliver a 90–100 miles per hour (mph) fastball today.

A review of literature indicated that throwing velocity can be increased with an improvement of throwing biomechanics (47, 65) and/or by resistance training (1, 7, 26, 30, 32, 45, 50, 58, 62–64, 69). This portion of the review will only focus on the affects of resistance training on throwing velocity.

Biomechanically, the overhand throw is a complex motion involving the entire body in a coordinated manner (65). Although the throwing arm receives primary analytical attention, the trunk and lower extremities play a vital role in throwing mechanics. Toyoshima et al. (65) conducted a biomechanical study on the overhand throw. The results indicated that 46.9% of the velocity of the overhand throw could be attributed to the stride and body rotation, whereas 53.1% of the velocity was due to action of the arm. Therefore, resistance-training programs for baseball players to improve throwing velocity, particularly for pitchers, should be designed to include arm, trunk, and lower-body exercises.

According to Baker (2), resistance-training exercises are classified as general, special, or specific depending on their biomechanical characteristics and effects on the neuromuscular system. General resistance-training exercises increase the overall maximal strength of the muscles. In throwing, examples of these exercises are the supine bench press, latissimus dorsi pull-downs, shoulder press, straight- or bent-arm pullover, biceps curls, triceps extensions, shoulder dumbbell exercises (lateral raise, supraspinatus raise, internal rotation, external rotation, flexion, and abduction), ulnar and radial deviations, wrist rolls, squats, leg curls, and leg extensions (1, 6, 18, 21, 26, 30, 42, 50, 56, 63, 64).

Once the player’s strength levels have been increased, special resistance exercises can be used to train the athlete for muscular power development. Examples of traditional upper-body power exercises are explosive isotonic exercises (e.g., power cleans, snatches, pulls and push presses); ballistic resistance training; plyometric training (e.g., medicine ball); and isokinetics (24, 30, 33, 45, 70). The training effect of these special resistance exercises is to convert general muscular strength to the special quality of power that is relevant to throwing (2). These power exercises are characterized by a more rapid execution and a higher muscular power output.

Specific resistance exercises are designed to follow the concept of specificity by providing a training stim-
that is very similar to actual motion in competition. Examples of these exercises for baseball-throwing motion are weighted baseballs, surgical tube exercises, and the Exer-genie cord (1, 7, 14, 15, 32, 52, 56, 62, 63, 70). These exercises attempt to mimic the high-velocity ballistic throwing motion.

The purpose of this portion of the paper is to review the relative effectiveness of general, special, and specific training exercises on increased throwing velocity. In addition, the role and application of these respective exercises for baseball players at different ages and levels will be discussed.

**Effects of Resistance Training**

The effects of resistance-training programs on throwing velocity have been reported since the 1960s (7, 18, 32, 52, 63, 67). In general, these studies focused on identifying the type of resistance training that would most effectively improve throwing velocity (1, 15, 16, 18, 30, 42, 56). Recent research has also attempted to determine the possible mechanisms by which throwing velocity is increased and how the throwing velocity is affected by various resistance-training methods.

**General Resistance Training**

In theory, general resistance training aims to improve the contractile capabilities of the muscle. Before the 1980s, general resistance-training programs consisted of traditional isotonic exercises. These isotonic exercises heavily concentrated on the development of upper-body strength (1, 49, 62–64). These upper-body exercise protocols were popularly used because of the influence of the study of Toyoshima et al. (66). The results of this study suggested that certain upper-body major muscles evoke strong trunk and shoulder rotation, and thus enhance throwing velocity (66). The contribution to lower-body movement (the kinetic link biomechanical principle) in the throwing motion was not studied in these early studies. Nonetheless, high school and collegiate baseball position players and pitchers improved their throwing velocity by using these traditional upper-body isotonic exercises.

It should be pointed out that some of the important studies in throwing velocity using isotonic resistance training were published in the form of master or doctoral degree theses (1, 18, 26, 53, 56, 62). The fact that these studies were not published in refereed journals should not be used to discredit their value since many findings of these graduate theses have been verified by other investigators (45, 49, 50, 64).

Traditionally, isotonic resistance training used in throwing velocity studies among high school baseball players involved upper-body free-weight exercises and shoulder dumbbell exercises. Bagonzi (1) reported that upper-body training exercises significantly increased throwing velocities. The training protocol consisted of 2 exercise sessions per week for 18 weeks. The 18 training weeks were divided into 6 3-week cycles. Interestingly, the results of this study indicated that there were no significant increases in throwing velocity until the sixth cycle (16th–18th week).

Popescue (49) also reported an increase of throwing velocity (3.8 mph) using an isotonic-training program designed to strengthen the upper-body throwing muscles in high school players. The studies of both Bagonzi (1) and Popescue (49) were conducted in the off-season. In contrast, Jackson (26) reported no significant increase in throwing velocity within the same high school age group (15–19 years) during an 8-week in-season competitive period. In Jackson’s study (26), although strength and velocity gains were the intent, only 5 shoulder dumbbell exercises (supraspinatus raise, internal rotation, external rotation, shoulder flexion, and shoulder abduction) were used. It should be noted that although the throwing velocity was not significantly increased in this study, the shoulder dumbbell exercise protocol did maintain the subjects’ throwing velocity and actually produced a slight increase of 0.62 mph. Therefore, this exercise protocol could be used as part of an in-season maintenance resistance-training program.

Similar to the above studies for high school baseball players, general isotonic throwing velocity studies using collegiate players also involved traditional upper-body exercises. Swangard (63) found a significant increase in throwing velocity after an 8-week upper-body resistance exercise program with collegiate pitchers. The exercises included the arm pullover, standing press, biceps curl, shoulder shrug, supine lateral raise, wrist curl and extension, ulnar and radial deviations, and squats. In a related study, Potteiger et al. (50) found a significant increase in throwing velocity (2.3 mph) using a traditional upper- and lower-body isotonic exercise protocol with collegiate position players. These investigators used a progressive resistance-training protocol with the following exercises: the bench press, military press, latissimus pull-down, biceps curl, triceps extension, squat, leg curl, and leg extension. Sullivan (62) used progressive and nonprogressive isotonic upper-body resistance-training protocols to determine the effects of resistance training on throwing velocity among college men (non–baseball players). The isotonic exercises used were wrist curls, supine lateral raises, and bent-arm pullovers. Although the investigator found a significant increase in throwing velocity with the isotonic upper-body exercise protocol, the results of the study also revealed that (a) free-weight exercise was more effective than wall pulley exercise (which simulated throwing motion), and (b) progression or nonprogression resistance-exercise protocols had no significant differential effects on throwing velocity.

Newton and McEvoy (45) recently reported a significant increase in throwing velocity that resulted
from upper-body isotonic resistance training. Twenty-four elite collegiate baseball players (age 18.6 ± 1.9 years) trained twice per week for 8 weeks. The isotonic resistance-training protocol consisted of 3 sets of 8 to 10 repetitions maximum (RM) for the first 4 weeks. Thereafter, they performed 3 sets of 6RM to 8RM for the last 4 weeks. The isotonic exercises included the conventional bench press and barbell pullover exercises that are commonly used by baseball players to train upper-body muscles in throwing. The results of this study showed a 4.1 and 22.8% increase in throwing velocity and upper-body muscular strength, respectively. The increased upper-body muscular strength may have contributed to the significant increase of throwing velocity in the resistance-training group. However, it also has been shown that the correlation between muscular strength and throwing velocities was not very high. Therefore, it was suggested that there were other factors also involved in determining throwing velocity.

In contrast, Shenk (56) reported no significant increase in throwing velocity with a progressive isotonic resistance-training program for the upper body in college men (non-baseball players). The isotonic resistance-training group's exercise protocol consisted of 21 exercises performed 3 days per week for an 8-week period. Of the 21 exercises, 17 were upper-body exercises and only 4 were lower-body exercises. In a related study, Edwards (16) also found no significant increase in throwing velocity among collegiate baseball pitchers trained with upper-body exercises. The exercises consisted of 7 shoulder dumbbell exercises. The training protocol consisted of 3 sessions a week for 6 weeks. Each of 7 dumbbell exercises were performed with 3 sets of 10 repetitions. In the same study, however, a significant increase in throwing velocity was found in the other experimental group that used proprioceptive neuromuscular facilitation upper-body and arm/shoulder range of motion (ROM) exercises.

In summary, the majority of studies demonstrated that a significant increase in throwing velocity in high school and collegiate men can result from upper-body isotonic resistance training. See Table 1 for the summary of the general resistance-training throwing studies.

**Special Resistance Training**

As the baseball player's muscular strength adequately increases during the off-season, he or she should proceed into a preseason power-training program (54, 60, 61, 69). Special resistance exercises produce the explosive muscular power output needed for the ballistic throwing motion. As previously mentioned, the purpose of this training is to convert general muscular strength to the special quality of power as relevant to throwing (2).

There is a paucity of research regarding the effects of power training using explosive isotonic resistance exercises on throwing velocity. Lachowetz et al. (30) has conducted the only upper-body throwing-power research study using conventional isotonic free weights and machines. In this study (30), the resistance-training exercises were performed in an explosive manner. The investigators (30) reported a significant increase in throwing velocity in collegiate pitchers. During the 8-week training period, the exercise regimen combined a throwing program with traditional free weights, Cybex, Nautilus, and Cybex cable pulley exercises. In addition, a concentric/eccentric exercise phase was also added. The training protocol consisted of a throwing program for 3 days per week, which was combined with 4 resistance-training sessions per week at 3 sets of 10RM followed immediately by 5 additional concentric (assisted) and eccentric (un-assisted) repetitions for each exercise. The subjects were instructed to perform each muscular contraction explosively. The intent of this concentric/eccentric exercise was to specifically target the muscles for both acceleration and deceleration of the throwing arm. Interestingly, of the 11 upper-body exercises used in this study, 5 were shoulder cable pulley exercises that were performed in a way similar to the throwing motion. Therefore, it is unclear that the significantly increased throwing velocity in this study was the result of explosive power training, a movement-specific effect produced by the 5 shoulder cable pulley exercises, or the combination of both factors.

Ballistic resistance training is another example of power training that combines elements of plyometric training and weight resistance training (36). The exercise protocol involves the lifting of relatively light loads at high speeds. It should be noted that there are mixed opinions in the exercise community as to the use of light vs. heavy loads during explosive resistance training for the improvement of dynamic performances such as jumping, running, and throwing (4).

In a recent ballistic study using light loads (45% of 1 repetition maximum [1RM]), Newton et al. (44) investigated the kinematics, kinetics, and neural activation during explosive upper-body movements. Newton et al. (44) disclosed that the ballistic bench press throwing motion produced a significantly higher average velocity, peak velocity, average force, average power, and peak power than the traditional bench press. Additionally, the average muscle activity (electromyogram [EMG]) during the concentric phase was also higher for the ballistic bench press throw. Furthermore, Newton et al. (44) also revealed that although the ROM during the eccentric phases of the bench press and ballistic bench throw were similar, muscle activation during the concentric phase of the ballistic bench press throw occurred over a shorter time period and resulted in significantly higher peak and average velocities (20). Likewise, compared with
### Table 1. Summary of throwing velocity resistance training studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects</th>
<th>Training method</th>
<th>Strength change</th>
<th>Velocity change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td></td>
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<tr>
<td>Bagonzi (1)</td>
<td>High school</td>
<td>Isotonic</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Edwards (16)</td>
<td>College</td>
<td>Isotonic</td>
<td>Decrease</td>
<td>Decrease</td>
</tr>
<tr>
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<td>High school</td>
<td>Isotonic</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>Newton and McEvoy (45)</td>
<td>College</td>
<td>Isotonic</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Potteiger (50)</td>
<td>College</td>
<td>Isotonic</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Popescue (40)</td>
<td>High school</td>
<td>Isotonic</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Shenk (56)</td>
<td>College</td>
<td>Isotonic</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>Sullivan (62)</td>
<td>College</td>
<td>Isotonic</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Swangard (63)</td>
<td>College</td>
<td>Isotonic</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Thompson and Martin (64)</td>
<td>College</td>
<td>Isotonic</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td><strong>Special</strong></td>
<td></td>
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</tr>
<tr>
<td>Lachowetz et al. (30)</td>
<td>College</td>
<td>Isotonic</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>McEvoy and Newton (36)</td>
<td>Professional</td>
<td>Ballistic</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Newton and McEvoy (45)</td>
<td>College</td>
<td>Medicine ball</td>
<td>Increase</td>
<td>No change</td>
</tr>
<tr>
<td>Wooden et al. (71)</td>
<td>High school</td>
<td>Isokinetic</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td><strong>Specific</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Bagonzi (1)</td>
<td>High school</td>
<td>Overload baseballs</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Brose and Hanson (7)</td>
<td>College</td>
<td>Overload baseballs,</td>
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<td></td>
<td></td>
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<td>Increase</td>
<td>Increase</td>
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<tr>
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<td>Increase</td>
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<tr>
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<td>Increase</td>
<td>Increase</td>
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<tr>
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<td>Increase</td>
<td>Increase</td>
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<tr>
<td>Egstrom et al. (17)</td>
<td>College</td>
<td>Weighted balls</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Elias (18)</td>
<td>College</td>
<td>Overload baseballs</td>
<td>Increase</td>
<td>Increase</td>
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<tr>
<td>Logan et al. (32)</td>
<td>College</td>
<td>Exer-genie</td>
<td>Increase</td>
<td>Increase</td>
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<tr>
<td>Railey (52)</td>
<td>College</td>
<td>Wall pulley</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Shenk (56)</td>
<td>College</td>
<td>Surgical tube</td>
<td>No change</td>
<td>Increase</td>
</tr>
<tr>
<td>Sullivan (62)</td>
<td>College</td>
<td>Wall pulley</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>VanHuss et al. (67)</td>
<td>College</td>
<td>Overload baseballs</td>
<td>Increase</td>
<td>Increase</td>
</tr>
</tbody>
</table>

* General: traditional isotonic resistance training exercises that increase overall maximum strength of the muscles.

† Special: explosive resistance training exercises for muscular power development.

‡ Specific: resistance training exercises that attempt to mimic the high-velocity ballistic throwing motion.

the bench press, the velocity and force curves for the ballistic bench press throw are more similar to those curves recorded from typical explosive sport movements such as throwing, jumping, and striking (29). Moreover, several other studies (27, 33, 34, 39, 51, 70) also concurred that ballistic training with light loads (at 30–50% of 1RM) increase dynamic athletic performances.

Recently, McEvoy and Newton (36) reported a significant increase in throwing velocity (2.0%) using light loads in training. Eighteen professional players (age 24 ± 4 years) trained during a 10-week preseason period in conjunction with their normal baseball training. The exercise protocol consisted of explosive bench press throws and squat jumps (“advanced plyometric training”) for 3 sessions every 2 weeks with a load of approximately 30–50% of 1RM using a plyometric power system (43). The players performed with loads that could be progressively adjusted to an individual’s maximized mechanical power output. The investigators concluded that the significant increase in throwing velocity in the treatment group was possibly due to (a) a training-induced, velocity-specific improvement in strength, (b) an increase in rate of force development throughout the entire ROM, (c) an improved stretch-shortening cycle (SSC) performance, and (d) an improved instantaneous feedback on training performances. Ballistic training has been supported by numerous strength coaches who believe that the closer the velocity and movement pattern of the training exercise is to the actual competitive sport skill, the greater the transfer of training gains to the athletic performance (40, 42).

Plyometric training is another example of special resistance training used by many baseball players and trainers (10, 37, 45, 51). Traditional plyometric training is seen by the baseball community as a possible link between strength and speed of movement resulting in an increase of muscular power (10, 36). Baseball players utilize this type of training in lower-body exercises such as depth jumps and bounds and upper-body exercises in the form of medicine ball throws. Although
plyometric training is popular among baseball players, very little research has been conducted as to the effects of plyometric training on throwing or running speeds. Plyometric training research basically has been confined to the lower body such as vertical jumps (5, 55).

Newton and McEvoy (45) conducted the only baseball throwing velocity study using upper-body plyometric training. Subjects were collegiate (mean age of 18.6 years) baseball players with no previous weight-training experience and they were trained during the competitive season. The results of upper-body medicine ball exercises were compared with conventional isotonic resistance exercises (bench press and barbell pullover). The authors reported that both training groups significantly increased their strength from training: 22.8% for the conventional isotonic resistance-exercise group and 8.9% for the medicine ball exercise group, respectively. However, only the isotonic resistance-exercise group had a significant (4.1%) pre- to posttraining increase of throwing velocity. These findings suggested it may be necessary that players with no previous weight-training experience first begin with an isotonic resistance-training program in order to increase throwing velocity.

Isokinetic (IKN) training is a special resistance exercise that has a positive effect on throwing performance (9, 11, 23, 25). Numerous studies have reported the use of IKN to measure muscular strength (9, 20, 22) and torque output (19, 48, 59, 71). IKN exercise is thought to accommodate the exerciser because the resistance varies at each point in the ROM while the speed of the movement can be prefixed as desired (12, 41). The advantage of this type of exercise is that maximum resistance can be applied throughout the full ROM when the effort is maximum (12, 38). Past IKN studies have reported improvement of athletic performances (19, 59). However, there is a possible disadvantage when using IKN training to improve athletic performances, such as throwing, since most IKN exercise devices allow only a maximum angular velocity of up to 500° s⁻¹. This angular velocity is far below the velocity of joint action in most throwing and striking events (35). In the baseball throw, for example, internal rotation of the shoulder joint accelerates to an angular velocity of 6,180° s⁻¹ (47). Therefore, IKN training devices may inherently limit the required force production and power output needed to accelerate the arm fast enough to elicit a positive effect on throwing.

In a recent IKN study, Wooden et al. (71) determined if IKN training in throwing inhibits arm acceleration and torque production required for optimum throwing velocities. The authors compared the effects of IKN training and accommodative isotonic training in the individualized, dynamic, variable resistance (IDVR) mode. During preseason, 27 high school (age 15.5 ± 0.97 years) baseball players trained 3 times per week for 5 weeks. The IKN group exercised at 500° s⁻¹, and the IDVR group using the musculoskeletal evaluation rehabilitation and conditioning (MERAC) dynamometer trained at 100% of the variable resistance provided by the pretest results from the motor performance curve. The MERAC provided the option of accommodative isotonic resistance exercise in the IDVR mode. Therefore, with no preset speed, the limb can accelerate against the resistance to match the effort of the individual. These authors reported significant increases in throwing velocity and external rotator torque in the IDVR group but not in the IKN group. In addition, there was a significant increase in external rotator power in both groups, but no significant improvements in internal rotator torque and power for either group. These findings were possibly due to (a) an improvement in external rotator peak torque to body weight ratio; (b) an increase in external rotator concentric torque output, which in turn improved eccentric function; and (c) IDVR players’ ability to freely accelerate (possibly beyond the IKN’ 500° s⁻¹ limitation) the arm, simulating the actual throwing motion. It was suggested that IDVR resistance training may be more effective than IKN training in improving throwing velocity and external rotator torque output.

In summary, it appears that special upper-body resistance training can significantly improve throwing velocity in high school and collegiate players. A summary of the 4 throwing velocity special resistance-training studies is presented in Table 1.

### Specific Resistance Training

Finally, numerous studies claimed that a significant increase in throwing velocity (1, 7, 14, 15, 17, 18, 56, 62) resulted from specific resistance training. The research question is, can specific resistance training principally recruit the high-threshold motor units by imitating the actual throwing motion and velocity? Examples of specific resistance training are weighted implement training, surgical tubing exercises, wall pulleys, and the Exer-genie cord.

Weighted implement training involves exercising with modified standard competitive implements (e.g., baseballs) while duplicating the force-velocity output and full ROM specific to the competitive movement pattern (14, 15). Previous throwing studies have indicated that the throwing velocity of a standard 5-oz baseball can be increased significantly by overload training, or throwing a heavier baseball (7–15 oz; 1, 7, 17, 18, 31). In contrast, throwing velocity can also be increased using weighted implements that were slightly lighter than the standard competitive weights (13, 28, 66, 68).

DeRenne et al. (13–15) conducted 3 throwing and pitching velocity studies using under- and overweighted baseballs. During the first throwing velocity pilot study in 1985, DeRenne (13) reported a significant gain in throwing velocity using either lighter or heavi-
er baseballs. The underweighted baseball training group showed a significant increase in throwing velocity that was twice as great as the overweighted baseball group, 3 to 1.5 mph, respectively. The weighted baseballs used in this study were either 20% below or above the standard 5-oz weight. The training protocol consisted of a controlled lesson plan composed of pitch totals and a specific weighted baseballs throwing sequence.

In 1990, DeRenne et al. (15) replicated the 1985 study using 30 high school varsity baseball pitchers (ages 16–18). The results were similar to the 1985 DeRenne study (13). The underweighted group had a significant increase of 4.72 mph in throwing velocity, whereas the overweighted group also had a significant improvement of 3.75 mph. The control group, on the other hand, had only improved 0.88 mph.

In 1994, DeRenne et al. (15) conducted the third throwing velocity study using various combinations of standard, light, and heavy baseballs with 45 high school (age 16.6 ± 0.57 years) and 180 college (age 19.6 ± 0.46 years) pitchers. Each age group of pitchers were randomly assigned into 2 experimental groups and 1 control group. The training protocol consisted of the following: (a) group 1 pitched with a weighted sequence of a standard-heavy-light-standard baseball 3 days per week for 10 weeks; (b) group 2 pitched with a “block” training of a weighted sequence of standard-heavy-standard for the first 5 weeks, then standard-light-standard for the final 5 weeks; and (c) group 3 pitched only standard baseballs. The rationale for this training procedure was based on the Russian strength-training studies (28, 68), which suggested that a functional strength progression should be established prior to velocity training. In addition, previous baseball throwing studies only used either heavier or lighter baseballs and the weighted baseball sequence in training never was varied. It was the purpose of this particular study to determine the best sequence combination using weighted baseballs in training. The pitch totals for weighted baseballs in sequence were kept to a 2:1 ratio (nonstandard to standard weight), as was previously suggested (28, 68). The findings of this study revealed a significant increase of throwing velocity in both training groups with either population.

As previously stated, baseball throwing and pitching are high-velocity ballistic movements in which velocity is directly related to performance. The neurophysiological mechanism for increasing movement velocity resulting from the weighted implement training is not fully understood at this time. Since the peak force output of fast-contracting muscle fibers can be 4 times greater that that of slow fibers (21), it has been suggested that highly specific fast movements could recruit and fire these high-threshold fast muscle fibers (57). The results of the above-mentioned weighted implement training studies (13–15) may indicate that a greater exertion of muscle force at high speeds was due to a modification of the recruitment pattern of motor units in the central nervous system. Thus selective activation of either of the fast or slow motor units in muscle could be specifically trained.

Another specific resistance training mode that has been gaining popularity with baseball coaches, players, and trainers is surgical tube exercises. However, there appears to be a paucity of research on the effects of surgical tube training on throwing performance. Tubing exercises are used by position players and pitchers to mimic the total competitive throwing movement at or near game velocities and power outputs (3).

Recently, Shenk (56) examined the effects of a general isotonic strength-training program and a surgical tube exercise protocol on throwing velocity performed by 34 college men with organized baseball or softball experience. The tubing exercise protocol consisted of progressive resistance training by increasing the tubing tension when exercises were performed and increasing the number of sets and repetitions of each exercise for 3 training sessions per week over 8 weeks. The findings in this study showed that the throwing velocity of the surgical tube exercise group was significantly increased (1.9 mph), whereas the isotonic weight-training group had no changes. Another interesting finding of this study revealed that the significant increase in throwing velocity was made in the absence of any significant strength gains in both training groups. This finding is in contrast to Newton and McEvoy (45) who reported a strength gain using an isotonic upper-body training protocol. The lack of strength gains in Shenk’ study (56) was possibly due to differences in testing methods for velocity or strength assessment (8, 9, 53, 57). In contrast, Grant and Ritch (22) reported significant improvements (25%) in strength and endurance after using surgical tube exercises. During this preseason study (22), 19 college baseball players performed surgical tubing exercises with the dominant throwing arm. After 8 training weeks, IKN tests at speeds of 60°, 180°, and 300° revealed significant strength and endurance gains compared with the nontube, nondominate exercised arm. Further tubing research is needed to substantiate its effects on throwing velocity using high school or collegiate pitchers engaging in preseason and in-season training.

The last examples of specific resistance-training exercises that have a similar training stimulus as tubing exercises are isotonic resistance wall pulley exercises and the Exer-genie cord. A review of the literature indicated that there were 4 throwing velocity studies conducted with wall pulley devices and the Exer-genie cord. These studies all reported significant increases in throwing velocity after training (7, 32, 52, 62). Brose et al. (7) reported a significant increase in throwing
velocity among 21 collegiate freshman baseball players who trained 3 times per week for 6 weeks with wall pulley resistance exercises. During each exercise session, the players performed 1 set of 5 moderate-speed "throws" followed by 20 maximal repetitions. The overload wall pulley device was set at 10 lb of tension. Likewise, Railey (52) and Sullivan (62) reported the same results from isotonic resistance wall pulley exercises. In Railey's study (52), 30 college baseball players trained 4 times per week for 7 weeks. The wall pulley exercise group performed nonprogressive resistance exercises simulating the throwing motion. Sullivan's study (62) involved 58 collegiate nonbaseball subjects who trained 4 days per week for 6 weeks. The training protocols for the 2 wall pulley exercise groups consisted of 3 sets of 10 repetitions performed with either progressive or nonprogressive resistance exercises simulating the throwing motion. Sullivan's findings (62) also revealed (a) there was a significant difference in throwing velocity between the general isotonic weight-training group and the isotonic wall pulley exercise group in favor of the isotonic weight-training group, and (b) progressive resistance exercise and throwing practice protocols had no significant effect on increasing throwing velocity.

In a similar wall pulley training study, Logan et al. (32) reported a significant increase in throwing velocity (8.1 mph) using a resistance device called the Exer-genic cord. The subjects trained daily for 6 weeks. The results of this study (32) also revealed that the Exer-genic training group had significantly greater throwing velocity gains than the practice throwing training group. It is interesting to note that all 4 wall pulley studies resulted in significant increases in throwing velocities using nonprogressive resistance training protocols.

In summary, weighted implement training can significantly increase throwing velocity for both high school and college players by using weighted baseballs no more than 20% above or 20% below standard weight. Likewise, surgical tube and wall pulley exercises blend both resistance and speed of movement. These specific exercises all attempt to mimic the total body throwing action and, therefore, train the specific musculature at each joint. Conversely, traditional or general weight-training exercises attempt to work on isolated individual muscle groups. Additional advantages of the specific training concur that it may be more beneficial to learn a task as a whole movement than to divide it into component parts (6, 34). Weighted implement training may elicit specific neurophysiological adaptations in which selective motor unit activation/recruitment could occur. Further support of this hypothesis comes from the fact that surgical tube training significantly increased throwing velocity in collegiate baseball players with or without concurrent increases in strength. For a significant increase in throwing velocity, the training protocol should include a minimum of 3 training sessions per week for at least 8 weeks (22, 56). A minimal resistance that allows for overload and high speeds for sufficient power output should be used. Moreover, surgical tube exercise provides the maximum overload near the end of the ROM, whereas greater peak torques are achieved earlier in the ROM of general isotonic resistance training (46, 57). The combination of these 2 training modes may be needed when planning the total periodized throwing training program. Finally, the findings from the above-mentioned wall pulley training studies (32, 52, 62) suggested that general isotonic resistance training may be better than wall pulley training for non-baseball players to improve throwing velocity. For high school and collegiate baseball players, they may use general isotonic strength-training protocols combined with specific surgical tubing or wall pulley exercises. However, additional research is needed to determine the effects of surgical tube training on throwing velocity. Table 1 presents the summary of the 11 specific resistance throwing velocity training studies.

Practical Applications

Throwing velocity can be increased by resistance training. A rationale for general, special, and specific resistance training to increase throwing velocity has been presented. The following findings and recommendations relevant to strength and conditioning specialists and pitching coaches can be useful from the review of literature.

- Throwing velocity for high school and college players can be increased with general resistance training. The throwing-training protocol should be conducted over a minimum training period of 8 weeks using upper-body core exercises and a dumbbell shoulder routine.
- As the baseball player's general muscular strength and throwing velocity adequately increases during the off-season, he should proceed into a special upper-body power throwing velocity training program. The power-training protocol should consist of "exploding" lightweight loads of 30–50% of 1RM during the 6–8 training weeks.
- Specific resistance training consisting of light- and heavyweighted baseballs may be the single best method to increasing throwing velocity, provided the athlete follows the appropriate training protocol. Before a weighted implement training program commences, an athlete should participate in a general total-body isotonic resistance program followed by an upper-body power-training regimen.
- In order to produce the maximum training results, selection of appropriate throwing training exercises must be based on the athlete's chronological age, training experience, and skill level.
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