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Optimizing Baseball Pitching Performance: A Comparative Analysis of Strength Training and Weighted Ball Training on Velocity and Accuracy

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Abstract: *This paper looks at how two different training programs, weighted ball training and strength training, affect the pitching speed and accuracy of female baseball players. The study evaluates the outcomes of each technique and contrasts their effectiveness to determine the best one for enhancing pitching performance. Eight healthy baseball pitchers were evenly split into two groups for the eight-week trial. While the Weighted Ball Training group at Kinnaird College for Women University followed a program focused on weighted balls ranging from 5 to 9 ounces, the Strength Training Group at The University of Lahore participated in a biweekly systematic strength training program. While accuracy was assessed by examining strikes from 20 pitches at each phase, the pitching speed was calculated by averaging the three highest pitches. A sports radar gun was used to evaluate pitching speed. Following the end of the 8-week intervention, pre-measurements were carried out. From pre-test to post-test following training interventions, the weighted ball training group showed a marked increase in velocity (Cohen's d = 2.217, p-value = .043), whereas the strength training group indicated a notable improvement in accuracy (Cohen's d = 2.373, p-value = .019). The study results showed, therefore, that while strength training demonstrated more significant improvements in accuracy, weighted ball training had a more noticeable impact on speed.*

Key Words: *Strength Training, Weighted Ball Training, Velocity, Accuracy, Pitching Performance*

Introduction

With about three million kids participating in it annually in the United States, baseball is among the most beloved sports worldwide (Melugin et al., 2021). Compared to any other position in the game, throwing calls for more prolonged physical effort and exact mental and motor coordination (Birfer et al., 2019). Pitchers can deceive batters by changing their tempo, control, and grips, affecting pitch trajectory (Crotin et al., 2021). Though skilled pitchers can reach speeds of up to 100 mph (160 km/h), success is not assured by speed alone (Peterson et al., 2024). This study sought to evaluate how strength training and weighted ball training affected pitch accuracy and speed among female baseball players.

Pitching's effectiveness is a mix of speed and accuracy. Whether as a pitcher's wind-up or a quick infield release, throwing depends on a complicated interaction of physical forces, muscular coordination, and joint mechanics (Zhang et al., 2023). For health and performance, strength training offers many benefits. This training includes various exercises requiring muscles to oppose force or resistance (Lauersen et al., 2018). It reduces injury risk, improves joint range of motion, joint stability, bone strength and development, as well as both static and dynamic muscle function (Maestroni et al., 2020). However, the influence of strength training on pitching accuracy remains unclear because of limited studies in this area (Lust et al., 2009).

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Strength training is a form of exercise aimed at enhancing muscle size, power, and endurance. It is commonly known as resistance or weight training. To build the necessary muscle strength for contraction, individuals may use light weights, resistance bands, exercise machines, or perform bodyweight workouts (Riaz et al., 2024). The main goals of resistance training typically include building strength, increasing muscle size (hypertrophy), boosting power, and improving endurance. Strength training reduces the risk of injury by fortifying and stabilizing the joints involved in complex throwing movements. Therefore, integrating strength training into an overall athletic program is an effective strategy for enhancing baseball throwing performance (Ullah Khan, et al, 2024). The main objective of weighted ball training programs, particularly for pitchers, is to enhance throwing velocity (Caldwell et al., 2019). Weighted-implement practice with overweight or underweight baseballs is gaining in prominence across all levels of professional baseball. Escamilla et al. (2000) proposed that pace improvements may be attributed to enhanced power in the arms through practicing with heavyweight balls.

Few studies have investigated the effects of strength training on pitching velocity and accuracy. One study investigated the effects of core strengthening exercises on the throwing performance. Fourteen players with an average age of 14.93 ± 0.83 years finished a six-week training program consisting of three one-hour sessions per week. The program consisted of warm-up exercises, major exercises, and sensory motor training. Pitchers were asked to throw baseballs 10 times, and their accuracy was rated based on the number of hits. After six weeks of core strengthening training, improved baseball players' throwing abilities by increasing pitch speed and accuracy (Lee et al., 2015).

A multicenter prospective study investigated how weighted ball programs affected strength, velocity, range of motion, and injury rates in high school pitchers. Pitchers who participated in weighted-ball training demonstrated significantly higher average and peak fastball velocities (average fastball velocity: 114.26 km/h vs. 106.22 km/h; peak fastball velocity: 115.87 km/h vs. 109.44 km/h). This implies that weighted-ball programs can improve pitching velocity, and the majority of high school pitchers in this study increased their velocity with weighted-ball regimens, which were linked to higher average and peak speeds. (Bowman et al., 2023).

The purpose of this study was to investigate successful baseball training methods by closely examining how each approach affected pitching speed and accuracy. The association among throwing velocity and accuracy is unexplored, as these two key performance metrics are rarely studied together. In order to fill this existing gap, this study will investigate the effects of weighted-ball and strength training on pitching velocity and accuracy. This comprehensive method marks a big step forward in baseball training and sports science, with profound implications for improving player performance.

Research Methodology

Eight female baseball pitchers of the University of Lahore and Kinnaird College for Women University were divided into two groups: the Weighted Ball Training Group and the Strength Training Group. Pitching velocity was measured using a sports radar gun. Each pitcher was told to toss a baseball three times to determine pitch speed; the average of the three pitches was calculated. To determine accuracy, each pitcher was ordered to throw a baseball twenty times off the ground in the net. The balls that hit the target were scored, and the average of the scores was taken.

Pre-measurements were taken before the start of the training program, and post-measurements were taken after the completion of the 8-week intervention. A stratified sampling technique was used. SPSS version 27.0 was used to perform descriptive statistics, paired sample t-tests, and confidence intervals. A ρ-value of ≤0.05 was considered statistically significant.

Table 1

Training Plan for Strength Training Group

Week	Session 1	Session 2
1	Warm-up: Dynamic stretches, 5 min jog, Squats: 3x6 @ 30kg (60% 1RM) Bench Press: 3x6 @ 22.5kg (60% 1RM) Lat Pulldowns: 3x6 reps @ 22.5kg (60% 1RM)Tricep Dips: 3x6 (bodyweight) Cool-down: Static stretches	Warm-up: Dynamic stretches, 5 min jog, Deadlifts: 3x6 @ 35kg (65% 1RM) Pull-Ups: 3x max reps Dumbbell Shoulder Press: 3x6 @ 7kg Bicep Curls: 3x6 @ 7kg Cool-down: Static stretches

Week	Session 1	Session 2
2	Warm-up: Dynamic stretches, 5 min jog, Lunges: 3x6 @ 5 kg each hand, Shoulder Press: 3x6 @ 7kg, Bent-over Rows: 3x6 @ 22.5kg, Biceps Curls: 3x6 @ 6kg Cool-down: Static stretches	Warm-up: Dynamic stretches, 5 min jog, Leg Press: 3x6 @ 50kg Incline Bench Press: 3x6 @ 10kg Seated Cable Rows: 3x6 @ 22.5kg, Tricep Pushdowns: 3x6 @ 9kg Cool-down: Static stretches
3	Warm-up: Dynamic Stretches, 5 min jog, Deadlifts: 3x6 @ 40kg (70% 1RM) Incline Bench Press: 3x6 @ 27.5kg, Pull-ups: 3x max reps Tricep Pushdowns: 3x6 @ 11.5kg, Cool Down: Static stretches	Warm-up: Dynamic stretches, 5 min jog, Squats: 3x6 @ 36kg (65% 1RM), Bench Press: 3x6 @ 27.5kg (65% 1RM) Lat Pulldowns: 3x6 @ 25kg Tricep Dips: 3x6 (bodyweight), Cool-down: Static stretches
4	Warm-up: Dynamic stretches, 5 min jog, Leg Press: 3x6 @ 60kg, Dumbbell Flyes: 3x6 @ 5kg each hand, Seated Cable Rows: 3x6 @ 25kg, Hammer Curls: 3x6 @ 7kg Cool-down: Static stretches	Warm-up: Dynamic Stretches, 5 min jog, Lunges: 3x6 @ 12kg each hand Dumbbell Shoulder Press: 3x6 @ 9kg Bent-over Rows: 3x6 @ 25kg Bicep Curls: 3x6 @ 10kg. Cool-down: Static stretches
5	Repeat Week 1	Repeat Week 2
6	Repeat Week 3	Repeat Week 4
7	Repeat Week 1	Repeat Week 2
8	Repeat Week 3	Repeat Week 4

Table 2

Training Plan for Weighted Ball Training Group

Week	Session 1	Session 2
1	Warm-up: Dynamic stretches. Throw a 6 oz ball 8 times (3 sessions). Recovery time between each session. Cool-down: Static stretches	Warm-up: Dynamic stretches. Throw a 6 oz ball 8 times (3 sessions), Recovery time between each session Cool-down: Static stretches
2	Warm-up: Dynamic stretches. Throw a 6 oz ball 8 times (3 sessions) Recovery time between each session: Cool-down: Static stretches	Warm-up: Dynamic stretches. Throw a 6 oz ball 10 times (3 sessions) Recovery time between each session Cool-down: Static stretches
3	Warm-up: Dynamic stretches. Throw a 6 oz ball 8 times (3 sessions). Recovery time between each session: Cool-down: Static stretches	Warm-up: Dynamic stretches. Throw a 7 oz ball 10 times (3 sessions) Recovery time between each session Cool-down: Static stretches
4	Warm-up: Dynamic stretches. Throw a 6 oz ball 8 times (3 sessions). Recovery time between each session: Cool-down: Static stretches	Warm-up: Dynamic stretches Throw a 7 oz ball 10 times (3 sessions) Recovery time between each session Cool-down: Static stretches
5	Warm-up: Dynamic stretches. Throw a 7 oz ball 10 times (3 sessions) Recovery time between each session Cool-down: Static stretches	Warm-up: Dynamic stretches. Throw a 7 oz ball 10 times (3 sessions) Recovery time between each session Cool-down: Static stretches
6	Warm-up: Dynamic stretches. Throw a 7 oz ball 10 times (3 sessions) Recovery time between each session Cool-down: Static stretches	Warm-up: Dynamic stretches. Throw a 7 oz ball 10 times (3 sessions) Recovery time between each session Cool-down: Static stretches
7	Warm-up: Dynamic stretches. Throw a 7 oz ball 10 times (3 sessions) Recovery time between each session Cool-down: Static stretches	Warm-up: Dynamic stretches. Throw a 9 oz ball 10 times (3 sessions) Recovery time between each session Cool-down: Static stretches
8	Warm-up: Dynamic stretches. Throw a 7 oz ball 10 times (3 sessions) Recovery time between each session Cool-down: Static stretches	Warm-up: Dynamic stretches. Throw a 9 oz ball 10 times (3 sessions) Recovery time between each session Cool-down: Static stretches

Data Analysis and Results

To assess the normality of the data, the Shapiro-Wilk and Kolmogorov-Smirnov tests were conducted for both velocity and accuracy variables. The results showed that the significance values for velocity were 0.876 (Shapiro-Wilk) and 0.200 (Kolmogorov-Smirnov), while for accuracy, the values were 0.487 and

0.200, respectively. Since all p-values are above the 0.05 threshold, it indicates that the data for both variables follow a normal distribution. Therefore, it can be concluded that the data is normally and equally distributed, making it appropriate for further parametric analysis.

Table 3

Mean Comparison of Strength Training on Pitching Velocity and Accuracy

Variables	Pre-training		Post-training		t	p	R	Cohen's d
	M	SD	M	SD				
Velocity	41.50	10.083	43.25	10.046	-3.656	.035	.995	1.102
Accuracy	11.00	2.944	15.75	1.500	-4.608	.019	.755	2.373

Table 3 reveals that the training program significantly improved both velocity and accuracy in pitching performance. Velocity increased from a mean of 41.50 mph to 43.25 mph, with a p-value of .035 and a large effect size (Cohen's d = 1.102), indicating a meaningful change. The strong correlation (r=.995) suggests consistent improvement across participants. Accuracy also showed notable progress, rising from a mean of 11.00 to 15.75, with a p-value of .019 and a very large effect size (Cohen's d = 2.373), reflecting a highly impactful result. The reduced standard deviation in accuracy (from 2.944 to 1.500) suggests more stable performance post-training. Overall, the training intervention was highly effective in enhancing both speed and precision in pitching.

Table 4

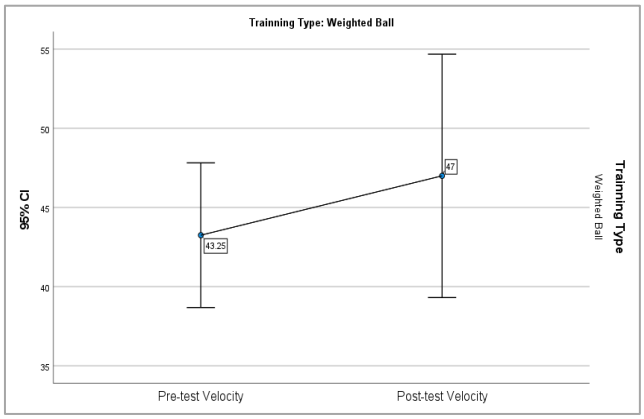
Mean Comparison of Weighted Ball Training on pitching velocity and accuracy

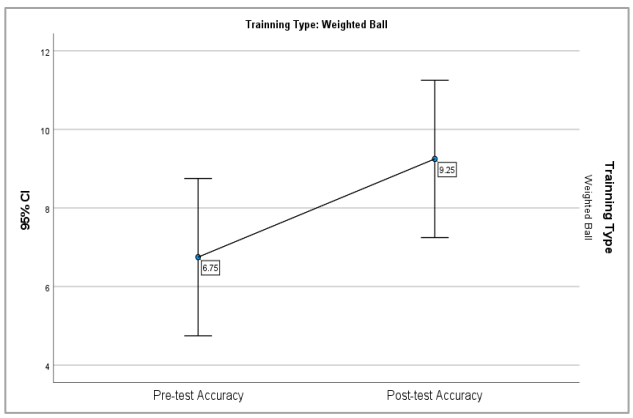
Variables	Pre-training		Post-training		T	p	R	Cohen's d
	M	SD	M	SD				
Velocity	43.25	2.872	47.00	4.830	-3.382	.043	.961	2.553
Accuracy	6.75	1.258	9.25	1.258	-8.660	.003	.895	.665

Table 4 presents the pre- and post-training comparison of velocity and accuracy, revealing significant improvements in both performance aspects. The average velocity increased from 43.25 mph to 47.00 mph after training, with a p-value of .043, indicating statistical significance. The effect size (Cohen's d = 2.553) is extremely large, reflecting a strong impact of the training on speed. The correlation coefficient (r = .961) also shows a very strong positive relationship, meaning participants consistently improved after training. In terms of accuracy, the mean rose from 6.75 to 9.25, with both pre- and post-training standard deviations being the same (1.258), indicating consistent accuracy improvements across participants. The p-value (.003) confirms a highly significant result, and while the effect size is moderate (Cohen's d = .665), it still suggests meaningful progress. The correlation (r=.895) is also strong, reinforcing that most participants showed improvement. Overall, the training program effectively enhanced both the speed and precision of pitching performance.

Figure 1

Comparison of Pre-Test and Post-Test Pitching Velocity and Accuracy of Weighted Ball Training



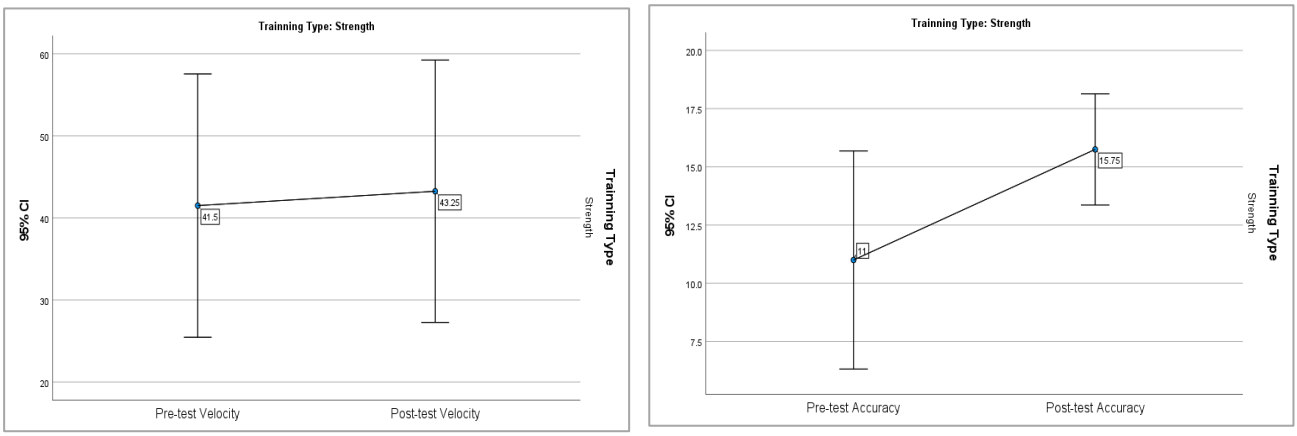


In Figure 1, both graphs highlight noticeable improvements in both pitching speed and accuracy following the weighted ball training. In the first graph, there's a clear boost in average velocity, increasing from 43.25 mph before training to 47 mph after training. The second graph reflects progress in accuracy, with the number of successful strikes rising from 6.75 to 9.25 out of 20 attempts. These outcomes suggest that the weighted ball program had a positive impact on both the power and precision of the athletes' throws.

Both graphs in figure 2 show a clear increase in pitching accuracy by means of various training techniques. Where average accuracy rose from 6.75 to 9.25 out of 20 pitches, the left graph shows the outcomes of weighted ball training. Conversely, the right graph indicates the outcomes of strength training, with accuracy rising more noticeably from roughly 11 to 15.75. These results imply that although both approaches improved accuracy, strength training produced a more noticeable change.

Figure 2

Comparison of Pre-Test and Post-Test Pitching Velocity and Accuracy of Strength Training



Discussion

The results of the study show that strength training and weighted ball training both greatly improve pitch speed and accuracy. The strength of the study is clear with total data for both measures across all eight subjects. The statistical summary shows an average accuracy of 10.6875 with a standard deviation of 3.28348 and an average velocity of 43.7560 with a standard deviation of 7.19126. These variables' normal distribution is confirmed by the Shapiro-Wilk and Kolmogorov-Smirnov tests, hence supporting the application of parametric tests in analysis. From 6.75 (SD = 1.258) to 9.25 (SD = 1.258) and mean velocity from 43.25 (SD = 2.872) to 47.00 (SD = 4.830), training with weighted balls greatly improved accuracy. The notable effect sizes for both velocity (Cohen's d = 2.217) and accuracy (Cohen's d = 0.577) highlight the considerable influence of this training on performance measures. Strength training also demonstrated significant improvements, with mean velocity increasing from 41.50 (SD = 10.083) to 43.25 (SD = 10.046) and mean accuracy rising from 11.00 (SD = 2.944) to 15.75 (SD = 1.500). The considerable effect sizes for both velocity (Cohen's d = 0.957) and accuracy (Cohen's d = 2.062) indicate that strength training enhances both metrics, with a more pronounced effect on accuracy. These findings are consistent with previous research. For instance, Reinold et al. (2018) found that weighted ball training significantly increased pitching velocity by 3.3% ($p < 0.001$) in the experimental group, although its effects on accuracy were inconclusive, similar to the moderate improvements observed here. According to Fredriksen et al. (2024), strength training is absolutely vital to enhance pitching speed and accuracy in line with the results of this study. Their results showed that the kinetic chain is a major factor in good throwing mechanics, thereby stressing the need for muscular strength and endurance, especially in the lower body.

The findings of this study correspond with the work done by Fleisig et al. (2006), which underlined important risk factors for shoulder and elbow injuries in young baseball pitchers by means of throwing biomechanics. Their study underlined the need for correct pitching mechanics and the negative consequences of repetitive action on injury risk. Likewise, the organized training course in this study produced notable improvements in pitching speed and accuracy, hence highlighting the importance of biomechanical changes. This consistency confirms the assumption that training programs focused on biomechanics boost athletic performance and may also lower the incidence of injuries. The similarities

between this study and the results of Fleisig et al. (2006) highlight the need to include biomechanical ideas into training programs for young athletes, therefore improving performance while giving injury avoidance first priority. This paper, following Carter et al.'s (2007) methodological recommendations, acknowledges the need for qualitative research in clarifying the complexity of social events. Including qualitative or mixed-method strategies—such as collecting player input and views on the training program—supports Carter et al.'s focus on knowing research subjects outside of statistical data. Combining qualitative ideas with statistical data enhances the results of the research and offers a more complete view of the experiences of the participants. This approach guarantees the validity of the study and highlights its relevance for academic research as well as practical sports training methods.

Conclusion

This study underlines the particular benefits of Strength Training and Weighted Ball Training for female baseball pitchers. While weighted ball training increased pitch speed, strength training improved accuracy. The results point to customized training strategies for certain performance goals. This short, small-sample study supports more deliberate and evidence-based training for coaches and athletes. Future studies should look at improved pitching development techniques, longer programs, bigger participant groups, and biomechanical studies. Future studies should use a bigger, more varied athlete sample, including people from all walks of life, age groups, and ability levels. Extending the training period beyond eight weeks would clarify the long-term effects of Strength Training and Weighted Ball Training, including plateaus and injury issues. Using mental conditioning strategies, assessing confidence, and looking at motivation throughout training helps to control psychological elements. A biomechanical study of pitching mechanics might clarify how different training strategies affect performance. Comparison studies between male and female athletes would help to highlight these results. Future research should either increase sample sizes or compensate for baseline pitching skill, strength, and technique to account for individual variances. Hybrid training techniques combining Strength and Weighted Ball Training might increase pitch speed and accuracy. These recommendations aim to improve the dependability and usefulness of research on baseball pitching performance.

Though several restrictions have to be acknowledged while reading the data, this study offers significant value. The small sample size makes generalizations difficult. More consistent and relevant results, as well as a larger participant base, would help future studies. Either training method may not have been fully evaluated by the eight-week study. The Weighted Ball Training group needs this due to the progressive changes in speed and precision. Extending training will improve our understanding of the long-term effects of both approaches. This study also ignores psychological factors as confidence and anxiety, which could affect pitching ability. Pitching is intellectually and physically demanding; thus, future studies should include psychological evaluations. This will show how mental conditioning and physical training affect pitching results.

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