Effects of Baseball Weighted Implement Training: A Brief Review

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SUMMARY

BASEBALL RESISTANCE TRAINING HAS BECOME A MAJOR COMPONENT OF MOST HIGH SCHOOL AND COLLEGIATE PITCHERS' AND HITTERS' CONDITIONING PROGRAMS. DURING THE PRECOMPETITIVE TRAINING PHASE, POWER TRAINING LASTING 1–2 MONTHS SHOULD INCLUDE A UNIQUE EXPLOSIVE TRAINING REGIMEN CALLED WEIGHTED IMPLEMENT TRAINING. WEIGHTED IMPLEMENT TRAINING REGIMENS USE PRECISELY CONSTRUCTED WEIGHTED BATS AND BASEBALLS IN SPORT-SPECIFIC TRAINING PROTOCOLS. THIS ARTICLE WILL REVIEW THE EFFECTS OF BASEBALL WEIGHTED IMPLEMENT TRAINING IN HIGH SCHOOL AND COLLEGIATE PITCHERS AND HITTERS AND PROVIDE STRENGTH AND CONDITIONING COACHES WITH PRACTICAL APPLICATIONS.

INTRODUCTION

There are numerous general, special, and specific annual resistance training programs designed by high school, college, and professional baseball strength and conditioning coaches with the goals of increasing athletic performance and decreasing the risk of injuries (5,18,40). Strength and conditioning coaches seeking to attain these goals have many choices as to which resistance training programs to select from or refer to when designing their own year-round baseball resistance training program. The 2 major sport skills of baseball, throwing and hitting, are comprised of explosive, rotational movements. When these movements are executed in the proper sequence, kinetic energy is transferred from the legs through the torso to the arms, allowing for maximal throwing/pitching and bat swing velocities (13,16,24,40).

Integrating strength and power training with sport skill development is a difficult task requiring strength and conditioning coaches to approach this challenge from a scientific basis. Therefore, once strength has been increased, it is essential that strength and conditioning coaches improve baseball players' rotational and ballistic/explosive movements through power training. To accomplish these goals, a pitcher's and a hitter's resistance training program must be centered on 2 main training principles: specificity of training and periodization (2). Specificity of training infers that there is a positive transfer of training effect when resistance training exercises are close to or identical to the sport skill–specific range of motion (ROM) (2). Exercises for throwing/pitching and hitting must be compatible with the alternating acceleration and deceleration movements. For example, throwing and hitting weight room exercises that duplicate the acceleration and deceleration arm and bat movements at a rate close to game speeds will bring about changes that will enable the thrower/pitcher and hitter to enhance their respective competitive performances (12,13,41). Periodization is a comprehensive training plan that is divided into various phases and cycles (4,5). According to Bompa (5), an annual periodized program includes 3 training phases: preparatory (preseason), competitive (season), and transition (offseason). The preparatory phase has been divided into 2 subphases called general preparation and specific preparation. Each of these phases can last between 1 and 3 months. The focus of the general preparation phase is anatomical adaptation and improvement of strength, whereas the specific preparation is used to increase maximum strength. The competitive phase is divided into 2 subphases called precompetitive and main competition. The duration of the precompetitive phase can be 1–2 months, whereas the main competition phase will be based on the length of the baseball season. During the baseball precompetitive phase, strength and conditioning coaches should emphasize the development of sport-specific, explosive rotational and linear power, which includes exercises that mimic the throwing and hitting motions of baseball players. A unique training protocol to enhance throwing and hitting

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performances that is researched based, sport specific, and conducted during the precompetitive training phase with possible injury prevention is called weighted implement training (7–15,17).

Weighted (modified lighter and heavier) implement training has been used by former Soviet Union researchers and strength coaches in track and field for decades (27–30,43,44). The Soviets modified their field event implements, such as the hammer, shot put, javelin, and discus. These weighted implements were used specifically in their specialized speed strength (power) training programs. The idea behind underweighted training for the track and field athletes was that their body segments would move at higher speeds with less muscle force generated because lighter than normal implements were thrown. On the other hand, the reason for using overweighted training for these athletes was that body segments would move at slower speeds with greater muscle force generated because heavier than normal implements were thrown. Using underweighted implements is considered speed training, whereas using overweighted implements is considered strength training. The Soviet findings suggested the following 3 outcomes: (1) the employment of varied resistance training enhances speed strength (power) development, (2) implement resistance variations in training should range from 5 to 20% lighter and heavier than standard implements, and (3) when training with weighted and standard weight implements, use a 2:1 frequency ratio of heavy or light implements to the standard weight implement (27–30, 43,44).

Weighted implement training for baseball consists of exercising with modified standard competitive implements (baseballs and bats) while safely duplicating the acceleration and deceleration arm and bat movements full ROM at or near game speeds. Pitchers and hitters exercise according to a specific guided research-based training regimen with weighted baseballs and bats close to competitive standards in attempts to increase throwing/pitching and bat swing velocities. If these sport skills can be improved, players will have better chances of being successful. For example, if a pitcher can throw with greater velocity, the hitter will have less time to see the pitched ball. Conversely, if the hitter has greater bat swing velocity, he will be able to wait longer before deciding whether or not to swing at a pitched ball. This could ultimately help a team win more games, and at the professional level, allow a player to have a potentially long and prosperous career.

The purpose of this article is to review research that has evaluated the effects of weighted implement training on throwing/pitching and hitting performances in youth, high school, and collegiate baseball players. Additionally, this article suggests practical applications on how and when to apply these findings.

THROWING/PITCHING WEIGHTED IMPLEMENT TRAINING RESEARCH

The game of baseball, like the former Soviet Union, has a history of weighted implement training in throwing/pitching with youth, high school, and collegiate players. Research findings of light- and heavy-weighted baseball studies have reported significant increases in throwing velocities (1,3,16,20,21,41,42). Interestingly, these findings were recorded at distances less than the standard high school and collegiate pitching distances of 60′ 6″. Since the 1980s, the youth, high school, and collegiate throwing and pitching weighted implement studies reported significant velocity increases while conducted at competitive distances (8,12,14,24).

INCREASED THROWING VELOCITY

Exercise researchers in the United States have demonstrated that throwing velocity of a standard 5 oz baseball could be increased significantly by throwing heavier baseballs (7–17 oz) (1,3,20,21,42). Other U.S. researchers have found that throwing and pitching velocity could also be increased using weighted baseballs in combination that were slightly lighter and heavier (±20%, 4–6 oz) than the standard, competitive 5 oz baseball (12,14). Thus, weighted implement training using modified baseballs weighing within ±20% of the standard 5 oz baseball duplicates the force–velocity output and full ROM specific to the competitive throwing and pitching movement patterns (8,12,14). Most recently, Fleisig et al. (24) reported significant increases in throwing velocities of youth pitchers when training with a light (4 oz) baseball. This information supports previous research and demonstrates that players ranging from youth to college age can increase throwing velocity by using weighted implement training. Table 1 summarizes the results of these studies.

The neurophysiological mechanism for increasing movement velocity resulting from the weighted implement training is not fully understood at this time. Because the peak force output of fast-twitch muscle fibers can be 4 times greater than that of slow-twitch fibers (22,45), it has been suggested that highly specific fast movements could recruit and fire these high-threshold fast-twitch muscle fibers (36,38,45). The results of throwing studies (8,12,14,24) may indicate that 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 (19). Thus, selective activation of either of the fast- or slow-twitch motor units could be specifically trained by the strength and conditioning coach.

THROWING ARM INJURIES

From 1995 to 1999, orthopedic surgeon James Andrews operated on the elbows of 184 pitchers, including 21 high school players (24). From 2000 to 2005, Andrews operated on the elbows of 624 pitchers, including 124 high school pitchers (24). Although these data are only from 1 sports medicine center in the United States, they suggest that there is an increase in the number of serious throwing arm injuries of amateur and professional

Table 1
Effects of over-underweighted throwing/pitching training on baseball velocity

Reference	Subjects	Training method	Significant velocity change
Overweight training			
Bagonzi (1)	High school	Overload baseballs	Increase
Brose and Hanson (3)	College	Overload baseballs	Increase
DeRenne et al. (12)	High school	Weighted baseballs	Increase
DeRenne et al. (14)	High school and college	Weighted baseballs	Increase
DeRenne (8)	High school	Weighted baseballs	Increase
Egstrom et al. (20)	College	Weighted balls	Increase
Elias (21)	College	Overload baseballs	Increase
Van Huss et al. (42)	College	Overload baseballs	Increase
Underweight training			
DeRenne (8)	High school	Underweighted baseballs	Increase
Fleisig et al. (24)	Youth	Underweighted baseballs	Increase
Overweight and underweight integral training			
DeRenne et al. (12)	High school and college	Over- and underweighted baseballs	Increase

pitchers. There are also data that detail baseball throwing arm injuries from the mid-1970s to 2006 (6,18,23,25,31–34). Conte et al. (6) reported increased injury rates to major league players in recent years, with the majority of injuries located in the throwing arm. Furthermore, Ebben et al. (18), while analyzing the strength and conditioning practices of major league baseball strength coaches, reported no coach using any weighted implement throwing protocols, yet throwing-related injuries have been on the rise at the major league level. Assuming, that most high school, collegiate, and professional pitchers are involved in a resistance training program, it would be advantageous for strength and conditioning coaches to provide the baseball players they train with a research-based resistance training program that has enhanced performance and has not reported any injuries.

POSSIBLE INJURY PREVENTION

Seven weighted baseball throwing research studies have reported no throwing arm injuries (3,12,14,20,21, 24,42), and one (24) has suggested that their program may reduce throwing arm injuries. Fleisig et al. (24) reported no difference in arm position; significant decreases in elbow varus torque and shoulder internal rotation torque; and increases in shoulder, elbow, and ball velocities in 34 youth pitchers when throwing the lighter 4 oz baseball. The investigators suggested that pitching with lighter baseballs may also reduce the risk of overuse injury in youth pitchers and also help develop arm speed (24). DeRenne et al. (12) also reported no related throwing injuries with 45 high school pitchers and 180 collegiate pitchers performing a specific weighted implement throwing/pitching protocol using lighter and heavier baseballs.

HITTING WEIGHTED IMPLEMENT TRAINING RESEARCH

As in the throwing/pitching studies since the 1980s, baseball hitting performances have also increased as a result of weighted implement training (7,10,11,13,15,17,35,37). In general, all warm-up and training hitting studies using light and heavy bats significantly increased bat swing velocities (7,10,11,13,15,17,35,37). Thus, baseball strength and conditioning coaches should review the following unique sport-specific hitting warm-up and training protocols before designing a periodized resistance training program.

WARM-UP

Researchers have reported that sport-specific resistance warm-up increases performances in explosive activities such as baseball hitting (7,11,15, 35,39). Specifically, these researchers stated that on-deck warm-up with implements that weigh ±12% of standard bat weight (30 or 31 oz) demonstrated the greatest change in bat velocity (7,11,15,35,39). Traditionally, baseball players have used weighted implements to warm up in the on-deck circle, in attempt to loosen up and to obtain greater bat velocity (7,11,15, 35,39). Commonly used warm-up implements include weighted bats, the commercial donut ring, the Power Swing Fan, and power tubes and sleeves. The donut ring, the Power

Swing Fan, and power tubes and sleeves are devices that slide onto the bat for overload resistance. As with the throwing weighted implement training research, strength and conditioning coaches should be familiar with the research on bat swing velocity that has used various weighted warm-up implements before incorporating this type of training into their baseball resistance training program. Once educated, strength and conditioning coaches should be prepared to "sell" to the hitting coaches and players their warm-up protocol versus traditional on-deck warm-ups, which have resulted in decreased bat velocities (7,11,15,35,39).

To date, there are only 5 research studies investigating the effects of warming-up with various weighted implements in the on-deck circle (7,11,15,35,39). Table 2 displays the results of these studies. Each of these warm-up studies used weighted bats before the swinging a standard 30 oz bat (7,11,15,35,39). The overloaded resistance devices used in all these studies were 2 commercial donut rings (16¾, 28 oz), the Power Swing Fan (32 oz), the Power Sleeve (4 oz), 6 heavy aluminum weighted bats (42, 45, 48, 51, 55.2, 56 oz), and 2 wooden bats (34, 48 oz). In addition, the underweighted bats in these studies weighed 9.6, 12, 23, 25, 27, and 29 oz. The results of 4 of these studies (7,11,15,39) indicated that average game bat swing velocity was increased for high school, college, and ex-college baseball players after warming-up in the on-deck circle using under- and overloaded bats within ±12% (27–34 oz) of a standard game bat weight (30 oz). In addition, DeRenne and colleagues (7,11,15) and Southard and Groomer (39) concluded that the very heavy commercial donut ring, a heavy 51 oz bat, and the very light 23 oz bat used in warm-up decreased game bat velocity by 5 mph. Moreover, Montoya et al. (35) reported that swinging a light (9.6 oz) or "normal" 31.5 oz bat produced the highest bat swing velocities compared with a heavy (55.2 oz) bat in the on-deck circle. Furthermore, Southard and Groomer (39) reported that after warming-up with 2 heavy-weighted bats of 34 and 56 oz, respectively, moment of inertia significantly increased, whereas bat swing velocity significantly decreased. It should be noted that the "normal" bat used in the study of Montoya et al. (35) and the standard bat used in the study of Southard and Groomer (39) were both an overloaded bat because they were either 1.5 or 4 oz heavier than the standard high school or college game bat reported by DeRenne and colleagues (7,11,15). Southard and Groomer (39) concluded that baseball batters should warm up with their respective standard game bat and that using a bat with a larger moment of inertia will reduce bat velocity and change the batter's swing pattern. Montoya et al. (35) also suggested not to swing a heavy bat in the on-deck circle because it produced the slowest bat swing velocities. These results and conclusions support, in part, the findings of DeRenne and colleagues (7,11,15), which suggested that players should warm up by swinging bats that are ±12% of their standard game bat weight (30 oz) before game competition.

WEIGHTED BAT IMPLEMENT TRAINING STUDIES

Three baseball training studies (13,17,37) have evaluated the effects of weighted bat implements used as a form of specific resistance training. As with throwing/pitching weighted implement training, these 3 weighted bat implement training studies adhered to the principle of specificity. Each of these studies used different training protocols and durations, which are shown in Table 3. These studies can be grouped in 2 categories: category 1 (17,37) used overweighted bats weighing 8–100% greater than standard game bat weight, and category 2 (13,37) used both underweighted and overweighted bats, which were either a practice fungo bat, bats weighing as light as (12%) weight of the standard game bat, or overweighted bats, weighing as much as 100% heavier than the standard game bat weight. As strength and conditioning coaches review these 3 training studies and plan their precompetitive power training phase while working with their hitting coaches, they should keep in mind that typically 6–8 weeks of training is needed to demonstrate muscular adaptations (26).

In category 1, the results of 2 overweighted bat studies (17,37) indicated an increase in bat swing velocity after a specific training protocol. DeRenne and Okasaki (17) reported a significant increase in bat swing velocity with 10 ex-college and professional baseball players after 7 weeks of swinging overweighted implements. The overweighted implements were a weighted wooden bat of 34 oz, which was 12% greater than the average standard game bat (30 oz), and a commercial air resistance power swing device. In another overweighted bat study, Sergo and Boatwright (37) conducted a 6-week bat training study with collegiate baseball players using either a standard game bat (29–31 oz) or an overloaded bat weighing more than 100% standard game bat weight (62 oz). The investigators (37) indicated that both training groups had a significant increase in bat swing velocity by 8.8 and 8.0%, respectively. It was noted by DeRenne et al. (13) that Sergo and Boatwright (37) may have assumed and/or not known that their 31 oz test bat, though legal (NCAA standard 29–31 oz), may have been an overweighted bat to some of the their respective players because the most popular collegiate game bats used in the 1990s weighed 29–30 oz (4). Additionally, the investigators (37) reported that there were no significant differences between groups, yet the control group, which had the greatest bat velocity increase (8.8%), trained with a standard bat (bat range of 29–31 oz) of their respective choice. Therefore, the control subjects who trained with bat weights of 29 or 30 oz may have actually trained with underweighted bats while testing with an overloaded bat of 31 oz.

Table 2
Effects of baseball warm-up implements on bat velocity

Reference	Subjects	Devices and weight	Results
DeRenne et al. (15)	High school	Donut ring (28 oz)	(1) Bats between ± 12% of game bat produced greatest bat swing velocity
		Power swing (32 oz)	(2) Bats lighter than 27 oz and heavier than 34 oz produced slowest bat swing velocities
		Power sleeve (4 oz)	(3) Bats weighing 23 and 51 oz and bat with donut ring produced slowest bat swing velocities
		Weighted aluminum bats (34, 42, 45, 48, 51 oz)	
		Underloaded aluminum bats (23, 25, 27, 29 oz)	
DeRenne and Branco (11)	College	Donut ring (16¾ oz)	(1) 25 and 27 oz bats produced greatest bat velocity
		Power swing (32 oz)	(2) Weights added to bats decreased bat velocities
		Power sleeve (4 oz)	
		Weighted aluminum bat (34, 42, 45, 48, 51 oz)	
		Underloaded aluminum bats (23, 25, 27, 29 oz)	
DeRenne (7)	College and ex-college semi-pros	Donut ring (16¾ oz),	(1) Swing bat within ± 12% (34–27 oz) of game bat
		Power swing (32 oz)	(2) Donut ring and Power Swing decreased bat velocity
		Wood weighted bat (34 oz)	
		Light bats (23, 25, 27 oz)	
Montoya et al. (35)	College (recreational)	Light bat (9.6 oz)	(1) Light and normal bat produced the fastest bat swing velocity
		Normal bat (31.5 oz)	
		Heavy bat (55.2 oz)	
Southard and Groomer (39)	College	Standard bat (9.1 N) = 30 oz	(1) Standard bat produced the fastest bat swing velocity
		Donut ring (15.6 N) = 56 oz	(2) Donut ring produced the slowest bat swing velocity
		Hollow plastic bat (3.34 N) = 12 oz	

In category 2, the researchers of the 2 under- and overweighted integral training studies (13,37) reported significant increases in bat swing velocity after training with under- and overweighted bats. In each study, the training protocol consisted of 100 swings per session with under- and overweighted bats. In the study by DeRenne et al. (13), players swung additional 50 times with their standard game bat (30 oz) for a total of 150

Table 3
Effects of over- and underweighted bat training on bat velocity

Reference	Subjects	Duration (wk)	No. of swings/wk	Bat weight (% of standard bat)	Significant increase (%)
Category 1: overweight training					
DeRenne and Okasaki (17)	Ex-college and pros	7	240	32 oz Power Swing (8.0)	Yes (NA)
				34 oz weighted bat (12.0)	Yes (NA)
Sergo and Boatwright (37)	College	6	300	62 oz (100.0)	Yes (8.0)
Category 2: overweight and underweight integral training					
DeRenne et al. (13)	College	12	600	Dry swings and batting practice, 31–34 oz and 27–29 oz (±12.0)	Yes (6.0 and 10.0)
Sergo and Boatwright (37)	College	6	300	62 oz (100.0) and fungo bat (NA)	Yes (8.2)

NA = not available.

swings, 4 sessions per week for 12 weeks. There was a 2:1 ratio of under- and overweighted bat swings to standard game bat swings. DeRenne et al. (13) reported that bat swing velocity increases with dry swing (6%) and live batting practice (10%) groups, respectively. The 10% improvement accomplished by the batting practice group is the most increase of any bat swing velocity study to date. The investigators (13) suggested that there is a possible transfer of training effect when the elements of the supplementary and overloading exercises (e.g., resistance training) are similar to those of the primary activity (baseball skills). Again, weighted bat implement training consisted of exercising with modified standard competitive bats while duplicating the accelerative nature and full ROM of the specific hitting pattern. Furthermore, the findings of DeRenne et al. (13) indicated that if the bats are no more than 12% lighter or heavier and have the correct heavy/light/standard resistance load ratios, bat velocities would significantly increase. In addition, Sergo and Boatwright (37) reported that all 3 research groups, including the control group, improved bat swing velocity between 8.0 and 8.8%. The investigators (37) concluded that players could swing any bat 100 times a day, 3 times a week for 6 weeks (1,800 total swings), and improve bat swing velocity. In contrast, DeRenne et al. (13) reported that the control group, using only the standard 30 oz bat, did not significantly improve bat swing velocity.

In summary, data presented in Table 3 indicate that swinging-specific overweighted or underweighted bats with a precise training protocol (swinging 240–600 times a week for 6–12 weeks) produced increases in bat swing velocity in either a dry swing or batting practice setting (13). In addition, though Sergo and Boatwright (37) reported that any bat swung 300 times a week for 6 weeks would increase bat swing velocity, there is some concern by coaches and researchers that the overweighted bat (62 oz) used in that study may cause players to alter their swing mechanics (13).

CONCLUSIONS

Baseball weighted implement training is a unique but essential training protocol that is research based, injury free, and, most important, enhances youth, high school, and collegiate players' performances. These unique training protocols should receive greater attention in resistance exercise prescription for baseball players and should be incorporated into the precompetitive power training phase. Strength and conditioning coaches play the most important role in the resistance training of baseball players because they are, or should be, familiar with the majority of exercise research and throwing injury–related information available. Furthermore, they may not be biased or swayed by past baseball traditional training methods and superstitions. A future topic for baseball research would be to examine in-season baseball weighted implement training to see how it affects baseball performance. This would indicate whether players' precompetitive throwing and hitting velocity increases are maintained during the competitive season with injury-free pitchers and hitters.

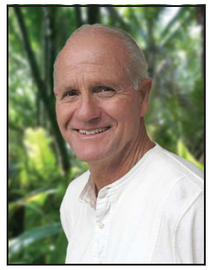
PRACTICAL APPLICATIONS

It is important that strength and conditioning coaches know that when working with pitchers and pitching coaches, they should be cautious if they design their own or use someone

else's light–heavy baseball throwing program that is not research based. It would be imperative to monitor these players because the outcome of these programs is unknown. Strength and pitching coaches should be confident that if they follow the precise throwing weighted implement training protocol designed by DeRenne et al. (12), their players should enhance throwing velocity and possibly have fewer or no injuries. These results have already been demonstrated with 225 competitive high school and collegiate pitches (12).

During the precompetitive training phase, strength and conditioning coaches have at least 2 choices as to how they could include hitting weighted implement training into their program. First, they could have players dry swing with weighted bat program of DeRenne et al. (13) in the weight room (e.g., bat swing stations) as part of the players' resistance training program. Second, strength and conditioning coaches could work with the hitting coach to implement and monitor weighted bat training protocol of DeRenne et al. (13) used by the hitters during live batting practice sessions. It should be noted that if strength and hitting coaches do not have overweighted baseball bats, they can make their own by adding golf club swing lead tape to the sweet spot of a baseball bat and cover it up with white athletic tape. This should protect the lead tape from coming off the bat, while at the same time securing it for multiple swings in batting practice. Coaches can purchase lead tape at a local golf supply store or online. Check the manufacturer's label to make sure that you are not adding more weight than desired. Typically 2 inches of lead tape is equivalent to 1 oz of weight. If coaches do not have underweighted baseball bats, they could use softball bats that weigh 27–29 oz or bats that are lighter and add lead tape to them for the proper weight.

Although weighted implement hitting warm-up studies have reported increased bat velocities during the precompetitive training phase, strength and conditioning coaches should also design and monitor with hitting coaches an in-season warm-up protocol for each game. Additionally, high school and collegiate strength and conditioning coaches should not conduct any weighted implement training program during the competitive season until research substantiates safe and positive training effects. Finally, because there have been no known baseball weighted implement training studies conducted with prepubescent athletes, strength and conditioning coaches should not train these respective players with any weighted implements until research substantiates safe and positive training effects for them.



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REFERENCES

1. Bagonzi JA. *The Effects of Graded Weighted Baseballs, Free Weight Training, and Simulative Isometric Exercise on Velocity of a Thrown Baseball* [master's thesis]. Indiana University, Bloomington, IN, 1978.
2. Baker D. Improving vertical jump performance through general, special, and specific strength training: A brief review. *J Strength Cond Res* 10: 131–136, 1996.
3. Brose DE and Hanson DL. Effects of overload training on velocity and accuracy of throwing. *Res Q* 38: 528–533, 1967.
4. Bompa T. Periodization of strength. *Sports Rev* I: 26–31, 1965.
5. Bompa T. *Periodization: Theory and Methodology of Training* (4th ed). Champaign, IL: Human Kinetics, 1994. pp. 194–210.
6. Conte S, Requa RK, and Garrick JG. Disability days in major league baseball. *Am J Sports Med* 29: 431–436, 2001.
7. DeRenne C. Increasing bat velocity. *Athletic J* 62: 28–31, 1982.
8. DeRenne C. Increasing throwing velocity. *Athletic J* 65: 36–39, 1985.
9. DeRenne C. Implement weight training programs. *Strength Cond J* 9: 35–37, 1987.
10. DeRenne C. The donut: Does it improve bat velocity? *Strength Cond J* 13: 43–45, 1991.
11. DeRenne C and Branco D. Overload or underload in your on-deck preparation? *Scholast Coach* 55: 32: 69, 1986.
12. DeRenne C, Buxton BP, Hetzler RK, and Ho KW. Effects of under- and overweighted implement training on pitching velocity. *J Strength Cond Res* 8: 247–250, 1994.
13. DeRenne C, Buxton BP, Hetzler RK, and Ho KW. Effects of weighted bat implement training on bat swing velocity. *J Strength Cond Res* 9: 247–250, 1995.
14. DeRenne C, Ho KW, and Blitzblau A. Effects of weighted implement training on throwing velocity. *J Appl Sports Sci Res* 4: 16–19, 1990.
15. DeRenne C, Ho KW, Hetzler RK, and Chai DX. Effects of warm-up with various weighted implements on baseball bat swing velocity. *J Appl Sports Sci Res* 6: 214–218, 1992.
16. DeRenne C, Ho KW, and Murphy JC. Effects of general, special, and specific resistance training on throwing velocity in baseball. *J Strength Cond Res* 15: 148–156, 2001.
17. DeRenne C and Okasaki E. Increasing bat velocity (Part 2). *Athletic J* 63: 54–55, 1983.
18. Ebben WP, Huntz MJ, and Simenz J. Strength and conditioning practices of major league baseball strength and conditioning coaches. *J Strength Cond Res* 19: 538–546, 2005.
19. Edgerton VR, Roy RR, Gregor RJ, Hager CL, and Wickieurcz T. Muscle fiber activation and recruitment. In: *Biochemistry of Exercise International Series on Sports Science*. Knuttgen HG, Vogel JA, and Poortmans J, eds. Champaign, IL: Human Kinetics, 1989. pp. 31–49.

20. Egstrom GH, Logan GA, and Wallis EL. Acquisition of throwing skill involving projectiles of varying weight. *Res Q* 31: 420–425, 1960.

21. Elias J. *The Effect of "Overload" Training on Speed in Baseball Pitching* [master's thesis]. Springfield College, Springfield, MA, 1964.

22. Faulkner JA, Claflin DR, and McCully KK. Power output of fast and slow fibers from human skeleton muscle. In: *Human Muscle Power*. Jones NL, McCarney N, and McComas AJ, eds. Champaign, IL: Human Kinetics, 1986. pp. 81–91.

23. Fleisig GS, Kingsley DS, Loftice JW, Dinnen K, Ranganathan R, Dunn S, Escamilla RF, and Andrews JR. Kinetic comparison among the fastball, curveball, change-up, and slider in collegiate baseball pitchers. *Am J Sports Med* 34: 423–430, 2006.

24. Fleisig GS, Phillips R, Shatley A, Loftice J, Dun S, Drake S, Farris JW, and Andrews JR. Kinematics and kinetics of youth baseball pitching with standard and lightweight balls. *Sports Eng* 9: 155–163, 2006.

25. Gugenheim JJ Jr, Stanley RF, Woods GW, and Tullos HS. Little League survey: The Houston study. *Am J Sports Med* 4: 189–200, 1976.

26. Harris RT and Dudley G. Neuromuscular anatomy and adaptations to conditioning. In: *Essentials of Strength Training and Conditioning*. Baechle TR and Earle RW, eds. Champaign, IL: Human Kinetics, 2000. pp. 20–21.

27. Jarver J. Varied resistance in power development. *Mod Athlete Coach* 10: 5–8, 1973.

28. Kanishevsky S. A universal shot. *Sov Sports Rev* 19: 207–208, 1984.

29. Konstantinov O. Training program for high level javelin throwers. *Sov Sports Rev* 14: 130–134, 1979.

30. Kuznetsov V. Speed and strength. *Yessis Rev* 10: 78–83, 1975.

31. Larson RL, Singer KM, Bergstrom R, and Thomas S. Little survey: The Eugene study. *Am J Sports Med* 4: 201–209, 1976.

32. Lyman S and Fleisig GS. Baseball injuries. *Med Sport Sci* 49: 9–30, 2005.

33. Lyman S, Fleisig GS, Andrews JR, and Osinski ED. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. *Am J Sports Med* 30: 463–468, 2002.

34. Lyman S, Fleisig GS, Waterbor JW, Funkhouser EM, Pulley L, Andrews JR, Osinski ED, and Roseman JM. Longitudinal study of elbow and shoulder pain in youth baseball pitchers. *Med Sci Sports Sci* 33: 1803–1810,2001.

35. Montoya BS, Brown LE, Coburn JW, and Zinder SM. The effects of different warm-up conditions on normal baseball bat velocity. *J Strength Cond Res* 22: 35, 2008.

36. Sale DG. Influence of exercise and training on motor unit activation. *Exerc Sport Sci Rev* 15: 95–151, 1987.

37. Sergo C and Boatwright D. Training methods using various weighted bats and the effects on bat velocity. *J Strength Cond Res* 7: 115–117, 1993.

38. Smith JL, Betts B, Edgerton VR, and Zenicke RF. Rapid ankle extension during paw shakes. Selective recruitment of fast ankle extensors. *J Neurophysiol* 43: 612–620, 1980.

39. Southard D and Groomer L. Warm-up with baseball bats of varying moments of inertia: Effect on bat velocity and swing pattern. *Res Q Exerc Sport* 74: 270–276, 2003.

40. Szymanski DJ, DeRenne C, and Spaniol FJ. Contributing factors for increased bat swing velocity: A brief review. *J Strength Cond Res* February 27, 2009 [epub Ahead of Print].

41. Van Den Tillaar R. Effect of different training programs on velocity of overarm throwing: A brief review. *J Strength Cond Res* 18: 388–396, 2004.

42. Van Huss WD, Albrecht L, Nelson R, and Hagerman R. Effect of overload warm-up on the velocity and accuracy of throwing. *Res Q* 33: 472–475, 1962.

43. Vasiliev LA. Use of different weight to develop specialized speed-strength. *Sov Sports Rev* 18: 49–52, 1983.

44. Verkhoshansky Y and Tatyan V. Speed-strength preparation of future champions. *Sov Sports Rev* 18: 166–170, 1983.

45. Walmsley BA, Hodgson JA, and Burke RE. Forces produced by medial gastrocnemius and soleus muscles during locomotion in freely moving cats. *J Neurophysiol* 41: 1203–1261, 1978.