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INJURIES IN OVERHEAD ATHLETES (J DINES AND CL CAMP, SECTION EDITORS)

The Evidence Behind Weighted Ball Throwing Programs for the Baseball Player: Do They Work and Are They Safe?

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Abstract

Purpose of Review Weighted baseball throwing programs have gained significant attention recently. They have been promoted as proven option for pitchers wishing to increase their throwing velocity and improve throwing mechanics. However, there is some concern that, if not applied properly, they may increase injury risk. In this review, we aim to (1) give a brief description of the potential mechanisms through with weighed ball programs that could improve throwing velocity, (2) summarize the available evidence regarding their effectiveness in increasing throwing velocity, (3) summarize the evidence on injury risk, and (4) propose directions for future studies.

Recent Findings Initial research on weighted ball programs was published in the 1960s. Recently there has been an increase in research as interest from baseball organizations, instructors, players, and medical providers has grown. A recent randomized controlled trial demonstrated that pitching velocity can be increased through a 6-week weighted ball program; however, with that, they found that the rate of injury also increased. An earlier systematic review outlined 10 studies that evaluated weighted ball programs effect on pitching velocity and reported that 7 studies described increases in throwing velocity, while most studies did not comment on injury risk. They note that the results on rate of injury have been variable, likely secondary to the variability in time and intensity of different programs.

Summary The inconsistency in the methodology of weighted ball programs and studies has made it challenging to draw (scientifically) meaningful conclusions. Nevertheless, several studies have offered empirical evidence in support of the claim that weighted ball programs can increase pitching velocity through improved throwing mechanics. At the same time, these studies have emphasized the improvements in performance, while the potential effects on injury mechanisms have been less well understood. There is a need for improved standardization of these programs to allow for future study and subsequent modification to optimize performance.

Keywords Baseball · Pitching · Weighted ball programs · Elbow injury · Shoulder injury

This article is part of the Topical Collection on *Injuries in Overhead Athletes*

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Introduction

Baseball is one of the most popular sports in the world; it is estimated that three million kids participate in baseball each year in the USA alone [1]. Because of this, there is a significant amount of attention paid to and resources spent on maximizing player performance at all levels, including professional. Increasing throwing velocity is particularly important for baseball player performance, especially for pitchers, as the average four-seam fastball velocity in Major League Baseball has seen a year over year increase from 91.7 MPH in 2008 to 93.3 in 2019 [ref]. The quest to further increase throwing velocity is intricate, as the throwing motion producing these high velocities is very complex. The throwing motion generally has been described as consisting of six different phases [2, 3]. As a baseball player throws a ball, their body progresses through these phases, transferring energy from the lower body to the upper body in what is commonly referred to as the "kinetic chain" [2, 4]. An understanding of the kinetic chain has led to development of weighted balls programs which aim to increase pitching velocity and improve mechanics. Escamilla et al. [5, 6] demonstrated that baseball-specific resistance programs increased throwing velocity in pitchers after only 4 and 6 weeks.

Whereas the standard baseball weighs 5 oz., weighted ball programs generally use balls that are underweight (4 oz.) to overweight (ranging up to 32 oz.). Although not specific to baseball [7], these programs have gained popularity in baseball over the last decade to improve pitching velocity through improved mechanics. As such, multiple studies have investigated the utility of these programs, with a specific focus on its effects on throwing velocity [8•]. The general theory behind the programs is that throwing lighter balls will increase arm speed and throwing heavier balls will lead to increased arm strength [6]. However, there is some concern that weighted ball programs may increase the risk of injury given their goal of increasing ball velocity. It is well documented that increased pitching velocity is correlated with increased elbow stress and elbow injury rates [9, 10]. Reinold et al. [11•] underlined that a 6-week weighted ball throwing program did increase pitch velocity, but it also increased shoulder external rotation passive range of motion (PROM) and injury rates.

With studies providing empirical support both in favor and against weighted ball programs as a safe and effective tool to improving pitching velocity, there is significant controversy in the baseball community regarding weighted ball programs. The long-term effectiveness has not sufficiently been studied, and findings of increased stress levels and range of motion have led to concerns about the potential increased injury risk to throwers. In this review, we will discuss the proposed mechanism of action through which weighted ball programs increase velocity and assess the available literature regarding its effectiveness and potential risk of injury.

Proposed Mechanism of Action

While several mechanisms of action have been proposed, a broad consensus has not been reached on how weighted ball throwing programs lead to an increase in throwing velocity. Fleisig et al. [8•] demonstrated that pitching with overweight or underweight balls leads to variations in kinematics and arm kinetics. For example, throwing overweight balls can result in increased maximal shoulder external rotation, which has been associated with increased velocity [12–14]. These programs can also result in decreased or increased elbow torque depending on the weight (ref?). The known variations produced by these exercises can be used in a training environment to maximize throwing velocity and proper mechanics.

The use of overweight baseballs (6–32 oz.) is commonly considered to be akin to resistance training—overloading a muscle with resistance greater than it is normally subjected to. Strengthening the rotator cuff muscles through plyometric exercises has been shown to lead to a significant increase in throwing velocity [15]. Therefore, Escamilla et al. [6] posited that speed gains could be due to an increase in arm strength from training with overweight balls. Conversely, Reinold et al. [11•] showed that after a 6-week weighted ball training program, the participants in the experimental training group demonstrated an increase in throwing velocity, but no increase in shoulder strength (external/internal rotation, elevation, abduction). The control group, who followed the same program using only the 5 oz. regulation ball had a 13% increase in ER and 6% increase in IR strength, but no increase in velocity. Previous studies have demonstrated that greater shoulder external rotation is correlated with increased pitch velocity [12–14]. Marsh et al. [16] found that pitchers who gained velocity after participating in a weighted ball training program showed no significant increase in shoulder external rotation. Therefore, while velocity gains can be made in the absence of increased shoulder ER, it is well established that increased shoulder ER generally correlates with increased throwing velocity. The use of underweight balls (< 5 oz.) has also been shown to lead to increased pitching velocity [17]. Fleisig et al. [18] hypothesized that using underweight balls helps create fast twitch muscle patterns which are more advantageous for elite throwers. Further investigation is warranted into the mechanisms of action behind weighted ball training programs.

Effectiveness of Weighted Ball Programs

Throwing Velocity

The primary goal of weighted ball programs is to increase throwing velocity, especially in pitchers. Caldwell et al. [19•] recently published a systematic review outlining the evidence. They reported on ten studies (Table 1) that have

thoroughly evaluated the programs impact on throwing velocity.

Although weighted ball throwing programs have garnered increased attention in recent years, the first known study evaluating weighted ball type programs was actually published in 1966 by Logan et al. [27]. In this study, a resisted pulley system was used in place of weighted balls. They ultimately determined that the program successfully increased throwing velocity in college pitchers. The resistance group ball velocity increased 9 mph compared to 4 mph in the control group that trained with normally weighted balls. Although this is an older study, it was well designed, included control groups, and involved a 4-week training period. Another study was published in 1968 by Straub et al. [25] who found different results following a 6-week training period. In this study, a control group was compared to group who threw progressively heavier balls each week with a maximum weighted ball of 17 oz. The participants of this study included high school–aged non-baseball players, and they found no significant improvements in velocity or accuracy. In our opinion, a major limitation of this study was that they did not limit inclusion to competitive baseball players.

A recent study by Marsh et al. [16] evaluated the results of a 6-week weighted program in 17 collegiate and professional baseball players. They did not observe significant changes in velocity or shoulder external rotation following completion of the programs. This study lacked a control group which presents a definite limitation. As mentioned previously, Reinold et al. [11•] recently performed a randomized controlled study on weighted ball programs. They randomized 38 healthy baseball pitchers to an experimental group and a control group. The experimental group experienced a statistically significant increase in pitch velocity and shoulder external rotation compared to the control group, but they also experienced an increased injury rate. This study likely provides the best available evidence regarding the effectiveness of weighted ball programs but also raises concerns that we will further discuss in this paper.

Caldwell et al. [19•] determined that 7 out of the 10 studies in their systematic review reported significant increases in throwing velocity following completion of weighted ball programs. The velocity increases ranged from 2 to 11 mph. The authors state that a limiting factor in the interpretation of their work was the significant variability in what the throwing programs entailed and length of the programs. This variability in weighted ball throwing programs makes it difficult to compare studies to one another. Nevertheless, throwing velocity can be increased through a variety of weighted ball programs. We believe that there needs to be a standardization of these programs to allow further targeted study which will permit modification to optimize performance.

Warm-Up

Throwing of over- and underweight balls during the warm-up process prior to competitive, full effort pitching has also been used, although much less studied. Straub et al. [25] evaluated the use of heavy balls (10 oz. and 15 oz.) prior to full effort pitching. Each of the three experimental groups started out throwing a standard weight (5 oz.) ball, after which they warmed up further with a 10 oz. or 15 oz. baseball. Following this, they returned to full effort throwing and their velocity was measured. No significant differences in pitching velocity were appreciated. More recently, Shin et al. [28] found similar results when evaluating the effects of 12 high school and collegiate baseball players using light and

Table 1 Studies evaluating weighted ball program impact on velocity—modeled after Caldwell et al. (2019) [19•]

Author	Year	# Participants	Training time (weeks)	Competition level	Weight of ball	Results
Reinold [11•]	2018	38	6	High school	2–32 oz.	Velocity increased 2.2 mph
Yang [17]	2013	24	10	High school	4.4 oz.	Velocity increased 2.1 mph
Szymanski [20]	2011	21	8	High school	7 oz.	No change reported
Morimoto [21]	2003	8	6 or 18 pitches (warm-up)	College	4.5 & 5.5 oz.	Velocity increased 3 mph*
DeRenne [22]	1994	225	10	High school & college	4 or 6 oz.	Velocity increased 5 mph*
DeRenne [23]	1990	30	10	High School	4–6 oz.	Velocity increased 4.72 mph (4 oz. ball) & 3.75 mph (6 oz. ball)
Litwhiler [24]	1973	5	12	College	7–12 oz.	Velocity increased 11.2 mph
Straub [25]	1968	48	6	High school	7–17 oz.	No change reported
Straub [25]	1968	60	20 pitches (warm-up)	High school	10 & 15 oz.	No change reported
Brose [26]	1967	21	6	College	10 oz.	No change reported
Logan [27]	1966	19	4	College	2.5–5.5 lb (pulley)	Velocity increased 9.28 mph

*Approximate value based off graph

overweight baseballs during warm-up. No difference in pitching velocity was appreciated. Morimoto et al. [21] found different results and determined that warming up with a lighter ball or a combination of lighter, standard, and over weighted baseballs could result in increased pitching velocity. The current available data is inconclusive on whether under or over weighted throwing during warm-up results in reliable increased throwing velocity. It is our belief that there may be a role in some pitchers, but it likely does not provide a benefit in all players. More research is necessary to determine its effectiveness.

Potential Risk of Weighted Ball Programs

Shoulder and elbow injuries in baseball are approaching epidemic levels [29]. These injuries are primarily from overuse and, if not treated appropriately, can eventually lead to arthritis and deformity. Pitchers are at the greatest risk of sustaining a severe shoulder/elbow injury and up to 74% of youth baseball players report some degree of arm pain while throwing [1]. Ultimately, 5% of youth pitchers end up suffering a serious elbow or shoulder injury that requires either surgery or retirement from sport. Increased throwing velocity and pitching volume have been shown to be significant predictors for injury [30]. Multiple institutions, such as the American Orthopedic Society for Sports Medicine, USA Baseball, Little League Baseball, and the American Academy of Pediatrics, have published guidelines for preventing pitching injuries [31–33], focusing on proper warm-up exercises and throwing technique, and limiting playing time and pitch counts. Given the high prevalence of pitching injuries, the overall risk of weighted ball programs should be carefully studied and weighed against any and all potential benefits. The thought is that the excess weight of the ball could contribute to additional forces on the already stressed shoulder and elbow joints, ultimately leading to injuries [34]. Additionally, there is concern that if these programs successfully increase velocity, this newly increased velocity may place the athlete at a higher risk for injury if a proper foundation in the lower kinetic chain is not established. Table 2 outlines studies that have published on injury risk.

Programs focused on pitching with underweight balls, however, have been proposed as a possible alternative that might have a protective effect against injury. Fleisig et al. [18] examined the kinematics and kinetics of pitching with a lightweight ball, specifically at the youth level, and found that using the lightweight ball leads to significant decreases in elbow varus torque and shoulder internal rotation torque. Okoroha et al. [34] also found that underweight baseballs were associated with decreased medial elbow torque forces. This is a particularly salient finding as elbow varus torque has been described as the greatest stress to the medial ulnar

Table 2 Studies evaluating weighted ball program injury risk

Author	Year	# Participants	Training time (weeks)	Competition level	Weight of ball	Results
Fleisig [8•]	2017	25	3 trials of 10 different exercises	High school and college	4,5,6,7,14,32 oz.	Increase in ball mass is associated with increased elbow flexion torque
Reinold [11•]	2018	38	6 weeks	High school	2–32 oz.	24% injury rate in experimental group
Marsh [16]	2018	17	6 weeks	College and professional	3.5–70 oz.	No increase in ER, elbow varus torque
Fleisig [18]	2006	34	10 full effort fastballs	Youth (9–12 years old)	4-5 oz.	With decreased ball weight, decreased elbow varus and shoulder IR torque
Okoroha [34]	2019	19	5 maximum effort fastballs	Youth (9–14 years old)	3,4,5,6 oz.	Increase in ball weight correlates with greater medial elbow torque
Reinold [35•]	2020	16	3 trials of 27 throws	High school	2,4,5 oz.; 5,6,9 oz.; 5,16,32 oz.	Shoulder ER increased with overweight balls, but not with underweight balls

collateral ligament (MUCL) [36, 37]. The incidence of MUCL tears has been increasing over recent years across all levels of play, and athletes are undergoing medial ulnar collateral ligament reconstruction surgeries at rising rates [11•]. Additionally, Fleisig et al. [18] found that lighter balls were associated with decreased elbow and shoulder kinematics. This could have an important impact, especially in the skeletally immature athlete as ossification centers may be particularly vulnerable to injury from high torque forces produced during pitching [38]. Although injuries were not specifically mentioned in their trial, the authors hypothesized that the changes in kinematics observed with underweight baseballs may reduce the risk of injury among youth pitchers.

Many studies have reported no increased risk of arm injury when training with overweight balls during the course of their throwing programs [6, 8, 18, 34, 39]. The studies in general had relatively small sample sizes and short observation periods—rarely including follow-up of the subsequent baseball season. Therefore, they may not have been adequately designed to accurately capture injury risk.

There are specific biomechanical adaptations that occur when pitching with weighted balls that might predispose to injury. For example, forces across the elbow joint are increased when throwing with overweight balls. Fleisig et al. [8••] found that elbow flexion torque was significantly greater on flat ground throws with 14 oz. and 32 oz. balls compared to 4–7 oz. balls. Okoroha et al. [34] found an increase in medial elbow torque with increasing ball weight in a dose response fashion in youth throwers. Both of these studies were meant to examine biomechanical parameters at the time of throwing and were not designed to examine injury rates from prolonged weighted throwing regimens. Another biomechanical consideration with weighted ball programs that may contribute to injury is the change in passive shoulder range of motion. Reinold et al. [11•] performed the first randomized controlled trial examining the effects of weighted ball programs and found that in just 6 weeks, the experimental group had a significant increase of 4.3 degrees in shoulder external rotation compared to the control group. In a subsequent study, Reinold et al. [35•] found that shoulder external rotation only increased with overweight balls. It did not increase with underweight balls. Previous research from Wilk et al. [40] has shown that 78% of pitching injuries occur in athletes with higher degrees of shoulder range of motion. Most throwers exhibit an obvious disparity where external rotation is excessive and internal rotation is limited compared to the non-throwing shoulder (ref). However, Marsh et al. [16] did not find a relation between weighted ball programs and an increase in shoulder external rotation range of motion or elbow valgus stress. The heterogeneity of these studies in regard to their protocols and participants makes it difficult to generalize results, and more standardized experimental procedures are needed in the future.

Reinold et al. [11•] effectively examined the injury rate during the 6-week training program and the subsequent baseball season. They found a high overall injury rate in the experimental group of 24%. Four participants suffered elbow injuries: 2 olecranon stress fractures, 1 partial UCL injury, and 1 UCL injury which required surgical reconstruction. Two injuries occurred during the training program and 2 occurred during the subsequent baseball season. Additionally, two participants sustained non-throwing related lower extremity injuries and were not able to complete the 6-week training period. There were no injuries reported in the control group. The authors noted that two of the injured players exhibited the greatest increases in shoulder external rotation range of motion and hypothesized that the rapid increase in external rotation may represent maladaptive damage to the static stabilizers of the shoulder. Interestingly, their training protocol was less intensive with regard to the total number of reps compared to many commonly performed programs. They used balls weighing up to 32 oz., and this excessive weight may have contributed to additional stress and injury risk in these players. However, as the protocols vary so widely across different studies, it is difficult to determine how much of a contributing factor ball weight is to this ultimate finding. Additional studies with adequate follow-up are required to determine if weighted ball training programs do indeed increase the risk of injury.

Future Directions

While many studies have demonstrated that weighted ball programs can lead to an increase in throwing velocity, the training regimens used have been heterogeneous, and their protocols have not been standardized. The ideal protocol for this type of program still remains unknown. Future studies should compare specific aspects of these weighted ball programs to determine the most effective regimen—in particular examining the ideal weight of the ball, what the appropriate pacing of the pitches should be, the timing before competition play, total number of pitches with the weighted balls, and address the impact on the lower segments of the kinetic chain.

Given the importance placed on total pitch counts in the development of overuse injuries, the dose-response characteristics of weighted ball training warrant further investigation. The vast majority of the studies do not comment on participant injury rate during the course of their intervention. Additionally, most do not have sufficient follow-up to determine if weighted ball training increases the risk of injury in the long term. Therefore, additional studies dedicated to long-term risk injury profile are still needed.

Lastly, there should also be a focus in future studies on examining the effects of weighted ball programs on the entire kinetic chain of an athlete. While the shoulder and elbow are certainly important, the base of support from the lower

extremities and core are necessary to generate top ball velocity. Therefore, programs centered on optimizing overall physical conditioning in combination with weighted ball programs may provide the most holistic approach to optimizing throwing speeds.

Conclusions

Weighted ball programs are increasingly being utilized by baseball pitchers to increase throwing velocity. There are various studies providing empirical support that these programs are, in fact, able to increase pitching velocity and maximal shoulder external rotation. With that, there is also concern that these programs may increase the risk of injury. Considering previously described mechanism, it appears that weighted ball programs alter the throwing biomechanics in pitchers leading to increased shoulder range of motion and elbow varus torque. These adaptations can help to increase throwing velocity; however, if not properly progressed, they likely place pitchers at increased risk for injury. Moving forward, significant efforts need to ensure that as these athletes experience an increase in throwing velocity, they also build an appropriate foundation to support it by optimizing the lower portions of the kinetic chain. An ideal program likely requires appropriate pacing, regular monitoring of stress/workload, avoidance of excessively heavy balls, and focused attention given to all aspects of the kinetic chain.

Compliance with Ethical Standards

Conflict of Interest Heath P. Melugin MD, Annie Smart MD, Martijn Verhoeven PhD, Joshua S. Dines MD, and Christopher L. Camp MD have no conflict of interest related to this topic.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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