REVIEW ARTICLE

Sports Med 2000 Apr; 29 (4): 259-272
0112-1642/00/0004-0259/$20.00/0

Effects of Throwing Overweight and Underweight Baseballs on Throwing Velocity and Accuracy

Rafael F. Escamilla,[1] *Kevin P. Speer,*[1] *Glenn S. Fleisig,*[2] *Steven W. Barrentine*[2] and *James R. Andrews*[2]

1 Michael W. Krzyzewski Human Performance Laboratory, Division of Orthopaedic Surgery, Duke University Medical Center, Durham, North Carolina, USA
2 American Sports Medicine Institute, Birmingham, Alabama, USA

Contents

Abstract

The purpose of this review is to determine how throwing overweight and underweight baseballs affects baseball throwing velocity and accuracy. Two studies examined how a warm-up with overweight baseballs affected throwing velocity and accuracy of 5oz regulation baseballs. One of these studies showed significant increases in throwing velocity and accuracy, while the other study found no significant differences. Three training studies (6 to 12 weeks in duration) using overweight baseballs were conducted to determine how they affected ball accuracy while throwing regulation baseballs. No significant differences were found in any study. From these data it is concluded that warming up or training with overweight baseballs does not improve ball accuracy. Seven overweight and 4 underweight training studies (6 to 12 weeks in duration) were conducted to determine how throwing velocity of regulation baseballs was affected due to training with these overweight and underweight baseballs. The overweight baseballs ranged in weight from 5.25 to 17oz, while the underweight baseballs were between 4 and 4.75oz. Data from these training studies strongly support the practice of training with overweight and underweight baseballs to increase throwing velocity of regulation baseballs. Since no injuries were reported throughout the training studies, throwing overweight and underweight baseballs may not be more stressful to the throwing arm compared to throwing regulation baseballs.

However, since currently there are no injury data related to throwing overweight and underweight baseballs, this should be the focus of subsequent studies. In addition, research should be initiated to determine whether throwing kinematics and kinetics are different between throwing regulation baseballs and throwing overweight and underweight baseballs.

Training with overweight and underweight implements has its roots in the speed-strength specificity training programmes of the former Soviet Union and European countries. Soviet athletes have been training with overweight and underweight implements for several decades. Some of the results from Soviet research[1-6] regarding the use of overweight and underweight implements during training are as follows: (i) the employment of varied resistance training enhances speed-strength (power) development; (ii) resistance variations in training should range between 5 and 20% of normal resistance; and (iii) a 2 : 1 frequency ratio of throwing weighted and regulation weight implements, respectively, maximised power output. However, most of the Soviet weight implement research was conducted with implements that weigh considerably more than a baseball, such as the shot put, hammer, discus and javelin. In these field events the distance thrown is of primary importance, while the accuracy of the throw is of less importance. In throwing a baseball, both velocity and accuracy are paramount in throwing performance, especially for baseball pitchers.

The premise behind underweight training is that body segments will move at higher speeds with less muscle force generated, since lighter than normal implements are thrown. Conversely, since heavier than normal implements are thrown during overweight training, body segments move at slower speeds with greater muscle force generated. Consequently, training with underweight implements is considered more as speed training, while training with overweight implements is considered more as strength training. The term ‘speed-strength’, which probably originated with the former Soviet Union, is synonymous with the term ‘power’. By definition, power is the product of speed and force (strength). Power training conditions the neuromuscular system to develop the greatest amount of force in the least amount of time, in order to overcome resistance with the greatest contraction speed possible. The force-time relationship is important in pitching, since there is a very short time interval (approximately 0.15 seconds) from foot contact to ball release in which to produce force.[7,8]

Baseball pitching is comprised of extremely rapid movements of the pelvis, upper torso and upper extremity. When the pitching movement is performed in proper sequence, kinetic energy is transferred up the body (i.e. legs to hips to trunk to arm to wrist to fingers) to the ball, which is sent toward the batter at speeds of up to 35 to 40 m/s.[7,8] Since increased throwing velocity allows a batter less time to decide whether or not to swing (typically less than 0.5 seconds for college and professional hitters), there has been much interest in ways to improve throwing velocity. One proposed training method used to increase throwing velocity involves throwing overweight and underweight baseballs. Increasing throwing velocity and accuracy is important to positional players as well. For example, throwing velocity and accuracy is critical for an outfielder trying to throw out a runner at home plate, or a third baseman trying to throw out a runner at first base.

The objective of this paper is to present a review of research done in the area of overweight and underweight resistance throwing, and to discuss 4 questions and their ramifications:

- Does throwing velocity with regulation 5oz baseballs increase as a result of warming up or training with underweight or overweight baseballs, and what is the long term effect?
- How does warming up or training with overweight and underweight baseballs affect the accuracy of throwing regulation baseballs?
- What are the ideal training weights for overweight or underweight baseballs for maximum improve-

ment in velocity and accuracy of throwing regulation baseballs?

- What is the ideal frequency ratio between throwing regulation baseballs and throwing overweight and underweight baseballs?

Relevant publications involving throwing overweight and underweight baseballs comprise 2 groups: (i) studies published from 1962 to 1973 that examined the effects of throwing overweight baseballs on throwing velocity and accuracy of regulation baseballs; and (ii) studies published from 1985 to 1994 that examined the effects of throwing overweight and underweight baseballs on throwing velocity of regulation baseballs. Surprisingly, there are no known published studies between 1994 and 1999 that examined the effects of throwing overweight and underweight baseballs on throwing velocity or accuracy. Table I summarises how training with overweight and underweight baseballs affects throwing velocity and accuracy.

1. Effects of Throwing Overweight Baseballs on Throwing Velocity and Accuracy

Five studies published between 1962 and 1973 investigated the effects of throwing overweight baseballs on throwing velocity and accuracy.[9-12,17] Van Huss et al.[17] looked at the effect of overweight warm-up on throwing velocity and accuracy. Fifty college freshman baseball players (all positions) threw during 2 testing conditions. Firstly, after a normal warm-up consisting of throwing regulation baseballs, ball velocities of 10 maximum throws using regulation baseballs were recorded. After a 10-minute rest period, each player threw 25 pitches with 11oz overweight baseballs. The first 15 pitches were thrown with gradually increasing velocity, followed by 10 maximum throws. Subsequently, 10 maximal throws with regulation baseballs were recorded. During these 2 testing conditions, accuracy was measured by having the participants throw at a rectangular grid target located at half the regulation pitching distance (9.2m). Possible scores ranged from 1 to 5, depending on where the ball struck the grid (i.e. in or out of the strike zone). The overweight warm-up significantly increased both throwing velocity and accuracy of regulation baseballs. Throwing velocity increased by approximately 5 to 10% due to the overweight warm-up.

Brose and Hanson[9] used 21 college baseball players (all positions) in studying the effects of overweight training on throwing velocity and accuracy.

Table I. Effects of training with overweight and underweight baseballs on throwing velocity and accuracy.

Reference	Number of participants	Age level	Duration (w)	Number of throws per week	Baseball weights (oz)	Significant increase in throwing velocity?	Significant change in accuracy?
Overweight training							
Brose & Hanson[9]	7	College	6	75	10, 160[a]	Yes	No
Litwhiler & Hamm[10]	5	College	12	165	7-12	Yes (5 m/s)	No
Logan et al.[11]	13	College	6	150	40[a]	Yes (6.5-11.6%)	NM
Straub[12]	24	High school	6	60	7-17	No	No
DeRenne et al.[13,14]	5	High school	10	NS	5-6	Yes (6.67 m/s)	NM
DeRenne et al.[14,15]	10	High school	10	150	5-6	Yes (5.3%)	NM
Underweight training							
DeRenne et al.[13,14]	5	High school	10	NS	4-5	Yes (1.34 m/s)	NM
DeRenne et al. [14,15]	10	High school	10	150	4-5	Yes (6.7%)	NM
DeRenne et al.[14]	17	High school	10	187	4	Yes (3.2%)	NM
Overweight and underweight integral training							
DeRenne et al.[14,16]	150	High school and college	10	198	4-6	Yes (4-6%)	NM

a Amount of resistance while throwing a baseball attached to a wall pulley.

NM = accuracy not measured in study; **NS** = number of throws not specified in study.

The players, whose ages were between 18 and 19 years, were divided evenly into 3 groups: a control group, an overweight throwing group and a wall pulley throwing group. All 3 groups trained 3 days per week on alternating days for 6 weeks. The control group threw regulation baseballs exclusively throughout their training sessions. The overweight throwing group threw 10oz baseballs during their training, while the wall pulley-throwing group performed the throwing motion with a baseball attached to a wall pulley device that provided 10lb of resistance.

Each group started each training session by throwing regulation baseballs to warm up. Subsequently, the control, overweight and wall pulley groups used regulation baseballs, 10oz baseballs and the wall pulley resistance, respectively, and performed 5 throws with moderate effort and 20 throws with maximum effort. The 3 groups ended each training session by performing 20 maximal throws with regulation baseballs. Throwing velocities of regulation baseballs were recorded for all groups at the beginning and end of the 6-week training session.

The 3 groups threw at a rectangular grip target positioned 10.7m away. Accuracy was measured by measuring the distance from the center of the target (in which they were aiming for) to where each ball hit. From pre-test to post-test measurements in ball velocities, significant increases were observed for the overweight and wall pulley groups, but not for the control group. The amount of improvement was not reported. No significant differences were found in throwing accuracy for any group.

Straub[12] looked at the effect of overweight warm-up and training on throwing velocity and accuracy of regulation baseballs. The volunteers, who consisted of 108 high school males (aged between 14 and 19 years), were divided into an overweight warm-up group (n = 60) and an overweight training group (n = 48). The overweight warm-up group was pre-tested for throwing velocity and accuracy during maximal throwing with regulation baseballs. The warm-up group was then subdivided into a high velocity group (30 volunteers with highest throwing velocity) and a low velocity group (30 volunteers with lowest throwing velocity), with each of these groups further subdivided into 3 subgroups of 10 volunteers. Regulation baseballs, 10oz baseballs and 15oz baseballs served as the experimental treatments, and were randomly assigned to the 3 subgroups of the high and low velocity groups. After an initial warm-up with regulation baseballs, the 3 subgroups of the high and low velocity groups performed 20 maximum effort throws with either regulation baseballs, 10oz baseballs or 15oz baseballs. Immediately after this overweight warm-up, all volunteers were post-tested for throwing velocity and accuracy during maximal throwing of regulation baseballs. There were no significant differences in throwing velocity or accuracy between pre-test and post-test scores for any group.

The 48 participants comprising the overweight training group were randomly assigned to an experimental group or a control group. These groups all trained 3 days per week on alternating days for 6 weeks, with each training session consisting of throwing 20 throws with maximum effort. The control group threw regulation baseballs exclusively throughout the 6 weeks of training, while the experimental group threw progressively heavier baseballs throughout the 6 weeks, starting at 7oz during the first week and progressively increasing 2oz every week. Therefore, 17oz baseballs were thrown by the sixth week of training. Throwing velocities of regulation baseballs were recorded for control and experimental groups at the beginning and end of the 6-week training session. There were no significant differences found in throwing velocity or accuracy between the pre-test and post-test scores for the control or experimental groups.

Litwhiler and Hamm[10] conducted a 12-week overweight study using 5 college pitchers. The purpose of the study was to determine how overweight training affected throwing velocity and accuracy during pitching with regulation baseballs. The weight of the overweight baseballs ranged from 7 to 12oz. The 7oz baseballs were used during the first 2 weeks of training, while the baseball weight was increased by 1oz after each subsequent 2-week training interval. Therefore, 12oz baseballs were used during the final 2 weeks of training. Each pitcher trained 3 days a week with a rest day in between. After a warm-up with regulation baseballs, 15 throws were performed with overweight baseballs, followed by 20 throws with regulation baseballs, 10 throws with overweight baseballs and 10 throws with regulation baseballs. Therefore, each session consisted of throwing 25 overweight baseballs and 30 regulation baseballs. The regulation baseballs were always thrown with maximum effort, while overweight baseballs were thrown with alternating sub-maximum and maximum efforts. During the 12-week training period the pitchers threw at a rectangular grid target that was located 18.4m away (i.e. regulation pitching distance). Ball accuracy was measured according to where the ball hit the grid (i.e. in or out of the strike zone). Prior to and after the 12-week training period, throwing velocity and accuracy was tested for all pitchers during maximum throwing of regulation baseballs. From pre-test and post-test measurements, throwing velocity increased an average of 5.0 m/s (11.2 miles per hour) due to the 12 weeks of training, but there was not a significant improvement in ball accuracy due to overweight training.

Logan et al.[11] examined the effects of throwing a baseball against resistance on throwing velocity of regulation baseballs. Three equal-sized groups of 13 collegiate baseball pitchers served as volunteers. Throwing velocities of regulation baseballs were recorded for the 39 volunteers at the beginning and end of the 6-week training session. Each group's pretest throwing velocities were not significantly different from each other (approximately 34 m/s for all 3 groups).

Group I trained by throwing a baseball attached to an isotonic resistance device (the Exergenie), which provided 2.5lb of resistance. This resistance was chosen since it was great enough to provide an overload effect, but believed small enough to minimally alter the normal throwing motion and segmental speeds of movement. Group II trained with regulation baseballs exclusively, while group III served as a control and did not throw or resistance train during the 6-week training period. The 6-week training sessions for groups I and II consisted of performing 30 normal overhand throws per day for 5 days per week.

From post-test measurements, group I had significantly greater throwing velocity compared to groups II and III, while groups II and III showed no significant differences in throwing velocity compared to each other. Post-test throwing velocity was 6.5% greater for group 1 compared to group 2, and 11.6% greater for group 1 compared to group 3. Performing the throwing motion against resistance was effective in increasing throwing velocity of regulation baseballs.

Four of the 5 studies above demonstrated that training or warming up with overweight baseballs produced an increase in the throwing velocity of regulation baseballs. One important question that arises from these results is what mechanism caused these increases in throwing velocities. From these data, it can be deduced that the observed increase in throwing velocity is possibly due to an increase in arm strength that resulted from training with overweight baseballs. Numerous weight training studies have shown that overloading a muscle with a resistance greater than that muscle is normally subjected to causes an increase in muscle strength.[18-23] Furthermore, there have been several studies that have demonstrated an increase in the throwing velocity of regulation baseballs due to participating in a weight training programme.[24-27]

There were a few limitations to the above studies that diminish their validity: (i) subjects were taken from a general population of high school males rather than baseball players;[12] (ii) the range of weighted baseballs thrown may be excessive, causing deviation from the normal throwing pattern seen during regular pitching;[12] (iii) a greater number of throws may be needed during the training sessions in order to find significant differences;[12] (iv) the percentage increases in throwing velocity appear high for only 6 weeks of training;[11] and (v) an improvement of 5.0 m/s seems inordinately high, especially in only 12 weeks of training.[10] As training started during the off season, when the pitchers may not have been throwing, any type of throwing programme could produce initial increases in throwing velocity, because the pitching arm would be in an unconditioned state. Different results may have been found if the throwing programme had started when the participants' pitching arms were already highly conditioned (e.g. at the end of the baseball season). Furthermore, using a control group who threw only regulation baseballs may have also produced different results.

2. Effects of Throwing Overweight and Underweight Baseballs on Throwing Velocity

DeRenne et al.[13-16] conducted several overweight and underweight throwing studies at the University of Hawaii from 1982 to 1988, which represents the published overweight and underweight literature from 1985 to 1994. These studies had the following objectives: (i) to determine the ideal weight ranges of overweight and underweight baseballs; (ii) to determine if training with overweight and underweight baseballs increased the velocity of 5oz regulation baseballs; (iii) to determine ideal pitch ratios and sequences for weighted baseballs; and (iv) to determine the incidence of arm injuries due to training with overweight and underweight baseballs. Their initial 1982 pilot study[13,14] was conducted to determine how 10 weeks of training with slightly overweight (0 to 20% greater weight than regulation baseballs) and underweight (0 to 20% less weight than regulation baseballs) baseballs affected throwing velocity of regulation baseballs. Ten high school baseball pitchers, whose age ranged between 16 and 18 years, served as volunteers. One group of 5 volunteers threw only underweight baseballs, while a second group of 5 volunteers threw only overweight baseballs. Both groups threw only regulation baseballs during the first 2 weeks of training. Each subsequent 2-week training period resulted in throwing baseballs that were 0.25oz lower for the underweight group and 0.25oz higher for the overweight group than the previous 2-week period. Therefore, over the 10-week training period the underweight group threw baseballs ranging from 4 to 5oz, while the overweight group threw baseballs ranging from 5 to 6oz.

The overweight and underweight groups trained 3 sessions per week during the 10 weeks of training. The underweight group began each training session with a 5- to 10-minute warm-up throwing regulation baseballs. Subsequently, 5 to 10 minutes of long toss throwing (up to 45m) and 15 minutes of bullpen throwing (i.e. pitching off a pitching mound while throwing to a catcher) was done at 50 to 75% maximum throwing effort using underweight baseballs. In addition, once per week the underweight group performed 10 to 15 minutes of maximum effort bullpen throwing using underweight baseballs, and 1 to 10 minutes of maximum effort bullpen throwing using regulation baseballs. The overweight group began each training session with a 15-minute warm-up using overweight baseballs during long toss throwing (up to 45m), followed by 10 to 15 minutes of bullpen throwing at 50 to 75% maximum effort. In addition, once per week the underweight group did 10 to 15 minutes of maximum effort bullpen throwing using overweight baseballs, and 10 minutes of maximum effort bullpen throwing using regulation baseballs. Throwing velocities of regulation baseballs were recorded for both groups at the beginning and end of the 10-week training session. From pre-test to post-test measurements in throwing velocities, significant increases in velocities were observed with both the underweight (1.34 m/s increase) and overweight (0.67 m/s increase) training groups. These preliminary data provided the impetus for several subsequent studies by these authors.

In 1984, DeRenne et al.[14,15] conducted a follow-up study to their 1982 pilot study, but this time a control group was used. Thirty high school baseball pitchers (aged between 16 and 18 years) were randomly and equally divided into overweight, underweight and control groups. Each of these 3 groups threw 50 pitches 3 times per week for 10 weeks. For each training session, the underweight group threw 30 regulation baseballs and 20 underweight baseballs, while the overweight group threw 30 regulation baseballs and 20 overweight baseballs. All 50 throws per training session for the control group were with regulation baseballs. All groups threw regulation baseballs for the first 2 weeks. Each subsequent 2-week training period resulted in throwing baseballs that were 0.25oz lower for the underweight group and 0.25oz higher for the overweight group than the previous 2-week period. Therefore, over the 10-week training period the underweight group threw baseballs ranging from 4 to 5oz, the overweight group threw baseballs ranging from 5 to 6oz and the control group threw regulation baseballs exclusively. From pre-test to post-test measurements in throwing velocities, significant increases in velocity were observed for the underweight group (6.7% increase) and overweight group (5.3% increase), but no significant difference in throwing velocities was found in the control group (1.2% increase).

A 1986 underweight throwing project was conducted[14] to determine how 10 weeks of training with slightly underweight baseballs (4oz) affected throwing velocity of 5oz regulation baseballs. Thirty-four high school pitchers were equally divided into a control group and an underweight group. Both groups performed 3 training sessions per week for 10 weeks. The training progression for the underweight group was as follows: (i) for weeks 1 to 3 there were 54 pitches thrown per session (nine 5oz, thirty-six 4oz and nine 5oz); (ii) for weeks 4 to 6 there were 60 pitches thrown per session (ten 5oz, forty 4oz and ten 5oz); (iii) for weeks 7 to 8 there were 66 pitches thrown per session (eleven 5oz, forty-four 4oz and eleven 4oz); and (iv) for weeks 9 to 10 there were 75 pitches thrown per session (twelve 5oz, fifty 4oz and thirteen 5oz). Throughout the 10 weeks of training the control group threw the same number of pitches per session as did the underweight group, but threw regulation baseballs exclusively. From pre-test to post-test measurements in throwing velocities, significant increases in velocity were observed for the underweight group (3.3% increase), but no significant difference in throwing velocities was found in the control group (0.69% decrease).

A 1987 to 1988 ‘integral’ project was conducted[14,16] with 225 high school and college baseball pitchers randomly and equally divided into overweight, underweight and control groups. Each group was comprised of 15 high school pitchers (mean age of 16.6 ± 0.57 years) and 60 college pitchers (mean age of 19.6 ± 0.46 years). The overweight and underweight integrated groups (groups 1 and 2) threw underweight, overweight and regulation baseballs in their training programme, while the control group (group 3) threw only regulation baseballs throughout the training cycle. The training protocol employed for the 3 groups is shown in table II. While group 1 threw regulation, overweight and underweight baseballs throughout the 10-week training period, group 2 trained with regulation and overweight baseballs during the first 5 weeks, and then trained with regulation and underweight baseballs during the last 5 weeks. All pitchers in all groups pitched at regulation pitching distance.

From pre-test to post-test measurements in throwing velocities, significant increases (approximately 4 to 6%) in throwing velocity were found in both high school and college pitchers in both experimental groups, but no significant difference in throwing velocity was found for the control group. Since the percentage increases in pitching velocity between group 1 and group 2 were approximately the same, this implies that both training protocols were equally effective in increasing pitching velocity.

The above data from DeRenne et al.[13-16] support work done by Vasiliev,[5] who concluded from his own weight implement research in speed-strength development that the most effective force was found in those combinations in which the lighter and heavier weights differed no more than 20% from the regulation weight of the implement. However, since work by Vasiliev[5] involved throwing the shot put, which is quite different than throwing a baseball, it is difficult to compare these data. It has also been recommended that resistance variations from the regulation weight of a throwing implement should not exceed 5%.[6] The protocol employed by group 2 (table II) was patterned after Soviet strength training studies[2,5] which showed that a functional strength base should first be established by throwing heavier implements prior to speed training by throwing lighter implements.

Furthermore, the employed 2 : 1 ratio of throwing weighted (overweight and underweight) baseballs to regulation baseballs, as well as the weighted baseballs being 20% greater than or less than the weight of regulation baseballs, were also patterned after Soviet throwing research.[1-6]

3. Related Research Question: Does Throwing Overweight and Underweight Baseballs Increase Injury Risk?

It is interesting that most of the training studies with overweight and underweight baseballs stated that there were no injuries reported throughout the training period.[10,13-16] However, performance, not throwing injuries, was the primary focus of these studies. Hence, it is difficult to draw definite conclusions regarding the relationship between throwing overweight and underweight baseballs and injury risk. In addition, these training studies were only 10 to 12 weeks in duration, which may not have been long enough to observe injury pattern differences between throwing regulation baseballs and throwing overweight and underweight baseballs. Therefore, additional studies are needed that are longer in duration and that focus more on injury risk in order to better understand what deleterious effects may occur due to throwing overweight and underweight baseballs.

4. Related Research Question: Are There Kinematic and Kinetic Differences Between Throwing Regulation Baseballs and Throwing Overweight and Underweight Baseballs?

Unfortunately, there are no known studies in the literature that have compared kinetic and kinematic parameters (except ball velocity) between throwing regulation baseballs and throwing overweight and underweight baseballs. Kinetic analyses will provide shoulder and elbow force and torque data between throwing regulation baseballs and throwing overweight and underweight baseballs. This will provide insight regarding the injury risk involved in throwing overweight and underweight baseballs. Kinematic analyses will provide insight regarding

Table II. Training schedule, lesson plan and weights of baseballs used (from DeRenne et al.,[16] with permission)

Weeks	Number of sessions	Total pitches	Sequence of pitches	Weight of baseballs (oz)
Group 1				
1-2	3	54	9-18-18-9 (R-H-L-R)	5-6-4-5
3-4	3	60	10-20-20-10 (R-H-L-R)	5-6-4-5
5-6	3	66	11-22-22-11 (R-H-L-R)	5-6-4-5
7-8	3	72	12-24-24-12 (R-H-L-R)	5-6-4-5
9-10	3	78	13-26-26-13 (R-H-L-R)	5-6-4-5
Group 2				
1-2	3	54	9-36-9 (R-H-R)	5-6-5
3-4	3	60	10-40-10 (R-H-R)	5-6-5
5-6	3	66	11-44-11 : 11-44-11 (R-H-R : R-L-R)	5-6-5; 5-4-5
7-8	3	72	12-48-12 (R-L-R)	5-4-5
9-10	3	78	13-52-13 (R-L-R)	5-4-5
Group 3				
1-2	3	54	54 (R)	5
3-4	3	60	60 (R)	5
5-6	3	66	66 (R)	5
7-8	3	72	72 (R)	5
9-10	3	78	78 (R)	5

H = heavy 6oz baseball; **L** = light 4oz baseball; **R** = regulation 5oz baseball.

throwing mechanics and help determine how throwing mechanics change as different weight baseballs are employed.

5. Related Research Question: Are There Kinematic and Kinetic Differences Between Throwing Regulation Baseballs and Throwing Overweight Implements?

The aforementioned overweight throwing studies used overweight baseballs that ranged between 7 and 17oz, with the heaviest baseball weighing approximately 3 times the weight of a regulation baseball. It is interesting that a football also weighs 3 times the weight of a regulation baseball. In fact, some major league professional baseball pitchers have employed a football as an overweight training implement.[14] Professional pitchers have stated that throwing a football provided a good warm up prior to throwing a baseball, helped minimise and alleviate shoulder and elbow joint stiffness and soreness the day after pitching, and helped strengthen the arm.[14] It is also believed that throwing a football helps reinforce good baseball throwing mechanics, especially when thrown with a tight spiral.[14] However, since these beliefs have not been validated scientifically, they should be viewed cautiously.

Although it is unknown how the kinematics and kinetics of throwing a 15oz football compare to throwing a 15oz overweight baseball, there may be some similarities. Hence, the kinematics and kinetics between throwing regulation baseballs and throwing a 15oz football may have similarities compared to the kinematics and kinetics between throwing regulations baseballs and throwing 15oz overweight baseballs. Although throwing a baseball is a similar arm motion compared to throwing a football, Fleisig et al.[8] have reported several kinematic differences between football throwing and baseball pitching. There were several significant kinematic differences between baseball pitching and football throwing (table III). With these numerous kinematic differences, the efficacy of throwing a football during baseball season should be questioned, since undesirable neuromuscular firing patterns may be detrimental to baseball pitching. Furthermore, the timing of when these kinematic parameters occur is also different between baseball pitching and football passing.[8] However, throwing a football (or other weighted implement) during the off-season may be an appropriate resistance implement that can be used to strengthen the arm.

An important question concerning throwing overweight baseballs is how the magnitudes of shoulder and elbow kinetics (i.e. forces and torques) compare to the kinetics generated while throwing regulation baseballs. Fleisig et al.[8] quantified shoulder and elbow kinetics between baseball pitching and football throwing and found significant kinetic differences occurred only during the arm deceleration phase (table IV). Since shoulder and elbow forces and torques were greatest during the deceleration phase of football throwing and baseball pitching, injury potential may also be greatest during this period. Hence, throwing an overweight ball, such as a football, may not only enhance the throwing velocity of regulation baseballs, but also may generate lower magnitude forces about the shoulder and elbow compared to baseball pitching.

Although shoulder and elbow injuries due to baseball throwing have been well documented,[28-44] there are no known studies that have reported shoulder and elbow injuries specifically due to throwing a football. Hence, research is needed in this area. However, it appears that baseball pitchers incur greater repetitive trauma to the shoulder and elbow compared to quarterbacks. Compared to a quarterback, a pitcher performs a greater number of throws during a season, and also renders a higher percentage of hard throws. For example, a starting pitcher in college or professional baseball throws approximately 100 pitches in a typical outing. In a football game, most college or professional quarterbacks average approximately 20 to 30 throws per game. Furthermore, most starting professional pitchers pitch in approximately 25 to 40 games per season, which is 2 to 3 times greater than the number of games that a quarterback will participate in.

There is only one other known study that has compared kinematic and kinetic parameters between

Table III. Kinematic comparison between baseball pitching and football passing (from Fleisig et al.,[8] with permission)

Parameter	Pitching (n = 26)		Passing (n = 26)	
	Mean	SD	Mean	SD
Instant of foot contact				
Stride length from ankle to ankle (% height)*	74	5	61	8
Shoulder abduction (°)	93	12	96	13
Shoulder horizontal adduction (°)*	–17	12	7	15
Shoulder external rotation (°)	67	24	90	33
Elbow flexion (°)*	98	18	77	12
Lead knee flexion (°)*	51	11	39	11
Arm cocking phase				
Maximum pelvis angular velocity (°/s)*	660	80	500	110
Maximum shoulder horizontal adduction (°)*	18	8	32	9
Maximum upper torso angular velocity (°/s)*	1170	100	950	130
Maximum elbow flexion (°)*	100	13	113	10
Instant of maximum shoulder external rotation				
Maximum shoulder external rotation (°)	173	10	164	12
Arm acceleration phase				
Maximum elbow extension velocity (°/s)*	2340	300	1760	210
Average shoulder abduction during acceleration (°)*	93	9	108	8
Instant of ball release				
Throwing velocity (m/s)*	35	3	21	2
Shoulder horizontal adduction (°)*	7	7	26	9
Elbow flexion (°)*	22	6	36	8
Trunk tilt forward (°)	58	10	65	8
Trunk tilt sideways (°)*	124	9	116	5
Lead knee flexion (°)*	40	12	28	9
Arm deceleration phase				
Maximum shoulder internal rotation velocity (°/s)*	7550	1360	4950	1080
Minimum elbow flexion (°)*	18	5	24	5
Average upper torso angular velocity (°/s)*	470	160	310	110

SD = standard deviation; * = p < 0.001.

throwing regulation baseballs and throwing overweight implements. Using 9 college baseball pitchers, Castagno et al.[45] compared kinematics and kinetics between throwing regulation baseballs (normal condition) and overload throwing while pitching off an indoor pitching mound. The overload condition consisted of throwing regulation baseballs while wearing a 7oz weighted glove positioned along the dorsal surface of the hand. Therefore, the total weight of the 7oz weighted glove and 5oz regulation baseball was 12oz. This study was unique in the sense that the extra weight was not released, since it was firmly attached to the back of the hand. Kinematic results show that the overload condition demonstrated greater shoulder external rotation during arm cocking, greater elbow extension angular velocity during arm acceleration, more forward trunk tilt near ball release and more elbow flexion throughout the pitch. Kinetic results consistently revealed greater elbow forces and torques and greater shoulder torques in the overload condition. Compared with the normal condition, the overload condition showed: (i) a 13% increase in elbow anterior force (392N *vs* 348N) during arm acceleration; (ii) a 31% increase in elbow flexor torque (80 N • m *vs* 61 N • m) during arm acceleration; (iii) an 81% increase in elbow valgus torque (38 N • m *vs* 21 N • m) during follow-through; (iv) a 26% increase in shoulder horizontal adduction torque (116 N • m *vs* 92 N • m) during follow-through; and (v) a 43% increase in shoulder abduction torque (139 N • m *vs* 97 N • m) during follow-through.

It is interesting that both the kinematic and kinetic results of Castagno et al.[45] differ from the results of Fleisig et al.[8] However, this is not surprising, since the overload condition from Castagno et al.[45] involved pitching a regulation baseball off a mound with a 7oz external weight attached to the hand, while the overload condition from Fleisig et al.[8] involved throwing a 15oz football. In both conditions, maximal or near maximal effort was used by all participants. What is surprising is that shoulder and elbow forces and torques in throwing a football (table IV) were less than pitching a regulation baseball, even though a football weighs 3 times that of a baseball. In contrast, the overload pitching condition from Castagno et al.[45] exhibited greater shoulder and elbow forces and torques compared to pitching a regulation baseball. From data by Castagno et al.,[45] there are at least 2 reasons why pitching with weighted implements during the competitive season may have deleterious effects. Firstly, the different kinematics seen in weighted pitching compared to regulation pitching may produce undesirable neuromuscular and motor patterns that may adversely affect normal pitching mechanics. Secondly, the higher shoulder and elbow forces and torques from weighted pitching may exacerbate shoulder and elbow stress, which is already high due to the repetitive trauma involved. Similar to throwing a football, pitching with weighted implements should be reserved primarily for off-season training, since it may alter neuromuscular throwing patterns compared to throwing regulation baseballs.

6. Conclusions

The purpose of this review was to determine the effects that warm-up and training with overweight and underweight baseballs had on throwing velocity and accuracy. One of the 2 warm-up studies showed that warming up with overweight baseballs enhanced throwing accuracy and velocity. With the scarcity of data, the effects that warming up with overweight baseballs have on throwing velocity and accuracy is inconclusive, and more research is needed. All 3 training studies show that training with overweight baseballs did not improve throwing accuracy. In contrast, 10 of the 11 training studies show that 6 to 12 weeks of training with overweight or underweight baseballs significantly increased throwing velocity of regulation baseballs. What is unclear is how long these increases in throwing velocity remain once training with overweight and underweight baseballs ends and the athlete begins throwing regulation baseballs exclusively (e.g. during the competitive season). More research is needed in this area.

The training studies with overweight baseballs show improvement in throwing velocity over a large range in weight variations. Since the overweight baseballs used in these studies ranged between 5.25 and 17oz, this may be an ideal weight range to use in training in order to maximise throwing velocity of regulation baseballs. In contrast, the underweight baseballs used were all within a narrow weight range between 4 and 5oz. From most of the research now available on weighted implement throwing, it appears that the ideal weight of overweight and underweight baseballs is within 20% of the weight of a regulation baseball. Hence, underweight baseballs would weight between 4 and 5oz, and overweight baseballs would weigh between 5 and 6oz. Future studies are now needed to compare kinematics and kinetics between throwing regulation baseballs and throwing overweight and underweight baseballs. These studies will help determine the efficacy of throwing overweight and underweight baseballs during the competitive season. If throwing mechanics are unaltered between weighted and regulation baseballs, and shoulder and elbow forces and torques are similar, there may be merit to training with overweight and underweight baseballs during the season, especially if throwing velocity increases.

DeRenne et al.[14,16] showed that the best frequency ratio of throwing slightly overweight and underweight baseballs to throwing regulation

Table IV. Kinetic comparison between baseball pitching and football passing (from Fleisig et al.,[8] with permission)[a]

Parameter	Pitching (n = 26)		Passing (n = 26)	
	Mean	SD	Mean	SD
Arm cocking phase				
Maximum shoulder anterior force (N)	310	50	350	80
Maximum shoulder horizontal adduction torque (N • m)	82	13	78	19
Maximum shoulder internal rotational torque (N • m)	54	10	54	13
Maximum elbow medial force (N)	260	50	280	60
Maximum elbow varus torque (N • m)	51	10	54	13
Arm acceleration phase				
Maximum elbow flexion torque (N • m)	47	9	41	8
Arm deceleration phase				
Maximum shoulder compressive force (N)*	850	140	660	120
Maximum elbow compressive force (N)**	710	110	620	110
Maximum shoulder adduction torque (N • m)*	79	23	58	34
Follow-through phase				
Maximum shoulder posterior force (N)	310	110	240	120
Maximum shoulder horizontal abduction torque (N • m)	85	51	80	34

a Elbow kinetic data are presented as forces and torques applied by the arm onto the forearm. Shoulder kinetic data are presented as forces and torques applied by the trunk onto the arm. Forces were normalised by bodyweight and torques were normalised by body weight and height.

SD = standard deviation; * $p < 0.01$; ** $p < 0.001$.

baseballs in order to maximise throwing velocity was 2 : 1. Additional studies may be helpful to investigate several other frequency ratio possibilities.

Throughout all overweight and underweight training studies there were no arm injuries reported. This may imply that training with overweight and underweight baseballs strengthens the arm and trunk musculature, thus minimising injury potential, or it may imply that forces generated at the body joints (in particular the shoulder and elbow) are lower when throwing overweight and underweight baseballs. Nevertheless, the relatively short time durations of the training studies may be too short to make any definite conclusions about injury risks, especially since there were also no injuries reported while throwing regulation baseballs exclusively. A long term study is needed regarding the incidence of throwing injuries when training with regulation baseballs, compared with training with overweight and underweight baseballs. A kinetic analysis is needed to compare shoulder and elbow forces and torques that are generated between throwing regulation baseballs and throwing overweight and underweight baseballs.

Some college and professional baseball organisations question the efficacy of training with overweight and underweight baseballs during the season, and that such training should be limited to the off-season. The rationale is that during the season baseball players need to be working on skills that are very specific to game needs. A player acquires a certain ‘feel’ for the baseball during throwing, and acquiring a different feel by training with overweight and underweight baseballs could produce detrimental effects. Throwing velocity and accuracy need to be perfected by repetitiously throwing baseballs of the same size, texture and weight that are used during competition. The common practice among pitchers is to simulate the game environment as closely as possible, which means throwing with regulation baseballs primarily, especially during the competition season. These beliefs among players and coaches seem consistent with the principles of neurophysiology. Neuromuscular coordination and timing could be adversely affected by throwing overweight and underweight baseballs during the season. Different muscle groups may even be recruited. More research involving kinematic analyses between throwing regulation baseballs and throwing overweight and underweight baseballs is needed before more definite conclusions can be made.

Acknowledgements

The authors extend a special thanks to Kevin Wilk, P.T. (HealthSouth Sports Medicine and Rehabilitation Center) and Coach Bill Thurston (Amherst College) for their critical review of this manuscript. We would like to thank Vern Gambetta (Chicago White Sox) for his insights and expertise involving training with overweight and underweight baseballs. We would also like to extend our gratitude to Coop DeRenne, D.Ed. (University of Hawaii) and Todd Royer, Ph.D. (Arizona State University) for their recommendations, and for providing us with current data relevant to overweight and underweight throwing. Lastly, we extend our gratitude to Andy Demonia (American Sports Medicine Institute) for his technical services in tracking the data and preparing it for analysis.

References

1. Kanishevsky S. A universal shot. Sov Sports Rev 1984; 19 (4): 207-8
2. Konstantinov O. Training program for high level javelin throwers. Sov Sports Rev 1979; 14 (3): 130-4
3. Kuznetsov V. Speed and strength. Yessis Rev 1975; 10 (3): 78-83
4. Verkhoshansky Y, Tatyan V. Speed-strength preparation of future champions. Sov Sports Rev 1983; 18 (4): 166-70
5. Vasiliev LA. Use of different weight to develop specialized speed-strength. Sov Sports Rev 1983; 18 (1): 49-52
6. Jarver J. Varied resistance in power development. Mod Athlete Coach 1973; 10 (6): 5-8
7. Escamilla RF, Fleisig GS, Barrentine SW, et al. Kinematic comparisons of throwing different types of baseball pitches. Med Sci Sports Exerc 1998; 14 (1): 1-23
8. Fleisig GS, Escamilla RF, Andrews JR, et al. Kinematic and kinetic comparison between baseball pitching and football passing. J Appl Biomech 1996; 12: 207-24
9. Brose DE, Hanson DL. Effects of overload training on velocity and accuracy of throwing. Res Q 1967; 38 (4): 528-33
10. Litwhiler D, Hamm L. Overload: effect on throwing velocity and accuracy. Athlet J 1973; 53: 64-5, 88
11. Logan GA, McKinney WC, Rowe Jr W, et al. Effect of resistance through a throwing range-of-motion on the velocity of a baseball. Percept Mot Skills 1966; 23 (1): 55-8
12. Straub WF. Effect of overload training procedures upon velocity and accuracy of the overarm throw. Res Q 1968; 39 (2): 370-9
13. DeRenne C, Tracy R, Dunn-Rankin P. Increasing throwing velocity. Athlet J 1985 Apr; 65 (9): 36-9
14. DeRenne C, House T. Power baseball. St Paul (MN): West Educational Publishing, 1993
15. DeRenne C, Kwok H, Blitzblau A. Effects of weighted implement training on throwing velocity. J Appl Sport Sci Res 1990; 4 (1): 16-9
16. DeRenne C, Buxton BP, Hetzler RK, et al. Effects of under- and overweighted implement training on pitching velocity. J Strength Cond Res 1994; 8 (4): 247-50
17. Van Huss WD, Albrecht L, Nelson R, et al. Effect of overload warm-up on the velocity and accuracy of throwing. Res Q 1962; 33 (3): 472-5
18. Hickson RC, Hidaka K, Foster C. Skeletal muscle fiber type, resistance training, and strength-related performance. Med Sci Sports Exerc 1994; 26 (5): 593-8
19. Maughan RJ, Watson JS, Weir J. Muscle strength and cross-sectional area in man: a comparison of strength-trained and untrained subjects. Br J Sports Med 1984; 18 (3): 149-57
20. McKenzie Gillam G. Effects of frequency of weight training on muscle strength enhancement. J Sports Med Phys Fitness 1981; 21 (4): 432-6
21. O'Shea P. Effects of selected weight training programs on the development of strength and muscle hypertrophy. Res Q 1966; 37 (1): 95-102
22. Reid CM, Yeater RA, Ullrich IH. Weight training and strength, cardiorespiratory functioning and body composition of men. Br J Sports Med 1987; 21 (1): 40-4
23. Sale DG. Neural adaptation to resistance training. Med Sci Sports Exerc 1988; 20 (5 Suppl.): 135-45S
24. Popescue MG. Weight training and the velocity of a baseball. Athlet J 1975; 55 (9): 74, 105-6
25. Thompson CW, Martin ET. Weight training and baseball throwing speed. J Assoc Phys Ment Rehabil 1965; 19 (6): 194-6
26. Wooden MJ, Greenfield B, Johanson M, et al. Effects of strength training on throwing velocity and shoulder muscle performance in teenage baseball players. J Orthop Sports Phys Ther 1992; 13 (5): 223-8
27. Potteiger JA, Williford HN, Blessing DL, et al. Effect of two training methods on improving baseball performance variables. J Appl Sport Sci Res 1992; 6: 2-6
28. Andrews JR. Bony injuries about the elbow in the throwing athlete. Instr Course Lect 1985; 34: 323-31
29. Andrews JR, Gidumal RH. Shoulder arthroscopy in the throwing athlete: perspectives and prognosis. Clin Sports Med 1987; 6 (3): 565-71
30. Andrews JR, Kupferman SP, Dillman CJ. Labral tears in throwing and racquet sports. Clin Sports Med 1991; 10 (4): 901-11
31. Carson Jr WG, Gasser SI. Little Leaguer's shoulder: a report of 23 cases. Am J Sports Med 1998; 26 (4): 575-80
32. Cicoria AD, McCue FC. Throwing injuries of the shoulder. Va Med 1988; 115 (7): 327-30
33. DaSilva MF, Williams JS, Fadale PD, et al. Pediatric throwing injuries about the elbow. Am J Orthop 1998; 27 (2): 90-6
34. Fleisig GS, Andrews JR, Dillman CJ, et al. Kinetics of baseball pitching with implications about injury mechanisms. Am J Sports Med 1995; 23 (2): 233-9
35. Gainor BJ, Piotrowski G, Puhl J, et al. The throw: biomechanics and acute injury. Am J Sports Med 1980; 8 (2): 114-8
36. Gore RM, Rogers LF, Bowerman J, et al. Osseous manifestations of elbow stress associated with sports activities. AJR Am J Roent 1980; 134 (5): 971-7
37. Jackson DW. Chronic rotator cuff impingement in the throwing athlete. Am J Sports Med 1976; 4 (6): 231-40
38. Jobe FW, Nuber G. Throwing injuries of the elbow. Clin Sports Med 1986; 5 (4): 621-36
39. Lombardo SJ, Jobe FW, Kerlan RK, et al. Posterior shoulder lesions in throwing athletes. Am J Sports Med 1977; 5 (3): 106-10
40. Mirowitz SA, London SL. Ulnar collateral ligament injury in baseball pitchers: MR imaging evaluation. Radiology 1992; 185 (2): 573-6

41. Nuber GW, Diment MT. Olecranon stress fractures in throwers: a report of two cases and a review of the literature. Clin Orthop 1992 (278): 58-61
42. Ringel SP, Treihaft M, Carry M, et al. Suprascapular neuropathy in pitchers. Am J Sports Med 1990; 18 (1): 80-6
43. Savoie FH. Arthroscopic examination of the throwing shoulder. J Orthop Sports Phys Ther 1993; 18 (2): 409-12
44. Timmerman LA, Andrews JR. Undersurface tear of the ulnar collateral ligament in baseball players: a newly recognized lesion. Am J Sports Med 1994; 22 (1): 33-6
45. Castagno PW, Richards JG, Axe MJ. The biomechanics of overload pitching [abstract]. Med Sci Sports Exerc 1995; 27 (5): 159S

Correspondence and offprints: Dr *Rafael Escamilla,* Duke University Medical Center, Division of Orthopaedic Surgery, P.O. Box 3435, Durham, NC 27710, USA.
E-mail: rescamil@duke.edu