Comparison of Three Baseball-Specific 6-Week Training Programs on Throwing Velocity in High School Baseball Players

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[1]Department of Physical Therapy, California State University, Sacramento, California; [2]Department of Health, Exercise, and Sports Sciences, Texas Tech University, Lubbock, Texas; [3]Andrews Institute Rehabilitation, Gulf Breeze, Florida; [4]American Sports Medicine Institute (ASMI), Birmingham, Alabama; [5]Champion Sports Medicine, Birmingham, Alabama; [6]Results Physical Therapy and Training Center, Sacramento, California; [7]Paulos Sports Injury and Joint Preservation Clinic, Salt Lake City, Utah; and [8]Andrews Research and Education Institute at the Andrews Institute, Gulf Breeze, Florida

Abstract

Escamilla, RF, Ionno, M, deMahy, MS, Fleisig, GS, Wilk, KE, Yamashiro, K, Mikla, T, Paulos, L, and Andrews, JR. Comparison of three baseball-specific 6-week training programs on throwing velocity in high school baseball players. *J Strength Cond Res* 26(7): 1767–1781, 2012. Throwing velocity is an important baseball performance variable for baseball pitchers, because greater throwing velocity results in less time for hitters to make a decision to swing. Throwing velocity is also an important baseball performance variable for position players, because greater throwing velocity results in decreased time for a runner to advance to the next base. This study compared the effects of 3 baseball-specific 6-week training programs on maximum throwing velocity. Sixty-eight high school baseball players 14–17 years of age were randomly and equally divided into 3 training groups and a nontraining control group. The 3 training groups were the Throwers Ten (TT), Keiser Pneumatic (KP), and Plyometric (PLY). Each training group trained 3 $d \cdot wk^{-1}$ for 6 weeks, which comprised approximately 5–10 minutes for warm-up, 45 minutes of resistance training, and 5–10 for cool-down. Throwing velocity was assessed before (pretest) and just after (posttest) the 6-week training program for all the subjects. A 2-factor repeated measures analysis of variance with post hoc paired *t*-tests was used to assess throwing velocity differences ($p < 0.05$). Compared with pretest throwing velocity values, posttest throwing velocity values were significantly greater in the TT group (1.7% increase), the KP group (1.2% increase), and the PLY group (2.0% increase) but not significantly different in the control group. These results demonstrate that all 3 training programs were effective in increasing throwing velocity in high school baseball players, but the results of this study did not demonstrate that 1 resistance training program was more effective than another resistance training program in increasing throwing velocity.

Key Words resistance training, little league, youth

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Introduction

Of the roughly 2.5 million baseball players in the U.S.A., approximately 99% participate at the youth (prehigh school) or high school level, leaving <1% of all baseball players at the collegiate or professional levels (2). With most U.S.A. baseball players participating in youth or high school baseball, it is important for the performance specialists to be knowledgeable in ways to enhance performance in youth or high school baseball players through various training methodologies.

One component of performance enhancement in baseball is throwing velocity. A pitcher who is able to throw the fastball pitch with greater throwing velocity allows less time for the batter to identify the pitch and decide whether or not to swing. Therefore, a fastball pitch thrown with greater velocity is often more difficult to hit compared with a fastball pitch thrown with less velocity, assuming similar ball movement and location over the plate. Moreover, a pitcher with a good fastball enhances the effectiveness of slower off-speed pitches, such as the changeup and curveball, which helps fool the hitter.

Throwing velocity is also important to position players. For example, a ground ball softly hit to the short-stop or third-baseman requires a hard throw with high throwing velocity and accuracy to throw out a fast runner. Similarly, an outfielder trying to throw out a base runner at home plate requires high throwing velocity and accuracy.

Although several studies have reported that employing a multiple week resistance training program improves throwing velocity in adults (1,7,8), there are only 2 known studies that have examined the effects of a resistance training program in youth or high school baseball players (3,11). Given maturation considerations, it is plausible to assume that the effects of a resistance training program in adults may be different than the effects of a resistance training program in youth related to throwing velocity. Escamilla et al. (3) examined the effects of a 4-week baseball conditioning program (throwing, stretching, and resistance training) on throwing velocity and shoulder range of motion and strength in 11- to 15-year-old baseball players. In this study resistance training, interval throwing, and stretching were integrated within the conditioning program. In addition, Wooden et al. (11) examined the effects of a 5-week resistance training program consisting of isolated shoulder internal and external rotation exercises on shoulder internal and external rotation shoulder torque and throwing velocity in 14- to 17-year-old baseball players. Because Escamilla et al. (3) integrated both interval throwing and resistance training in their program, and because Wooden et al. (11) used only shoulder internal and external rotation movements in their program, there are no studies we are aware of that exclusively examined the effects of a complete baseball-specific resistance training program on throwing velocity in youth or high school baseball players. Moreover, there are no studies we are aware of that employed plyometric or other types of explosive training exclusively in youth or high school baseball players, although 2 studies did use plyometric training in adult baseball players (1,7). Finally, there are no studies we are aware of that have investigated the effects of different types of baseball-specific resistance training programs on throwing velocity in youth or high school baseball players. This is important because it is unlikely that multiple types of resistance training programs all affect throwing velocity in the same manner.

The purpose of this study was to determine the effects of a short-term 6-week resistance summer training program on throwing velocity using 3 baseball-specific training groups and a nontraining control group. All the groups participated in postseason summer baseball during the 6-week study. The 3 training groups were the Throwers Ten (TT), Keiser Pneumatic (KP), and Plyometric (PLY). It was hypothesized that at the completion of the 6-week training program, all the 3 training groups would exhibit a significant increase in throwing velocity compared with their pretest values, whereas pretest and posttest throwing velocity values would be similar in the control group. Moreover, it was hypothesized that the PLY and KP training groups, which employed explosive, ballistic training that was specific to throwing, would exhibit a significantly greater increase in throwing velocity compared with the TT group, which employed slower and more controlled movement patterns.

Methods

Experimental Approach to the Problem

This study examined the effects of 3 baseball-specific 6-week resistance training programs on throwing velocity in high school baseball players. Because youth athletes increase musculature strength through maturation, which can affect throwing velocity, we used a control group to compare with the experimental (training) groups. To control the effects of age and training status on throwing velocity, we employed a randomization process in assigning the subjects to the 4 groups.

To test the hypothesis that at the completion of the 6-week training program all 3 training groups, but not the control group, would exhibit a significant increase in throwing velocity, pretest and posttest throwing velocity values were assessed. Throwing velocity was chosen as the dependent variable because it is one component of performance enhancement in baseball. The 3 training programs were chosen as independent variables because of their sport specificity to baseball movements.

Subjects

Sixty-eight high school baseball players between 14 and 17 years of age from the Pensacola, FL region, volunteered as subjects (62 right handed and 6 left handed) and were randomly and equally divided into a TT group, KP group, PLY group, and control group. The subjects' mean (*SD*) age, mass, and height are shown in Table 1. Inclusion criteria required each participant (a) to be a healthy high school baseball player with no current injuries; (b) to be able to correctly perform all exercises in the training program; (c) to be untrained and not involved in a resistance training program for at least 3 months before participating in this study; (d) to be able to attend at least 80% of the training sessions; (e) to be able to throw with 100% effort without pain during pretest and posttest sessions; and (f) to only participate in the sport of baseball and not any other sport. All the subjects and their parents provided written informed consent, and the protocol used for this study was approved by the Baptist Hospital Institutional Review Board.

Table 1. Mean (*SD*) age, mass, and height for throwers ten, Keiser pneumatic, plyometric, and control groups.*

Group	Age (y)	Mass (kg)	Height (m)
Throwers ten ($n = 14$)	15.2 (1.1)	75.9 (13.2)	1.78 (0.07)
Keiser pneumatic ($n = 15$)	15.4 (1.3)	72.3 (14.3)	1.80 (0.05)
Plyometric ($n = 14$)	15.8 (0.8)	73.0 (11.9)	1.79 (0.08)
Control ($n = 15$)	15.8 (1.4)	75.5 (12.7)	1.80 (0.06)

*There were no significant differences ($p < 0.05$) in age, mass, and height comparisons among control and training groups.

All the subjects participated in a summer baseball league, which consisted of playing 2–3 baseball games per week. Other than playing summer baseball games, the control group was instructed not to engage in additional sports or activities throughout the study, and they all acknowledged at the end of the 6-week period of the study that summer baseball was the only activity that they participated in. Other than playing summer baseball games, the 3 training groups participated in a 6-week resistance training program, as described below, and each subject in the training groups acknowledged that summer baseball and the resistance training programs were the only activities that they participated in throughout the study. Therefore, the primary difference between the control and training groups was that the training groups participated in a 6-week resistance training program while the control group did not.

Procedures

Description of the 3 Resistance Training Programs. The 3 resistance training groups trained 3 $d \cdot wk^{-1}$ for 6 weeks at the Andrews Research and Education Institute (Gulf Breeze, FL, USA), with each session comprised of 5–10 minutes of warm-up, approximately 45 minutes of resistance training, and 5–10 minutes of cool-down. The warm-up and cool-down involved light jogging and both static and dynamic stretching to prepare the body for resistance training.

A trainer knowledgeable in how to correctly perform all exercises in all 3 training programs supervised and trained the 3 groups during all the sessions for the 6-week duration of the study. During the initial week of training, the trainer first demonstrated and explained how to correctly perform all the exercises before the subjects performing the exercises. All the subjects rotated from exercise to exercise according to when the trainer gave the command to rotate to the next exercise station. Throughout all training sessions, the trainer corrected improper lifting technique, answered any questions the subjects had, and provided positive encouragement to work hard.

Because employing between 6 and 12 repetitions of multiple sets is common in resistance training programs for improving muscular strength, power, and hypertrophy (9), this repetition range was used in this study. Specifically, 8–12 repetitions were performed for the TT and KP groups (the greatest resistance possible that allowed 12 repetitions for weeks 1 and 4, 10 repetitions for weeks 2 and 5, and 8 repetitions for weeks 3 and 6), and 6–10 repetitions were performed for the PLY group (the greatest resistance possible that allowed 10 repetitions for weeks 1 and 4, 8 repetitions for weeks 2 and 5, and 6 repetitions for weeks 3 and 6). For each training session, 36 sets were performed in the TT group (18 different exercise movements performed for 2 sets), 32 sets were performed in the KP group (16 different exercise movement performed for 2 sets), and 32 sets were performed in the PLY group (32 different exercise movements performed for 1 set). For all 3 training groups, approximately 1–2 minutes of rest was permitted between sets.

Because volume (estimated by total number of repetitions performed) typically decreases as exercise intensity increases, and because plyometric training was considered higher intensity training (fewer repetitions used with a concomitant increase in resistance) compared with the training in the TT and KP groups, volume was approximately 20% less in the PLY group compared with that in the KP group and approximately 10% less in the KP group compared with that in the TT group. As the subjects in all 3 training groups increased their strength and power throughout the 6-weeks of training, they progressively increased the resistance in the tubing, dumbbells, Keiser equipment, or medicine balls they used, so they stayed within the assigned number of repetitions for any given week.

Descriptions of how the exercises were performed in the TT group are given in the Appendix. The TT program is commonly used among baseball players to increase arm strength and enhance thrower velocity during both training and rehabilitation (10). It was designed to exercise the major upper extremity muscles that are engaged during throwing. The program's goal is to be an organized and precise exercise program specific to the thrower to improve strength, power, and endurance in upper extremity musculature. The program commonly involves performing each repetition in a slow and controlled manner ($\sim$45–60$^\circ \cdot s^{-1}$) using both concentric and eccentric muscle actions (10). The TT program consists of 10 basic groups of exercises that use either dumbbells or elastic tubing as resistance (10).

Descriptions of how the exercises were performed in the KP group are given in the Appendix. The KP group used Keiser Equipment (Keiser Corporation, Fresno, CA, USA), which uses a pneumatic resistance system. Specifically, the Keiser Performance Trainer and the Keiser Functional Trainer were employed. Because pneumatic resistance was used, resistance was constant throughout the range of motion and unaffected by the speed of exercise. Unlike the TT group, the KP group used explosive training involving more baseball-specific functional training that used the lower extremity, trunk, and upper extremity in sequence. Because power generated during throwing is primarily in transverse and diagonal planes, the exercises chosen were performed primarily in these planes. The exercises were generally performed as explosively as possible as the muscles shortened because of concentric muscle actions, followed by eccentric muscle actions as the body slowly returned back to the starting position. The arm deceleration exercise was an exception to explosive concentric training, as described in the Appendix.

Descriptions of how the exercises were performed in the PLY group are given in the Appendix. The PLY resistance program consisted of using medicine balls or elastic tubing to perform quick explosive movements. All the exercises were performed employing the stretch-shortening cycle, which involved a rapid eccentric muscle action (prestretch) followed by a countermovement that consisted of a rapid concentric muscle action to produce peak force as quickly as possible. All of the medicine ball exercises involved the entire body, sequencing from the lower extremity to the trunk to the upper extremity, and these movements largely occurred in transverse and diagonal planes, which were chosen because of their specificity to throwing and similar baseball movements. Some of the tubing exercises also involved the entire body, whereas several other tubing exercises involved only movements of the throwing shoulder. Because of the ballistic and explosive nature of PLY training, slightly fewer repetitions were employed during PLY training compared with the training performed by the TT and KP groups. All the subjects used medicine balls that weighed between 1.8 and 3.6 kg.

Pretest/Posttest Assessment for Throwing Velocity. Throwing velocity measurements for all the subjects were conducted at the Andrews Research and Education Institute (Gulf Breeze, FL, USA) 2 days before the start of the resistance training program (pretest) and 2 days after the completion of the resistance training program (posttest). Before pretesting or posttesting, each subject first performed their own warm-up routine that they normally employed before throwing hard, which involved light jogging, stretching, and throwing. Once subjects acknowledged they were ready to throw hard, 5–10 maximum effort throws were performed, resting approximately 20 seconds between throws to prevent muscular fatigue. For the pretest and posttest, environmental conditions were similar and new regulation weight baseballs were used. All the throws were performed using a 2 step throw. For right-handed throwers, they stepped first with their right foot, then their left foot, followed by the throw. For left handed throwers, they stepped first with their left foot, then their right foot, followed by the throw. Each subject started on a line that was 22.9 m from a 1.8-m diameter circular target, with the center of the target approximately at chest level (1.30 m high). This distance was chosen because it was slightly longer then the distance a pitcher would throw and slightly shorter than a typical distance a position player would throw. The circular target size was chosen because it approximated a target in which a ball could be caught by simply moving the arm in all directions without moving the body. Throwing velocity was recorded from a calibrated Jugs Tribar Sport radar gun (Jugs Pitching Machine Company, Tualatin, OR, USA) as the ball left the pitcher's hand and was accurate within 0.22 $m \cdot s^{-1}$. The same tester was used for both the pretest and posttest. Throwing velocities from the first 5 maximum effort throws that landed within the circular target were recorded, and the throw with the highest throwing velocity value was used in subsequent statistical analyses.

Program Compliance. Of the 68 subjects who started the program, 58 were included in the statistical analysis. Five of the 68 subjects were omitted because they dropped out of the study as a result of unforeseen events (e.g., family vacation), and another 5 were omitted because they missed >20% (>4 sessions) of the training sessions because of unforeseen events. An attendance compliance rate of approximately 80% was required to be included in subsequent statistical analyses, which equates to attending at least 14 of the 18 training sessions.

Questionnaire. During the posttest, each subject in the training groups anonymously completed a questionnaire asking their satisfaction with their resistance training program. All the subjects were asked about their perception of the resistance program and how it affected their baseball performance. The specific questions asked were, "What effect did the training program have on your baseball performance?", "What is your overall impression of the training program?", "How hard did you work during the training program?", and "Would you like to continue training using a similar training program?".

Table 2. Throwing velocity mean (*SD*) data between pretest and posttest sessions for throwers ten, Keiser pneumatic, plyometric, and control groups.*

Group	Pretest	Posttest	*p*
Throwers ten ($n = 14$)	32.0 (1.9) $m \cdot s^{-1}$ 71.6 (4.3) $mi \cdot h^{-1}$	32.6 (1.5) $m \cdot s^{-1}$ 72.8 (3.3) $mi \cdot h^{-1}$	0.013*
Keiser pneumatic ($n = 15$)	32.4 (2.5) $m \cdot s^{-1}$ 72.4 (5.6) $mi \cdot h^{-1}$	32.8 (2.4) $m \cdot s^{-1}$ 73.3 (5.4) $mi \cdot h^{-1}$	0.048*
Plyometric ($n = 14$)	33.0 (2.3) $m \cdot s^{-1}$ 73.9 (5.2) $mi \cdot h^{-1}$	33.7 (2.3) $m \cdot s^{-1}$ 75.4 (5.1) $mi \cdot h^{-1}$	0.001*
Control ($n = 15$)	32.6.1 (3.1) $m \cdot s^{-1}$ 72.9 (6.9) $mi \cdot h^{-1}$	32.5 (2.5) $m \cdot s^{-1}$ 72.6 (5.6) $mi \cdot h^{-1}$	0.540

*Significant differences ($p < 0.05$) between pretest and posttest.

Statistical Analyses. A 1 factor analysis of variance (ANOVA) was used assess significant differences ($p \leq 0.05$) in age, mass, and height among the 3 training groups and the control group. A 2-factor repeated measures ANOVA was employed ($p \leq 0.05$) to assess differences in throwing velocity measurements from the pretest and posttest (within-subjects factor) and the 4 training groups (between-subjects

Table 3. Posttraining questionnaire results for the TT, KP, and PLY groups.*†

Question	Greatly increased performance	Slightly increased performance	No effect	Decreased performance
What effect did the training program have on your baseball performance?	TT: 2 KP: 3 PLY: 1	TT: 12 KP: 12 PLY: 12	TT: 0 KP: 0 PLY: 1	TT: 0 KP: 0 PLY: 0
Question	Really enjoyed the program	Enjoyed the program to some degree	Neutral	Did not enjoy the program
What is your overall impression of the training program?	TT: 7 KP: 10 PLY: 10	TT: 7 KP: 5 PLY: 4	TT: 0 KP: 0 PLY: 0	TT: 0 KP: 0 PLY: 0
Question	Very hard	Somewhat hard	Not hard	
How hard did you work during the training program?	TT: 10 KP: 14 PLY: 14	TT: 4 KP: 1 PLY: 0	TT: 0 KP: 0 PLY: 0	
Question	Yes	Maybe	No	
Would you like to continue training using a similar training program?	TT: 10 KP: 5 PLY: 8	TT: 4 KP: 10 PLY: 6	TT: 0 KP: 0 PLY: 0	

*TT = throwers ten; KP = Keiser pneumatic; PLY = plyometric.
†The numbers shown represent the number of subjects in a group who answered either "greatly increased performance," slightly increased performance," "no effect," or "decreased performance."

factor). For ANOVAs with significant differences, post hoc paired Bonferroni *t*-tests ($p \leq 0.05$) were performed to assess which groups differed from each other.

Results

Age, mass, and height comparisons among control and training groups are shown in Table 1. Mean (*SD*) throwing velocity comparisons between pretest and posttest measurements for the control and training groups are shown in Table 2. There was a significant difference between pretest and posttest throwing velocity values ($p < 0.001$), and a significant interaction ($p = 0.027$) between group and test factors. Compared with pretest throwing velocity measurements, throwing velocity measurements were significantly greater during the posttest in the TT, KP, and PLY training groups but not in the control group.

The results from the posttraining questionnaire are shown in Table 3. All the subjects in all the 3 training groups said the training program greatly or somewhat improved their baseball performance, with the exception of 1 subject from the PLY group said the training program had no effect on his baseball performance. All the subjects in all the 3 training groups said they really enjoyed training program or they enjoyed the training program to some degree. All the subjects in all the 3 training groups said they worked very hard or they worked somewhat hard. Lastly, all the subjects in all the 3 training groups said they may continue or they would continue with a similar training program.

Discussion

As hypothesized, throwing velocity significantly increased (1.2–2%) in all 3 training groups after the 6-week resistance training program. These results demonstrate that a short-term resistance training program results in increased throwing velocity in high school baseball players. Because high school baseball players are often involved in multiple sports and activities, and often have a shorter attention span compared to adult athletes, a short-term baseball-specific resistance program may an attractive alternative compared with a longer duration program (e.g., 8–12 weeks). These results also demonstrate that no single resistance training program was conclusively more effective than another resistance training program in increasing throwing velocity. However, the TT and PLY programs may be the easiest and most practical programs to execute given only minimum and inexpensive resistance devices are needed (tubing, dumbbells, medicine balls), whereas the KP group used more expensive and bulky equipment in their training not as easily assessable. This is reflective in the posttraining questionnaire, in which approximately 70% of the subjects in the TT group said they would like to continue training using a similar training program, whereas only 33% of the subjects in the KP group gave the same answer despite the fact that all the subjects enjoyed the KP training program. Because this study is the only known study that investigated the effects of multiple resistance training programs on throwing velocity in youth or high school baseball baseballs, additional research is needed for these age groups in assessing the effectively of other types of resistance training programs on throwing velocity.

The results from this study are similar to the results from Escamilla et al. (3) and Wooden et al. (11) who also examined the effects of resistance training on throwing velocity in youth or high school baseball players. Escamilla et al. (3) reported that after youth (11–15 years old) baseball players performed resistance training and interval throwing 3 $d \cdot wk^{-1}$ for 4 weeks, there was a significantly increase in throwing velocity (4.0% increase from 25.1 to 26.1 $m \cdot s^{-1}$), while there was no significant difference in pretest (24.2 $m \cdot s^{-1}$) and posttest (24.0 $m \cdot s^{-1}$) throwing velocity values in a control group that did not train. One important difference between Escamilla et al. (3) study and this study is that in Escamilla et al. (3) both resistance training and interval throwing were employed in the conditioning program, so it is difficult to know how much the increase in throwing velocity was because of the resistance training and how much was because of interval throwing. Further research is needed to investigate the effects of an interval throwing program on throwing velocity.

Wooden et al. (11) reported that after 14- to 17-year-old high school baseball players performed dynamic, variable resistance (DVR) training, or isokinetic (IKN) training, which both included isolated shoulder internal and external rotation exercises performed 3 $d \cdot wk^{-1}$ for 5 weeks, the DVR training group increased throwing velocity by 0.92 $m \cdot s^{-1}$, which was significantly greater than both the IKN training group (0.38 $m \cdot s^{-1}$ increase in throwing velocity) and a control group (0.15 $m \cdot s^{-1}$ decrease in throwing velocity) who did no training. Moreover, there was no significant difference in throwing velocity between the IKN group and the control group. It can be concluded from these results that IKN training, in which velocity is relatively constant without acceleration, may not be as effective as other modes of resistance training that allow acceleration to occur. This is important because throwing a baseball is acceleratory in nature, and resistance training that permits acceleration is more baseball specific compared with training at a constant speed. The 0.9–1.0 $m \cdot s^{-1}$ (2.0–2.2 $mi \cdot h^{-1}$) increase in throwing velocity reported by Escamilla et al. (3) and Wooden et al. (11) are similar in magnitude although slightly greater than the 0.4–0.7 $m \cdot s^{-1}$ (0.9–1.5 $mi \cdot h^{-1}$) increase in throwing velocity reported in this study.

The results from this study for high school baseball players are similar to the results from the literature that examined the effects of resistance training on throwing velocity in adult baseball players (1,7,8). Carter et al. (1) investigated the effects of an 8-week upper extremity PLY training program on the IKN strength and throwing velocity in collegiate baseball players. Compared with a control group that participated in off-season nonplyometric strength and conditioning activities, the PLY training group exhibited significantly greater throwing velocity (2.4% increase) at the end of the 8-week PLY program (38.1 $m \cdot s^{-1}$, 85.2 $mi \cdot h^{-1}$) compared with the pretraining throwing velocity (37.2 $m \cdot s^{-1}$, 83.2 $mi \cdot h^{-1}$). Moreover, there were no significant differences in any of the strength measurements between the PLY and strength groups from pretraining to posttraining. It can be concluded from these data that although resistance training and PLY training both resulted in strength gains, only the PLY training group influenced throwing velocity. These results are supported by data from Grezios et al. (4), who reported that the stretch-shortening cycle, which is the foundation of PLY training, is the type of muscle contraction that primarily occurs in overhead throwing, such as in throwing a baseball.

Newton and McEvoy (7) also used a PLY training group in their study but reported opposite findings compared with Carter et al. (1) and this study. Newton and McEvoy (7) primarily used adult baseball players (mean age of 18.6 ± 1.9 years) and assessed the effects of upper body PLY medicine ball training, upper body conventional weight training, and nontraining on throwing velocity. The training PLY and weight training groups trained 2 $d \cdot wk^{-1}$ for 8 weeks, whereas the nontraining control group did not train. These authors reported that the weight training group significantly increased their throwing velocity (4.1% increase) from 31.7 $m \cdot s^{-1}$ (pretraining) to 33.0 $m \cdot s^{-1}$ (posttraining), but there were no significant differences in throwing velocity in the PLY medicine ball group (increased from 31.0 $m \cdot s^{-1}$ pretest to 31.5 $m \cdot s^{-1}$ posttest) or the control group (decreased from 32.5 $m \cdot s^{-1}$ pretest to 32.3 $m \cdot s^{-1}$ posttest). Other than this study and the studies from Newton and McEvoy (7) and Carter et al. (1), we are not aware of other studies that have assessed the effects of PLY training on throwing velocity. Moreover, this study is the only study we are aware of that assessed the effects of PLY training in youth or high school baseball players.

Lachowetz et al. (5) and Potteiger et al. (8) also examined the effects of resistance training on throwing velocity in adult baseball players. Employing a 4-$d \cdot wk^{-1}$ upper body strength program for 8 weeks in collegiate baseball players, Lachowetz et al. (5) reported that the resistance training group significantly increased their throwing velocity 2.3% from 30.9 $m \cdot s^{-1}$ (pretraining) to 31.6 $m \cdot s^{-1}$ (posttraining), but there were no significant differences in throwing velocity in a control group that did no training (decreased from 31.5 $m \cdot s^{-1}$ pretest to 31.0 $m \cdot s^{-1}$ posttest).

Potteiger et al. (8) also used collegiate baseball players to assess to effects of resistance training on throwing velocity. The subjects were randomly assigned to 2 groups and trained 4 $d \cdot wk^{-1}$ for 10 weeks. One group performed weight training combined with sprint training (WS), and the other group performed an aerobic dance program (AE). From pretraining to posttraining, the WS group significantly increased their throwing velocity 3.0% from 33.5 $m \cdot s^{-1}$ pretest to 34.5 $m \cdot s^{-1}$ posttest, whereas there was no significant difference in pretraining and posttraining throwing velocity values in the AE group (33.0 $m \cdot s^{-1}$ pretest to 32.6 $m \cdot s^{-1}$ posttest). It can be concluded from these data that aerobic activities may not be an effective manner to increase throwing velocity. In contrast, what is clear from the aforementioned resistance training studies in the literature is that a 1.2–4.1% increase in throwing velocity (mean increase between 2.5 and 3%) is a reasonable outcome to expect from 4 to 10 weeks of baseball-specific resistance training.

A limitation in this study is the short duration of the resistance training programs. Programs of greater duration may have resulted in greater increases in throwing velocity. Further studies are needed to investigate this. However, short duration is also one of the strengths of this study, which demonstrated that significant increases in throwing velocity occur in only a few weeks of training. This is important because many preadult baseball players may not be compliant with a long-term resistance training program. Because preadults are active in both school and extracurricular activities, a short-term resistance training program may be preferred over a long-term resistance training program. However, how long the increased throwing velocity effects of a short-term resistance training program lasts after completing a resistance training program is unknown, and this needs to be investigated. It is likely that these increased throwing velocity effects are transient without a consistent year round resistance training program. However, a maintenance resistance training program of 1–2 times per week may be adequate to maintain the performance enhancing effects of a baseball-specific resistance training program. For example, it has been demonstrated that after 12 weeks of training for 3 sessions per week, reducing the training frequency to 1 or 2 sessions per week for an additional 12 weeks of training maintained rotator cuff strength gains in previously untrained subjects (6).

Another limitation is that some exercises in all 3 training groups required a learning curve for some of the subjects, and this may have affected the performance results to some degree. It took a few training sessions before some of the subjects really felt comfortable performing some of the exercises. The exercises that were easiest and quickest to learn were those exercises in the TT group, whereas the exercises that were hardest and took the longest to learn were those exercises in the KP group. Also, it took longer for the younger kids to learn some of the more complex exercises compared with the older kids. Nevertheless, after a few sessions, all the subjects were able to perform all the exercises correctly as taught by the trainer.

The training status of the subjects can also affect performance results. Untrained individuals who begin a new resistance training program typically increase strength (and perhaps performance also) faster during the first several weeks or months of training compared with trained individuals who simply continue a training program they have already been performing for an extended period of time. Although the subjects had varying maturation levels based on age, the randomization of the subjects into the 4 groups helped control for effects of age levels. Moreover, all the subjects had not participated in a resistance training program at least 3 months before when they started the training program in this study, so all the subjects were considered "untrained" in resistance training when they started the program. This implies that any type of resistance training program may likely have resulted in strength increases but not necessarily performance improvement such as increased throwing velocity. Additional studies are needed to more thoroughly assess the effects of resistance training in this age group on baseball performance variables.

Future studies are also needed to investigate the effects of resistance training programs on throwing velocity in more narrow age ranges compared with this study and related studies in the literature. For example, in both this study and in Wooden et al. (11), the subjects were between 14 and 17 years old with a mean age between 15 and 16 years old. In Escamilla et al. (3), the subjects were between 11 and 15 years old with a mean age between 12 and 13 years old. It is still unclear if younger and older youth or high school baseball players (such as 3 groups of 11-, 14-, and 17-year-old baseball players) would respond in a similar manner to a resistance training program in terms of throwing velocity, and which types of resistance programs are most effective in younger and older youth or high school baseball players. Future studies are also needed to examine additional training programs with high biomechanical specificity to baseball pitching to determine if there are training programs that stand out from all others in terms of improving throwing velocity.

Practical Applications

The results of this study demonstrated that all 3 short-term baseball-specific resistance training programs were effective in enhancing throwing velocity in high school baseball players, but it was not conclusive that one resistance training program was more effective than another resistance training program in increasing throwing velocity. In only 6 weeks, throwing velocity significantly increased 1.2–2% in the 3 resistance training groups, compared with a nonsignificant change in the control group who did not participate in resistance training. Increased throwing velocity may be helpful for a pitcher, because the batter will have less time to make a decision in whether or not to swing at the pitch, and may help position players, such as a catcher, infielder, or outfielder trying to throw out a runner attempting to advance to the next base.

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References

1. Carter, AB, Kaminski, TW, Douex, AT, Knight, CA, and Richards, JG. Effects of high volume upper extremity plyometric training on throwing velocity and functional strength ratios of the shoulder rotators in collegiate baseball players. *J Strength Cond Res* 21: 208–215, 2007.
2. Conte, S, Requa, RK, and Garrick, JG. Disability days in major league baseball. *Am J Sports Med* 29: 431–436, 2001.
3. Escamilla, RF, Fleisig, GS, Yamashiro, K, Mikla, T, Dunning, R, Paulos, L, and Andrews, JR. Effects of a four week youth baseball conditioning program on throwing velocity. *J Strength Cond Res.* In press.
4. Grezios, AK, Gissis, IT, Sotiropoulos, AA, Nikolaidis, DV, and Souglis, AG. Muscle-contraction properties in overarm throwing movements. *J Strength Cond Res* 20: 117–123, 2006.
5. Lachowetz, T, Evon, J, and Pastiglione, J. The effect of an upper body strength program on intercollegiate baseball throwing velocity. *J Strength Cond Res* 12: 116–119, 1998.
6. McCarrick, MJ and Kemp, JG. The effect of strength training and reduced training on rotator cuff musculature. *Clin Biomech (Bristol, Avon)* 15(Suppl 1): S42–S45, 2000.
7. Newton, RU and McEvoy, KP. Baseball throwing velocity: A comparison of medicine ball training and weight training. *J Strength Cond Res* 8: 198–203, 1994.
8. Potteiger, JA, Blessing, DL, and Wilson, GD. Effects of varying recovery periods on muscle enzymes, soreness, and performance in baseball pitchers. *J Athl Train* 27: 27–31, 1992.
9. Stone, MH, O'Bryant, H, Garhammer, J, McMillan, J, and Rozenek, R. A theoretical model of strength training. *Natl Strength Cond Assoc J* 4: 36–40, 1982.
10. Wilk, KE, Meister, K, and Andrews, JR. Current concepts in the rehabilitation of the overhead throwing athlete. *Am J Sports Med* 30: 136–151, 2002.
11. Wooden, MJ, Greenfield, B, Johanson, M, Litzelman, L, Mundrane, M, and Donatelli, RA. Effects of strength training on throwing velocity and shoulder muscle performance in teenage baseball players. *J Orthop Sports Phys Ther* 15: 223–228, 1992.

Appendix

Descriptions of How the Exercises Were Performed in the Throwers Ten Group

Although there are slightly different versions of the TT program, the version used in this study is as follows: 1A. Diagonal Pattern D2 Extension: Started with throwing arm overhead, shoulder externally rotated, and forearm supinated (Figure 1A). Tubing was then pulled down and across the body in a diagonal pattern to the opposite side of the hip while internally rotating the shoulder and pronating forearm, leading with the thumb (Figure 1B). 1B. Diagonal Pattern D2 Flexion: Reverse movement pattern compared with Diagonal Pattern D2 Extension (Figures 2A, B). 2A. Shoulder External Rotation at 0° Abduction: Started with throwing arm at side with elbow flexed 90° and the shoulder fully internally rotated. The shoulder was then externally rotated through full range of motion by pulling tubing outward. 2B. Shoulder Internal Rotation at 0° Abduction: Started with the throwing arm at the side with the elbow flexed 90° and the shoulder fully externally rotated. The shoulder was then internally rotated through the full range of motion by pulling tubing inward. 2C. Shoulder External Rotation at 90° Abduction: Started with the throwing arm abducted 90°, elbow flexed 90°, and the shoulder fully internally rotated. The shoulder was then externally rotated through the full range of motion by pulling tubing backwards. 2D. Shoulder Internal Rotation at 90° Abduction: Start with the throwing arm abducted 90°, elbow flexed 90°, and the shoulder fully externally rotated. The shoulder was then internally rotated through the full range of motion by pulling tubing forward. 3. Shoulder Abduction to 90° (Lateral Raise): Using 2 dumbbells, the subject stood with arms at the side, elbows fully extended, and palms facing inward. Both shoulders were then abducted 90°. 4. Scaption with External Rotation: Using 2 dumbbells, the subject stood with arms at the side, elbows fully extended, and shoulders externally rotated. The subject then raised both the arms 90° in the scapular plane (shoulders horizontally flexed forward 30–45°) with the thumbs up. 5. Bent Over Horizontal Abduction (Reverse Flys): Using 2 dumbbells, the subject bent over with knees slightly bent and trunk parallel to the ground, arms hanging vertically downward, elbows extended, and palms facing each other. Both shoulders were then horizontally abducted 90°. 6. Bent Over

Figure 1. A) Diagonal pattern D2 extension start position and B) diagonal pattern D2 extension end position.

Figure 2. A) Diagonal pattern D2 flexion start position and B) diagonal pattern D2 flexion end position.

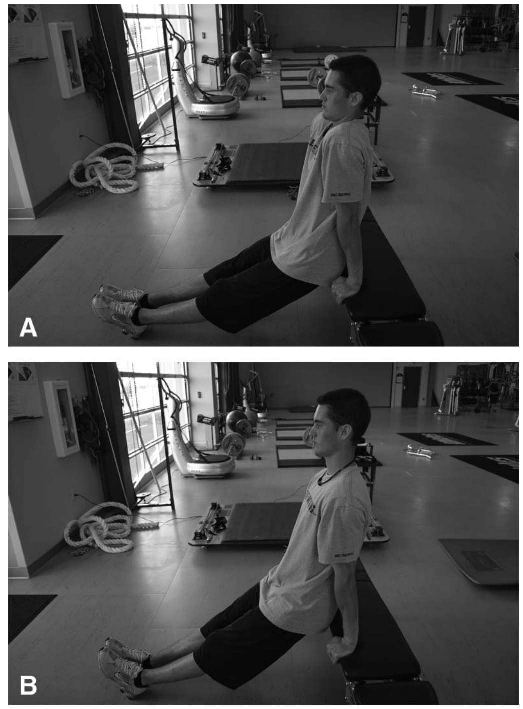

Figure 3. A) Press-up start position and B) press-up end position.

1-Arm Rows: Using 1 dumbbell, the subject bent over with knees slightly bent and trunk parallel with ground, and arm hanging vertically downward, elbows extended, and palm facing inward. The subject then flexed the elbow and pulled the dumbbell up to the torso, and then repeated using the other arm. 7. Press-ups: Started with the buttocks just off a bench with the arms down at the side, elbows fully extended, hands on the bench, legs out in front, and the shoulders shrugged up toward the ears (Figure 3A). The subject then slowly pushed downward through the hands to elevate the buttocks and the torso (Figure 3B). 8. Push-ups: With hands slightly wider than shoulder width, the subject pushed up as high as possible by fully extending elbows, and then roll shoulders forward and fully protract scapulae. 9A. Elbow Extension (Overhead Triceps Extension). Using 2 dumbbells, the subject stood with arms overhead and elbows fully flexed. The subject then fully extend both elbows while keeping both arms stationary. 9B. Elbow Flexion (Biceps Curl): Using 2 dumbbells, the subject stood with arms against sides, elbows extended, and forearms supinated with palms facing forward. The subject then fully flexed both elbows. 10A. Wrist Extension: Using 2 dumbbells, while seated both forearms were supported on thighs with forearms pronated (palms down) and wrists fully flexed. The subject then fully extended wrists. 10B. Wrist Flexion: Using 2 dumbbells, while seated both forearms were supported on thighs with forearms supinated (palms up) and wrists fully extended. The subject then fully flexed wrists. 10C. Forearm Supination and Pronation: Started with throwing arm at side, elbow flexed 90°, and forearm fully supinated (Figure 4). The subject then fully pronated forearm until palm was facing down, and then fully supinated forearm until palm was facing up again.

Figure 4. Forearm pronation start position and forearm supination end position.

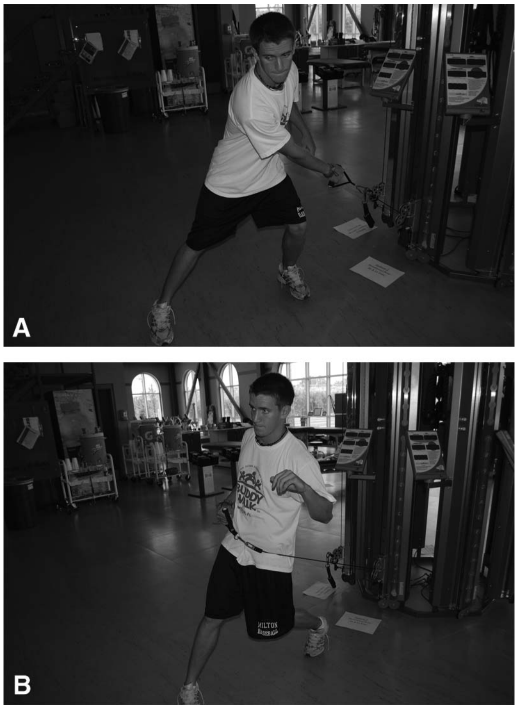

Figure 5. A) Rotational row start position and B) rotational row end position.

Figure 6. A) Diagonal lift start position and B) diagonal lift end position.

Descriptions of How the Exercises Were Performed in the Keiser Pneumatic Group

1. Rotational Row–performed both sides of the body (Figures 5A, B) 2. Diagonal Lift–performed both sides of the body (Figures 6A, B) 3. Diagonal Pattern D2 Extension–similar movement pattern as performed in the TT program, except used both arms simultaneously. 4. Diagonal Pattern D2 Flexion–similar movement pattern as performed in the TT program, except used both arms simultaneously. 5. Arm Acceleration–performed with the throwing arm only (Figures 7A, B). 6. Arm Deceleration–performed with the throwing arm only (Figures 8A, B)–both extremities were used to pull the handle back, and then one extremity was used to slowly allow the body to move forward through eccentric muscle actions from posterior musculature, simulating the arm deceleration phase of pitching. 7. Stability Chops–performed both sides of body (Figures 9A, B).

8. Rotary Lift–performed both sides of the body (Figures 10A, B). 9. Flys–standing with the shoulders abducted 90° and palms facing forward, the subject horizontally adducted both shoulders by bringing both arms across chest until hands were together. 10. Reverse Flys–opposite movement compared with Flys. 11. Push-Pulls–performed both the sides of the body (Figures 11A, B).

Descriptions of How the Exercises Were Performed in the Plyometric Group

Medicine Ball Exercises. 1. Chest Pass–performed first with right foot forward and then performed with left foot forward (Figures 12A, B). 2. Perpendicular Throw–performed first with the right foot forward and then performed with the left foot forward, and performed on both sides of the body (Figures 13A, B). 3. Ear Throw–Performed with ball first held on right side of body and then with ball held on left side of body (Figures 14A, B). 4. Rotary Straight Arm Throw–performed on both sides of the body (Figures 15A, B). 5. Hitter's Push–performed on both sides of the body (Figures 16A, B). 6. Squat to Thrust (Figures 17A, B). 7. Overhead Slam (Figures 18A, B). 8. Wood Chop (Figures 19A, B). 9. Diagonal Wood Chop–performed on both sides of the body (Figures 20A, B).

Tubing Exercise. 10. Flys–similar movement pattern as performed in the KP program. 11. Reverse Flys–Opposite movement compared to Flys. 12. Shoulder Extension (Figures 21A, B). 13. Shoulder Flexion–Opposite movement compared with Shoulder Extension. 14. Scaption with External Rotation–similar movement pattern as performed in the TT program. 15. Shoulder External Rotation at 0° Abduction–similar movement pattern as performed in the TT program. 16. Shoulder Internal Rotation at 0° Abduction–similar movement pattern as performed in

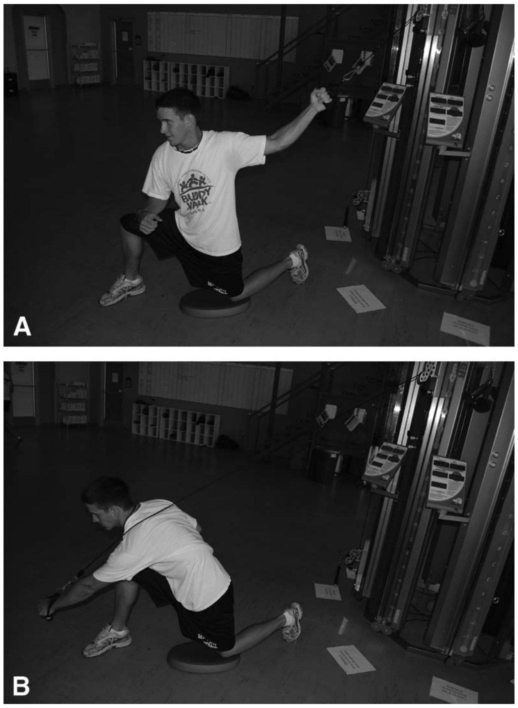

Figure 7. A) Arm acceleration start position and B) arm acceleration end position.

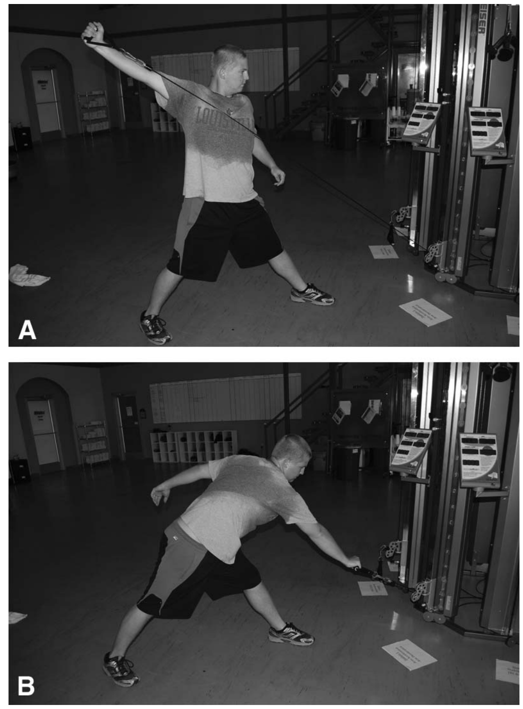

Figure 8. A) Arm deceleration start position and B) arm deceleration end position.

the TT program. 17. Shoulder External Rotation at 90° Abduction–similar movement pattern as performed in the TT program. 18. Shoulder Internal Rotation at 90° Abduction–similar movement pattern as performed in the TT program. 19. Scapular Protraction (Figures 22A, B). 20. Bench Press–Similar as performing a dumbbell bench press but performed in the standing position. 21. Arm Acceleration–similar movement pattern as performed in the KP group, as shown in Figures 7A, B. 22. Arm Deceleration–similar movement pattern as performed in the KP group, as shown in Figures 8A, B. 23. Trunk Rotation–performed on both sides of the body (Figures 23A, B).

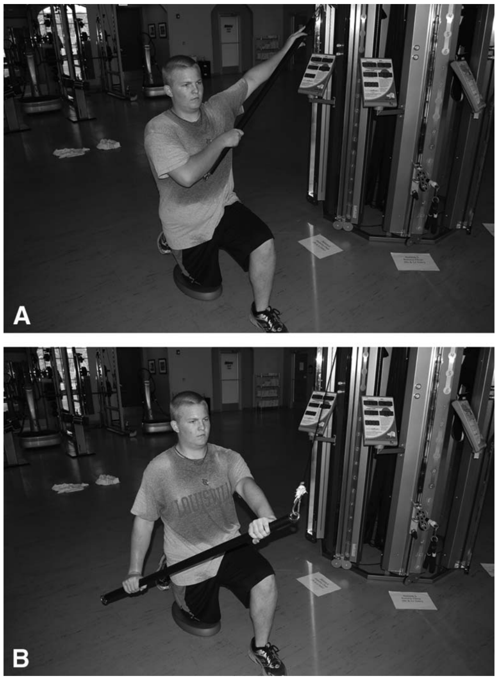

Figure 9. A) Stability chops start position and B) stability chops end position.

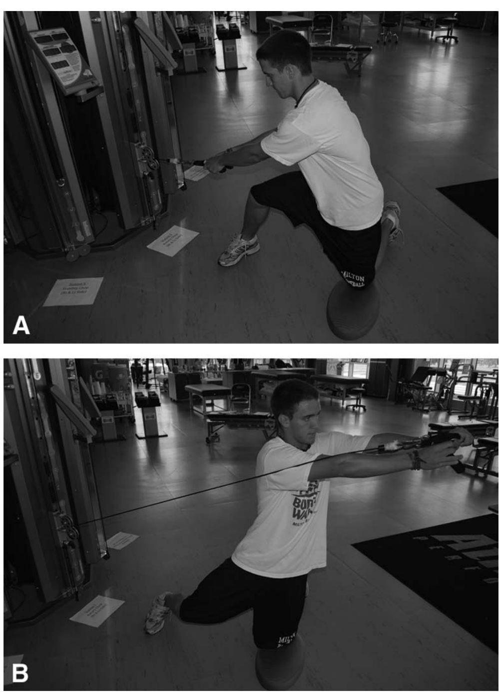

Figure 10. A) Rotary lift start position and B) rotary lift end position.

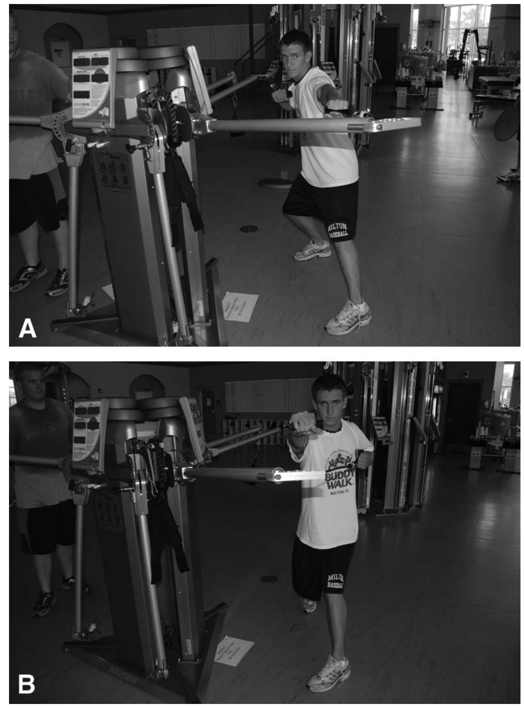

Figure 11. A) Push-pull start position and B) push-pull end position.

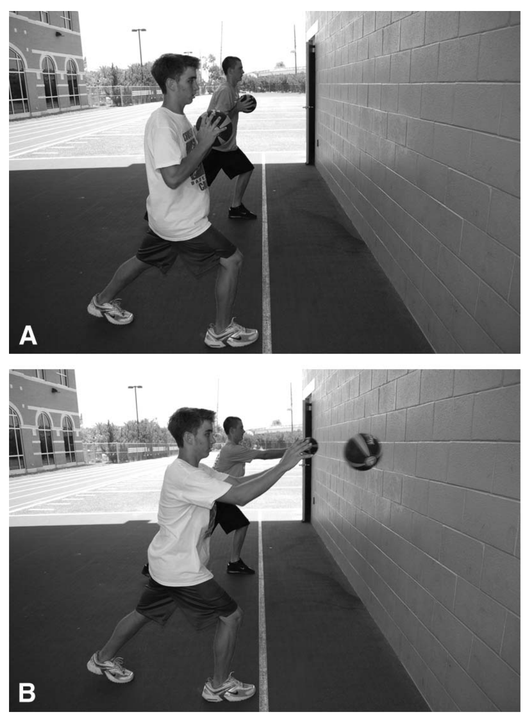

Figure 12. A) Chest pass start position and B) chest pass end position.

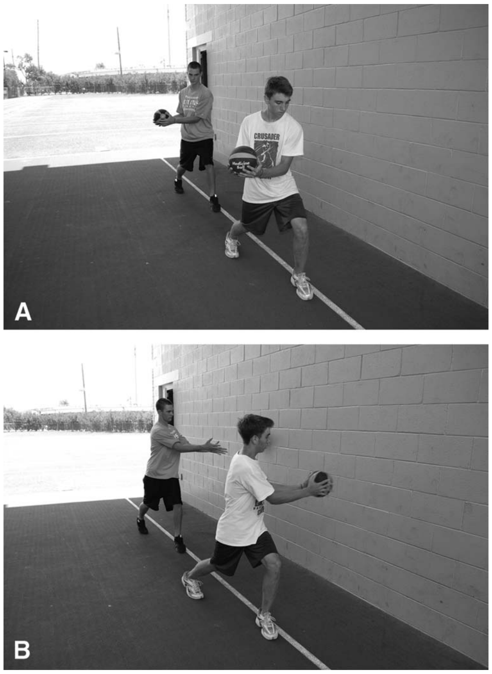

Figure 13. A) Perpendicular throw start position and B) perpendicular throw end position.

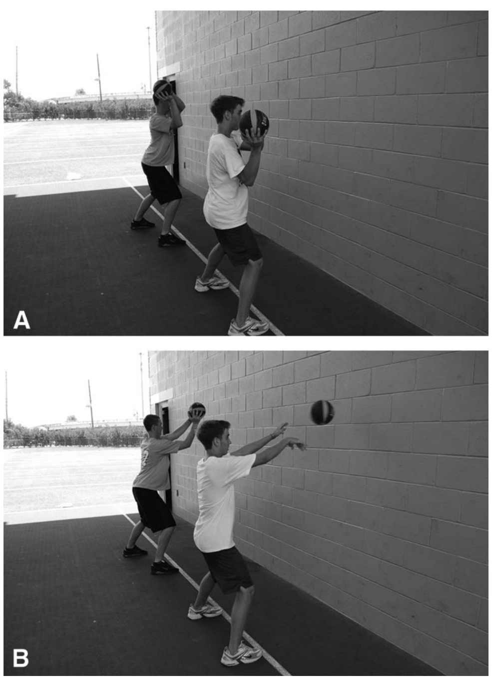

Figure 14. A) Ear throw start position and B) ear throw end position.

Figure 15. A) Rotary straight arm throw start position and B) rotary straight arm throw end position.

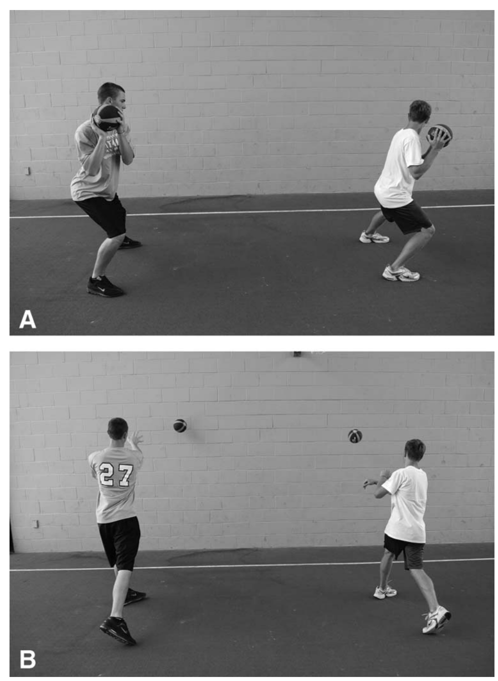

Figure 16. A) Hitter push start position and B) hitter push end position.

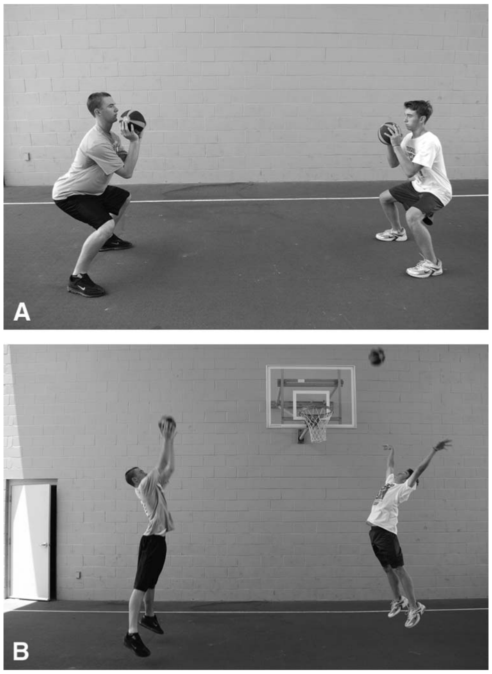

Figure 17. A) Squat to thrust start position and B) squat to thrust end position.

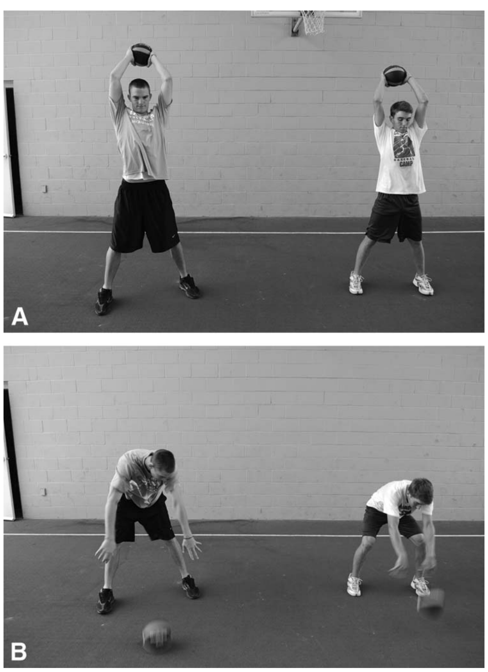

Figure 18. A) Overhead slam start position and B) overhead slam end position.

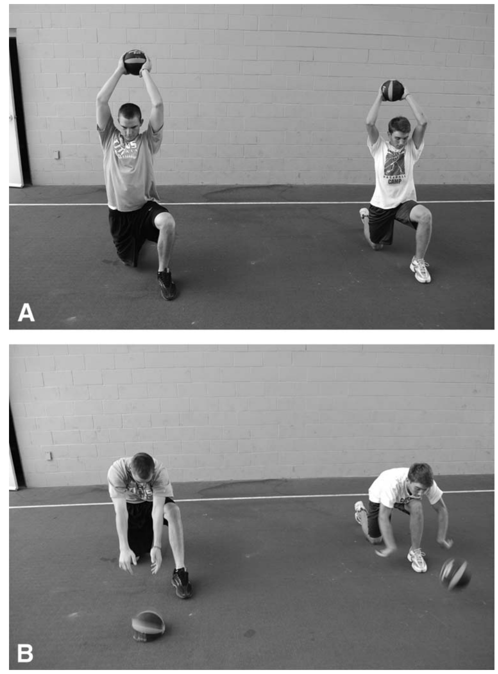

Figure 19. A) Wood chop start position and B) wood chop end position.

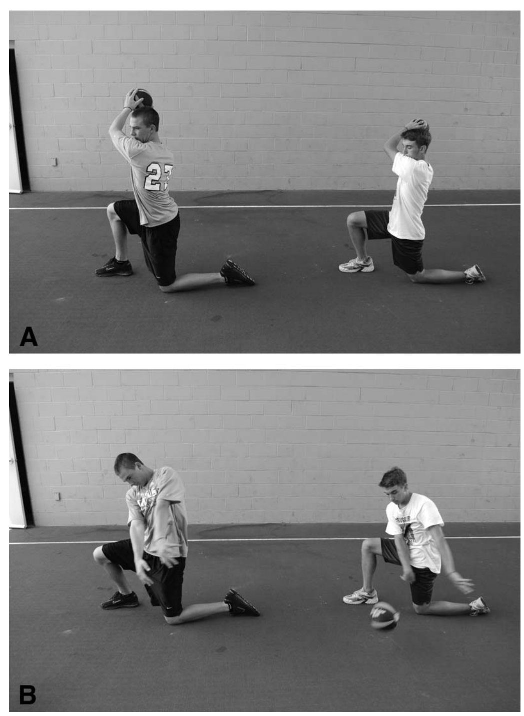

Figure 20. A) Diagonal wood chop start position and B) diagonal wood chop end position.

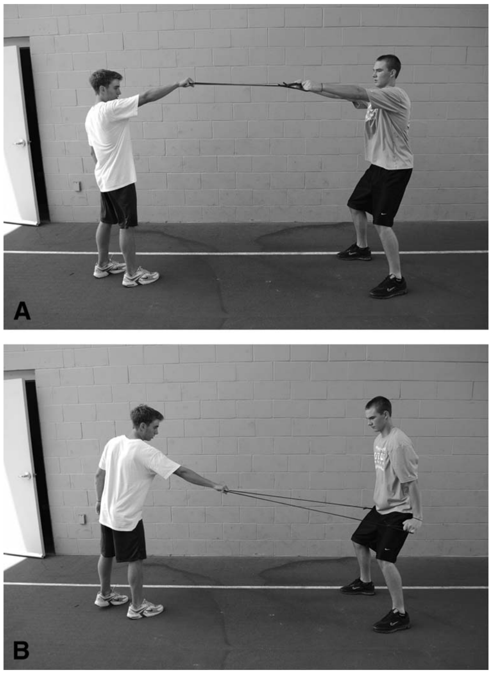

Figure 21. A) Shoulder extension start position and B) shoulder extension end position.

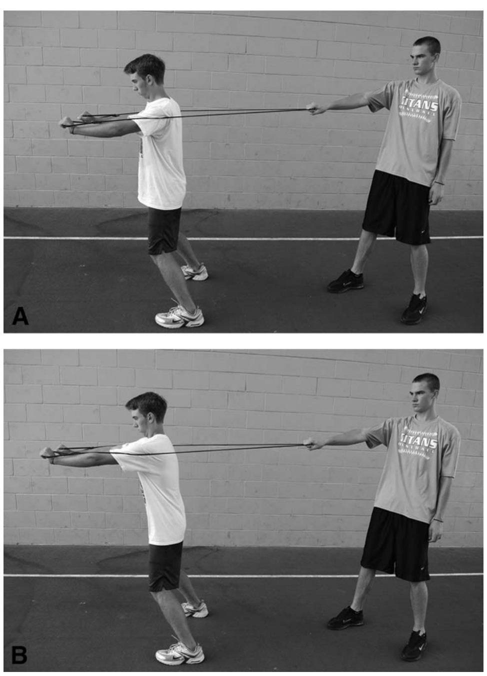

Figure 22. A) Scapular protraction start position and B) scapular protraction end position.

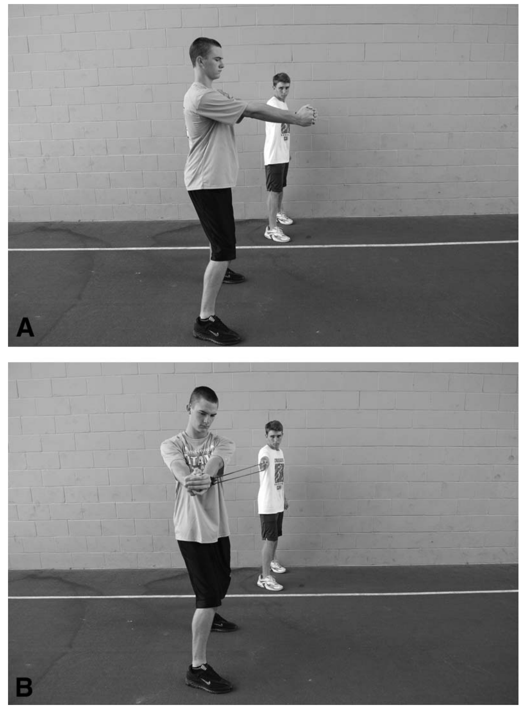

Figure 23. A) Trunk rotation start position and B) trunk rotation end position.