



# Effectiveness of Mental Training Program on Pitching Accuracy and Speed of Young Baseball Athletes

Gano Sumarno\*, Yusuf Hidayat, Dian Budiana, Dede Rohmat Nurjaya

Universitas Pendidikan Indonesia, Indonesia

\*Correspondence: E-mail: ganosumarno@upi.edu

## ABSTRACT

Research on the determinants of pitching performance in young baseball athletes has largely focused on anthropometric, biomechanical, and pitch-count factors, while psychological factors remain under-explored. Although increased pitch counts are associated with higher pitching velocity, they also elevate the risk of shoulder and elbow injuries. This study aimed to examine the effect of a mental training program on pitching accuracy and velocity of baseball athletes aged 12–15 years. A pre-experimental one-group pretest-posttest design was employed with 10 pitchers selected via total sampling. The intervention consisted of a 16-session mental training program conducted over four weeks, covering relaxation, goal setting, self-talk, imagery, and pre-performance routines. Data were analyzed using the Wilcoxon signed-rank test, Hedges'  $g$ , bootstrap confidence intervals, and the minimal detectable change (MDC95). Results showed significant improvements in accuracy and velocity. All athletes demonstrated improvement, with seven exceeding the MDC95 threshold. No velocity-accuracy trade-off was observed. These findings support mental training as a strategy to enhance pitching performance without increasing pitching load, although the findings require confirmation in controlled studies.

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## INTRODUCTION

Pitching is the most complex and demanding form of throwing in baseball. The movement engages the entire body and relies on an efficient kinetic chain to transfer energy from the lower extremities and torso to the upper extremities. A pitcher's quality is conventionally assessed via two indicators that are interrelated yet mechanically and cognitively distinct: pitch velocity and pitch placement accuracy. Velocity reflects the capacity for force production and transfer, whereas accuracy reflects fine motor control, release point consistency, and attentional regulation. In young athletes, both indicators are still in an active developmental phase, making them responsive to training interventions.

However, research on the determinants of pitching performance in young age groups has thus far focused almost exclusively on physical variables. Shitara et al. (2026) conducted a cross-sectional study of 348 baseball players aged 9–12 years and found that high pitch velocity was independently associated with pitching experience (OR = 3.45), a pitching load of  $\geq 100$  pitches per week (OR = 5.16), and dominant-hand grip strength (OR = 1.17). Conversely, regarding accuracy, only the duration of baseball playing experience emerged as a significant factor (OR = 1.23). These findings align with previous research linking pitch velocity to age, height, body weight, and muscle strength (Nakata et al., 2013; Sgroi et al., 2015; Werner et al., 2008), as well as to variations in pitching mechanics (Stodden et al., 2005).

This pattern of findings raises a serious practical issue. Although a high weekly pitch count is the strongest predictor of increased pitch velocity, it has also been proven to be a major risk factor for shoulder and elbow injuries in young pitchers. Lyman et al. (2001) and Fleisig et al. (2011) prospectively demonstrated that the accumulation of throwing loads increases the risk of pain and serious upper-extremity injury, while Olsen et al. (2006) identified excessive throwing volume as a risk factor for overuse injuries. Dowling et al. (2020) further asserted that load monitoring based solely on in-game throws tends to underestimate the true cumulative load. In other words, the most empirically documented pathway for performance enhancement is precisely the one that poses the greatest medical risk to young athletes. Consequently, there is a need for an alternative approach that can enhance performance without increasing mechanical stress on the shoulder and elbow joints.

A notably underexplored dimension concerns psychological determinant. This empirical void has been recognized by researchers in the discipline; for instance, Shitara et al. (2026) explicitly reported the failure to assess psychological attributes, including attentional focus, competitive anxiety, and cognitive decision-making, as a primary limitation of their investigation. This situation highlights a clear empirical gap: research on pitching performance among young baseball athletes remains dominated by the study of physical factors, whereas the contribution of psychological factors as performance determinants has received little exploration.

In fact, meta-analytic evidence regarding the effectiveness of psychological interventions in sports is quite robust. Brown and Fletcher (2017) synthesized 35 randomized controlled trials and found moderate positive effects of psychological and psychosocial interventions on sports performance, with effects persisting for at least one month after the intervention ended. Reinebo et al. (2024) reported significant moderate effects for psychological skills training, mindfulness- and acceptance-based approaches, and imagery. The theoretical foundations for the four mental training components used in this study are also well-established. Lang's (1979) bio-informational theory explains that imagery containing both

stimulus and response propositions activates neural patterns resembling actual movement execution. The PETTLEP model by Holmes and Collins (2001) translates this functional equivalence principle into seven operational dimensions that make imagery more closely resemble the real-world context. Locke and Latham's (2002) goal-setting theory explains the mechanisms of directing attention, mobilizing effort, and fostering persistence through specific and challenging goals. Meanwhile, Bandura's (1997) self-efficacy theory explains how belief in one's own capabilities mediates task choice, perseverance, and resilience in the face of failure. There are also specific theoretical reasons why pitching accuracy should be the target of the psychological intervention yielding the highest returns. A moderator analysis by Hatzigeorgiadis et al. (2011) demonstrated that self-talk interventions are more effective for tasks requiring fine motor control than for gross motor tasks, and more effective for relatively novel tasks than for highly practiced ones. Pitching accuracy in youth athletes fulfils both criteria because it represents a fine motor task characterized by closed and self-paced execution. Furthermore, this action incorporates a pre-performance pause that facilitates cognitive routines and has not yet reached complete automaticity. Yet, it is precisely at this most promising theoretical juncture that empirical evidence is scarcest.

This empirical gap is further compounded by two factors. First, research on psychological interventions in baseball remains heavily skewed toward batting performance, while pitching, particularly with respect to accuracy, is seldom evaluated as an outcome measure. Second, research on psychological interventions for youth baseball athletes in Indonesia is extremely limited; this is significant because differences in development systems, competition intensity, and cultural contexts compared to the United States and Japan could influence intervention effectiveness. Next, the final gap is methodological. The speed-accuracy trade-off principle formulated by Fitts (1954) predicts that increasing movement speed generally comes at the expense of precision, and vice versa. In the context of pitching, the relationship between the two remains inconclusive: Manzi et al. (2022) found no difference in ball speed between high- and low-accuracy professional pitchers, whereas Shitara et al. (2026) actually found higher accuracy in the high-speed group. Theoretically, mental training operates by optimizing the regulation of attention and arousal rather than by increasing physical capacity. Consequently, such interventions have the potential to simultaneously improve pitching accuracy and speed without triggering a trade-off between these performance indicators. Measuring speed and accuracy concurrently within a single intervention design, therefore, serves not merely to provide comprehensive data but to test this hypothesis. This combination has never been tested on a youth baseball population.

This study aims to examine the effect of a mental training program on the pitching accuracy and speed of young baseball athletes. Specifically, the study addresses three questions: (1) whether there is a difference in pitching accuracy before and after the mental training program; (2) whether there is a difference in pitching speed before and after the program; and (3) whether the patterns of change in both variables indicate a speed-accuracy trade-off. The research hypothesis posits that the mental training program improves both indicators, with a greater proportional improvement in accuracy, given its nature as a fine motor task that is more responsive to cognitive regulation.

## **METHODS**

### **Research Design**

This study employs a quantitative approach using a pre-experimental one-group pretest–posttest design (Campbell & Stanley, 1963). All participants received the same treatment

without a comparison group, and measurements were taken at two time points: before (pretest) and after (posttest) the implementation of the mental training program.

The selection of this design was based on practical and ethical considerations: the limited number of active pitchers available at the club meant that dividing them into two groups would result in inadequate cell sizes and raise fairness issues, as half the athletes would be denied a potentially beneficial intervention for an entire training season. The authors acknowledge that the absence of a control group precludes definitive causal inferences because potential threats to internal validity, including biological maturation, testing effects, the Hawthorne effect, and regression toward the mean, cannot be entirely eliminated. These implications are explicitly discussed in the limitations section, and all interpretations of the results are framed as preliminary indications rather than causal evidence.

### Participants

The sample comprised 10 youth pitchers from Flash Bandung, recruited via a total sampling technique where all athletes meeting the inclusion criteria were enrolled. The participants' ages ranged from 12 to 15 years, with an average of 4–5 years of baseball training experience. Inclusion criteria were: (1) registered as an active athlete training at least four times a week; (2) playing the pitcher position or regularly performing pitching duties during practice and matches; (3) free from upper or lower extremity injuries that would limit throwing activity; and (4) having obtained written permission from a parent or guardian. Exclusion criteria included missing more than 2% of the intervention sessions or missing any of the measurement sessions.

### Ethical Considerations

The research procedures received ethical approval from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Muhammadiyah Surakarta (No. 6180/B.1/KEPK-FKUMS/II/2026). Information regarding the study's objectives, procedures, benefits, and risks was provided to the athletes, parents/guardians, and coaches prior to implementation. Written informed consent was obtained from the parents or guardians of all participants, accompanied by verbal assent from the athletes. Participants retained the right to withdraw at any time without consequence to their status within the club. Participant identities were anonymized in all reporting of results.

### Measurement Instruments and Procedures

**Pitching accuracy.** Accuracy was measured using a zoned target system positioned 18 meters from the pitching point. Each athlete performed 20 pitches, with instructions to place the ball as precisely as possible within the target zones. Scoring was based on a zone-weighting system, and raw scores were converted to a 0–100 scale. It should be noted that all observed accuracy scores were multiples of five, indicating a measurement resolution of five points per unit of change. The implications for the analysis of responses are discussed in the Results section.

**Pitching velocity.** Ball velocity was measured using a Bushnell 101911 radar gun positioned behind the catcher. Each athlete performed 20 full-effort pitches, and the highest value among all pitches was used for analysis. Velocity is reported in its original unit of kilometers per hour without transformation, thereby enabling direct comparison with normative values established in the youth baseball literature.

**Treatment of the two outcomes.** Accuracy is expressed on a 0–100 scale, whereas velocity is expressed in kilometers per hour. Because these metrics utilize incompatible units, a direct

weighted sum of the raw values is metrically invalid and was not employed in this study. Consequently, accuracy and velocity were analyzed and reported as two distinct primary outcomes.

A standardized composite was constructed as a supplementary indicator summarizing overall performance. Accuracy and velocity scores were individually standardized into T-scores ( $M = 50$ ,  $SD = 10$ ) using the baseline distribution as the reference, after which they were averaged with equal weighting. This procedure normalized the scales of both variables prior to combination, ensuring that the contribution of each variable was not determined by differences in measurement units. This composite is reported as a secondary outcome and does not replace the analysis of the two primary outcomes. Both measurements were conducted by two trained assessors using identical procedures for the pre-test and post-test, under comparable conditions regarding timing, location, and field state. Prior to measurement, all athletes completed a standardized 10-minute warm-up.

### **Intervention Program**

The mental training program was conducted over 16 sessions spanning four weeks, with a frequency of four sessions per week and a duration of 20–25 minutes per session. The program was designed based on the logic of "cumulative layering," wherein each new component was introduced only after the previous one had been mastered, and previously introduced components continued to be practiced in subsequent sessions. The program structure comprised five stages: Stage 1 – Relaxation. Introduction to diaphragmatic breathing and progressive muscle relaxation, simplified to suit the cognitive capacity of young athletes. The objective was to establish basic arousal regulation skills as a foundation for subsequent components. Stage 2 – Goal Setting. Formulation of process and performance goals that were specific, measurable, and challenging yet realistic, based on the principles of Locke and Latham (2002). Athletes set weekly targets that were reviewed in consultation with the coach. Stage 3 – Self-talk. Development of instructional self-talk focused on key technical cues (e.g., release point and gaze direction) and motivational self-talk to maintain persistence following an off-target throw. Stage 4 – Imagery. Imagery exercises were structured across the seven PETTLEP dimensions (Holmes & Collins, 2001), including physical, environmental, task, timing, learning, emotional, and perspective elements, while emphasizing response propositions in accordance with Lang (1979). Stage 5 – Integrated Pre-performance Routine. The four components were combined into a concise routine performed by the athlete before every throw, thereby transitioning the psychological skills from isolated training sessions into the actual pitching context. The program was administered by qualified personnel and ran concurrently with the club's regular technical and physical training programs, which remained unmodified throughout the study period. Athlete attendance was recorded for every session, resulting in an average attendance rate of 97%.

### **Data Analysis**

Data were analyzed using both descriptive statistics (mean, standard deviation, median, minimum and maximum values) and inferential statistics. The normality of the score difference distribution was tested using the Shapiro-Wilk test. Given the small sample size ( $n = 10$ ) and the observed deviation from normality in the accuracy score differences ( $W = 0.833$ ;  $p = 0.036$ ), the Wilcoxon signed-rank test was employed as the primary analysis for all variables to ensure analytical consistency. A paired t-test was reported as a sensitivity analysis to verify that conclusions did not depend on the choice of statistical procedure.

Effect sizes were reported using Hedges'  $g$  for paired data, calculated as Cohen's  $d_z$  corrected for small-sample bias, alongside 95% confidence intervals derived from a bootstrapping procedure with 10,000 resamples (Lakens, 2013). Rank-biserial correlation was reported as the effect size accompanying the Wilcoxon test. Effect size interpretation followed Cohen's (1988) conventions.

Since statistical significance at the group level does not guarantee meaningful change at the individual level, an analysis of individual responders was also conducted. The standard error of measurement (SEM) was estimated from the baseline test's standard deviation and the correlation between measurements; subsequently, the minimal detectable change at a 95% confidence level was calculated as  $MDC_{95} = 1.96 \times \sqrt{2} \times SEM$ . Athletes whose improvement exceeded the  $MDC_{95}$  were classified as responders. It should be noted that this estimate is an approximation because a separate test-retest reliability assessment was not performed; consequently, the correlation between measurements incorporates the effect of the intervention, and the implications of this are discussed in the limitations section.

As an additional analysis, Spearman's correlation between baseline and post-test rankings was calculated to assess the stability of performance order among athletes, and Pearson's correlation between baseline scores and the magnitude of improvement was calculated to examine the potential for regression to the mean. All tests were two-tailed with a significance level of 0.05. The analysis was performed using Python 3 (SciPy and pandas software packages).

## RESULTS

All 10 athletes completed the intervention program and participated in both measurement sessions, with no missing data. Individual data from the pre-test and post-test are presented in Table 1.

**Table 1.** Pre-Test and Post-Test Scores for Pitching Accuracy, Speed, and Composite T-Score (N = 10)

| Athlete   | Accuracy (0-100) |              |              | Speed (km/h) |              |              | Composite t-score |              |               |
|-----------|------------------|--------------|--------------|--------------|--------------|--------------|-------------------|--------------|---------------|
|           | Pre              | Post         | $\Delta$     | Pre          | Post         | $\Delta$     | Pre               | Post         | $\Delta$      |
| A1        | 75               | 80           | +5           | 89           | 92           | +3           | 64.6              | 70.8         | +6.2          |
| A2        | 60               | 70           | +10          | 81           | 85           | +4           | 46.8              | 57.5         | +10.7         |
| A3        | 65               | 70           | +5           | 77           | 81           | +4           | 47.0              | 54.1         | +7.1          |
| A4        | 65               | 75           | +10          | 90           | 95           | +5           | 58.1              | 69.7         | +11.6         |
| A5        | 60               | 65           | +5           | 80           | 83           | +3           | 46.0              | 52.2         | +6.2          |
| A6        | 65               | 75           | +10          | 76           | 84           | +8           | 46.2              | 60.3         | +14.1         |
| A7        | 70               | 80           | +10          | 80           | 85           | +5           | 53.3              | 64.8         | +11.6         |
| A8        | 70               | 85           | +15          | 87           | 90           | +3           | 59.2              | 72.7         | +13.5         |
| A9        | 65               | 75           | +10          | 75           | 82           | +7           | 45.3              | 58.6         | +13.3         |
| A10       | 50               | 65           | +15          | 74           | 80           | +6           | 33.5              | 49.6         | +16.1         |
| <b>M</b>  | <b>64.50</b>     | <b>74.00</b> | <b>+9.50</b> | <b>80.90</b> | <b>85.70</b> | <b>+4.80</b> | <b>50.00</b>      | <b>61.03</b> | <b>+11.03</b> |
| <b>SD</b> | <b>6.85</b>      | <b>6.58</b>  | <b>3.69</b>  | <b>5.86</b>  | <b>4.99</b>  | <b>1.75</b>  | <b>8.93</b>       | <b>8.15</b>  | <b>3.48</b>   |

Note:  $\Delta$  = difference between post-test and pre-test scores. Accuracy is expressed on a scale of 0–100; speed is in km/h. The composite T-score is the equally weighted average of the accuracy and speed T-scores, using the pre-test distribution as the reference distribution ( $M = 50$ ;  $SD = 10$ ).

Shapiro-Wilk test results indicated that the difference in accuracy scores deviated from a normal distribution ( $W = 0.833$ ;  $p = 0.036$ ), whereas the differences in speed ( $W = 0.902$ ;  $p = 0.232$ ) and the composite T-score ( $W = 0.897$ ;  $p = 0.276$ ) did not show significant deviation. In accordance with the analysis plan, the Wilcoxon signed-rank test was used as the primary analysis for all variables. A summary of descriptive and inferential statistics is presented in Table 2.

**Table 2.** Comparison of Pitching Scores Between the Initial and Final Tests

| Variable          | Pre-test<br>M (SD) | Post-test<br>M (SD) | Difference<br>M (SD) | CI 95%<br>difference | Z; p         | Hedges' g [95% CI] |
|-------------------|--------------------|---------------------|----------------------|----------------------|--------------|--------------------|
| Accuracy (0-100)  | 64.50<br>(6.85)    | 74.00<br>(6.58)     | 9.50 (3.69)          | [6.86; 12.14]        | -2.80; 0.002 | 2.35 [1.79; 4.35]  |
| Speed (km/h)      | 80.90<br>(5.86)    | 85.70<br>(4.99)     | 4.80 (1.75)          | [3.55; 6.05]         | -2.80; 0.002 | 2.51 [2.05; 4.28]  |
| Composite t-score | 50.00<br>(8.93)    | 61.03<br>(8.15)     | 11.03 (3.48)         | [8.54; 13.52]        | -2.80; 0.002 | 2.90 [2.24; 5.64]  |

Note: Z and p values were obtained from the Wilcoxon signed-rank test (exact p). CI = confidence interval; Hedges' g confidence intervals were obtained via bootstrapping with 10,000 resamples. Rank-biserial correlation = 1.00 for all three variables. The T-score composite is a secondary outcome.

Pitching accuracy improved from  $64.50 \pm 6.85$  in the initial test to  $74.00 \pm 6.58$  in the final test. The mean difference of 9.50 points (SD = 3.69; 95% CI [6.86; 12.14]) represents a proportional increase of 14.73% and is statistically significant ( $Z = -2.80$ ;  $p = 0.002$ ; rank-biserial  $r = 1.00$ ), with a very large effect size ( $g = 2.35$ ; 95% CI [1.79; 4.35]). A sensitivity analysis using a paired t-test yielded the same conclusion:  $t(9) = 8.14$ ;  $p < 0.001$ . Pitching velocity increased from  $80.90 \pm 5.86$  km/h to  $85.70 \pm 4.99$  km/h, with a mean difference of 4.80 km/h (SD = 1.75; 95% CI [3.55; 6.05]) or a proportional increase of 5.93%. Expressed in units commonly used in English-language literature, this increase is equivalent to approximately 2.98 mph. Individual improvements ranged from 3 to 8 km/h. This change is statistically significant ( $Z = -2.80$ ;  $p = 0.002$ ) with a very large effect size ( $g = 2.51$ ; 95% CI [2.05; 4.28]); the sensitivity analysis yielded  $t(9) = 8.67$ ;  $p < 0.001$ . The composite T-score, as a secondary outcome, increased from  $50.00 \pm 8.93$  to  $61.03 \pm 8.15$ , with a mean difference of 11.03 T-score points (SD = 3.48; 95% CI [8.54; 13.52]); this was statistically significant ( $Z = -2.80$ ;  $p = 0.002$ ;  $g = 2.90$ ; 95% CI [2.24; 5.64]), and sensitivity analysis yielded  $t(9) = 10.02$ ;  $p < 0.001$ . Of note for interpretation, the improvement occurred in all athletes without exception: all 10 athletes showed score increases in both accuracy and speed, with no instances of decline or stagnation. This pattern of individual change is presented in Figure 1.

Since speed is reported in its original units, participants' performance levels can be positioned against available norms. Shitara et al. (2026) reported a median speed of 72.0 km/h among 348 players aged 9–12 years, with a mean of 79.0 km/h for the high-speed group and 65.1 km/h for the low-speed group. All participants in the current study were already above that cohort's median at baseline, and 6 out of 10 had surpassed the high-speed group mean; following the program, all participants exceeded that mean. This comparison provides only a general indication and cannot be interpreted as a direct equivalence due to differences in measurement protocols. Shitara et al. conducted measurements at a throwing distance of 16 meters, using instructions that emphasized control over maximal speed. Furthermore,

potential differences in the participants' age ranges also limit the comparability of results between the two studies.

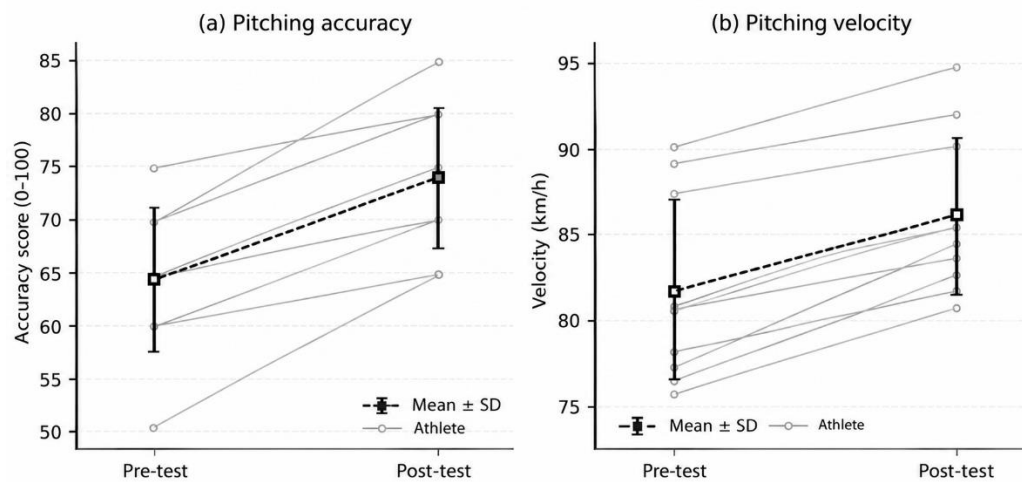


**Figure 1.** Individual Changes in Pitching Accuracy (A) and Velocity (B) Scores from The Initial to The Final Test

Note: Gray lines indicate the trajectory of each athlete; black lines indicate the group mean with standard deviation. The dash-dot line in panel (b) marks the median velocity of the cohort from Shitara et al. (2026) as a reference for comparison.

An analysis of individual responders is presented in Table 3. Using the MDC95 threshold, 7 out of 10 athletes (70%) demonstrated improvements exceeding the minimal detectable change threshold in both accuracy and speed, while 8 out of 10 (80%) did so for the composite T-score. Athletes who did not exceed the threshold still showed a positive direction of change, but the magnitude fell within a range that could not be conclusively distinguished from measurement error. It should be noted that the five-point resolution of the accuracy measurement meant the MDC95 threshold of 7.36 fell between one and two scale units; consequently, athletes who improved by exactly one scale unit were automatically classified as non-responders. The classification for the accuracy variable is therefore conservative. The distribution of individual improvements relative to the MDC95 threshold is visualized in Figure 2.

**Table 3.** Analysis of Individual Respondents Based on Minimal Detectable Change

| Variable          | SD pre | r pre-post | SEM  | MDC95 | Respondent |
|-------------------|--------|------------|------|-------|------------|
| Accuracy (0–100)  | 6.85   | 0.850      | 2.65 | 7.36  | 7/10 (70%) |
| Speed (km/h)      | 5.86   | 0.960      | 1.17 | 3.23  | 7/10 (70%) |
| Composite t-score | 8.93   | 0.921      | 2.51 | 6.96  | 8/10 (80%) |

Note: SEM = SD of pre-test  $\times \sqrt{1 - r}$ ; MDC95 =  $1.96 \times \sqrt{2} \times \text{SEM}$ . The value of  $r$  represents the correlation between pre-test and post-test scores; thus, the SEM estimate is approximate (see the Limitations section).

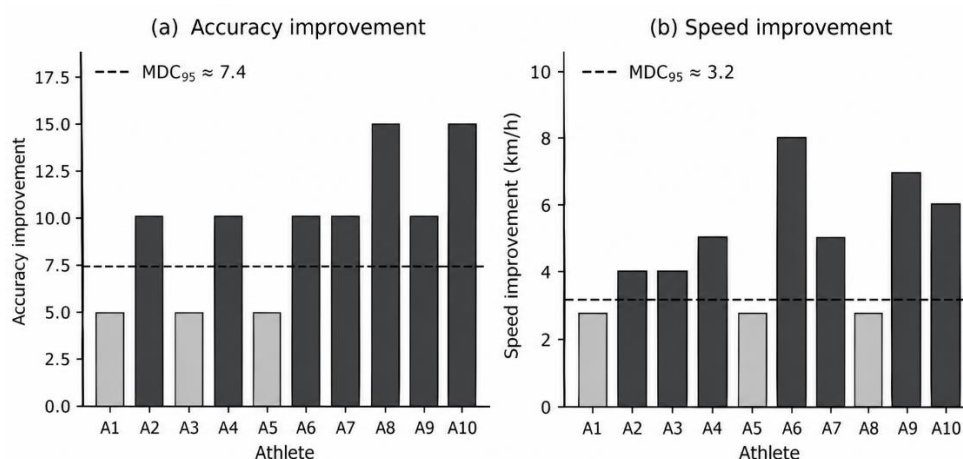


**Figure 2.** Magnitude of Individual Improvements in Accuracy (A) and Speed (B) Relative to The MDC95 Threshold

Rank-order analysis revealed that the performance ranking among athletes remained relatively stable from the initial to the final test, with Spearman correlations of 0.926 for accuracy and 0.924 for speed (both  $p < 0.001$ ). This indicates that the program did not alter the hierarchy of ability within the group but rather shifted the entire group to a higher level. The correlation between initial test scores and the magnitude of improvement was negative but non-significant for accuracy ( $r = -0.341$ ;  $p = 0.335$ ) and approached significance for speed ( $r = -0.609$ ;  $p = 0.062$ ), suggesting a tendency for athletes with lower initial scores to achieve greater improvements.

A comparison of variables showed that the proportional improvement in accuracy (14.73%) was more than double the proportional improvement in speed (5.93%). No athlete exhibited an increase in speed accompanied by a decrease in accuracy, or vice versa; thus, there was no indication of a speed–accuracy trade-off in the data.

## DISCUSSION

This study examined the effect of an integrated mental training program on the pitching accuracy and velocity of young baseball athletes. Three key findings emerged. First, both performance indicators improved significantly following the program. Second, the proportional improvement in accuracy was more than double the improvement in velocity. Third, improvements occurred across all athletes without any indication of a speed–accuracy trade-off.

### Accuracy Improvement as the Key Finding

The 14.73% improvement in accuracy was the finding most consistent with theoretical predictions. Moderator analysis by Hatzigeorgiadis et al. (2011) indicates that self-talk interventions are more effective for fine motor tasks and tasks that have not yet been automated. Pitching accuracy in young athletes meets both of these conditions. Unlike velocity, which is largely governed by force-production capacity, accuracy depends on release-point consistency, postural stability, and the ability to maintain attentional focus on cues directly targeted by instructional self-talk and PETTLEP-based imagery.

The most likely mechanism explaining this finding is the narrowing of attentional focus. The pre-performance routine practiced during the program's fifth stage directed athletes toward specific technical cues immediately before the pitch, thereby reducing room for

distracting thoughts. This explanation aligns with Lang's (1979) bio-informational theory, which posits that imagery activates response propositions that mirror actual motor execution, as well as the functional equivalence framework developed by Holmes and Collins (2001). However, as this study did not include psychological measurements as a manipulation check, the proposed mechanism remains inferential and has not been directly proven.

These findings provide an alternative perspective to Shitara et al. (2026), who demonstrated that pitching accuracy was exclusively predicted by the duration of playing experience, whereas anthropometric characteristics, joint range of motion, and muscular strength exhibited no predictive value. These findings are often interpreted as an indication that accuracy depends on an accumulation of experience that cannot be accelerated. However, data from this study suggest a plausible alternative interpretation: what accumulates with experience may not be solely mechanical proficiency, but also cognitive regulation skills that, unlike experiential tenure itself, can be systematically trained within a relatively short timeframe.

### **Speed Increases and the Issue of Magnitude**

The speed increase of 4.80 km/h was statistically significant, yet its proportional magnitude (5.93%) was far smaller than that observed for accuracy. This relative pattern makes theoretical sense. Throwing velocity is fundamentally constrained by morphological and physiological determinants that remain unchanged across short-term psychological interventions, including muscle mass, biological maturity, anthropometric segment lengths, and handgrip strength (Nakata et al., 2013; Sgroi et al., 2015; Shitara et al., 2026; Werner et al., 2008). Mental training does not augment raw muscular strength.

Precisely for this reason, the absolute magnitude of the increase warrants specific discussion and cannot be taken at face value. An increase of 4.80 km/h corresponds to approximately 2.98 mph, a magnitude that typically aligns with gains reported in the literature following months of structured physical conditioning rather than psychological interventions conducted over only a few weeks. Three possible explanations merit equal consideration.

First, this increase may indeed reflect a genuine effect driven by non-physical mechanisms. Relaxation components can reduce unnecessary antagonist muscle co-contraction, thereby making energy transfer through the kinetic chain more efficient without altering force-production capacity; meanwhile, improved arousal regulation allows athletes to throw closer to their actual capacity more consistently. Within this framework, mental training does not enhance maximum capacity but rather narrows the gap between capacity and actual performance. This interpretation aligns with the findings of Stodden et al. (2005) regarding the role of mechanical variations in throwing velocity, although this study did not conduct a biomechanical analysis, so the hypothesis could not be verified.

Secondly, and equally plausibly, a portion of the observed improvement may have arisen from confounding factors unrelated to the experimental intervention. Biological growth and maturation occur rapidly during this age range, and throwing velocity is known to correlate strongly with age, height, and body weight. Regular club-based technical and physical training conducted concurrently during the study period also contributed to this trend. Thirdly, some of the improvement could result from familiarity with the measurement procedure itself: repeating the throwing task using the same protocol can lead to an increase.

### **Absence of a Speed-Accuracy Trade-off**

Fitts's Law (1954) predicts that increasing movement speed generally comes at the cost of precision. In the data from this study, however, both indicators improved simultaneously

across all athletes. This finding is significant because it demonstrates that the pathway to improvement via psychological intervention differs qualitatively from the pathway involving maximal physical effort. When a pitcher attempts to throw harder by exerting more force, a trade-off typically emerges. Conversely, when improvements stem from movement efficiency and the quality of attentional regulation, both indicators can move in the same direction.

These findings also provide context for existing disagreements in the literature. Manzi et al. (2022) found no difference in velocity between high- and low-accuracy professional pitchers, whereas Shitara et al. (2026) observed higher accuracy in the high-velocity group. Both studies were cross-sectional and thus described inter-individual relationships. In contrast, the present study examined changes within the same individuals, demonstrating that at the intra-individual level, both metrics can improve concurrently. This distinction in the level of analysis must be considered when comparing results across studies.

### **Implications for Youth Athlete Coaching**

The most critical practical implication of this study concerns athlete safety. Shitara et al. (2026) found that a workload of  $\geq 100$  pitches per week was associated with a 5.16 times greater likelihood of falling into the high-velocity group. However, that same pitching volume is a prospectively documented risk factor for shoulder and elbow injuries (Fleisig et al., 2011; Lyman et al., 2001; Olsen et al., 2006). Coaches of youth athletes thus face a dilemma: the empirically most proven path to performance improvement is also the most medically hazardous one.

Mental training offers a solution to this dilemma, as it does not add a single pitch to the athlete's cumulative workload. The program in this study was implemented alongside regular training without increasing throwing volume, yet it still yielded improvements in both performance indicators. This characteristic is highly valuable for youth development, where protecting developing upper extremities is a top priority. The practical recommendation is to incorporate mental training as a routine component of the development program, rather than treating it as an optional add-on leading up to competitions. The observation that the largest gains tended to occur among athletes with lower baseline values, although not reaching statistical significance, suggests that mental training may offer substantial utility for players who have yet to attain technical mastery. However, this trend must be interpreted with caution, as a similar pattern is also characteristic of regression to the mean, as discussed in the following section.

### **Limitations**

This study has several limitations that should be considered when interpreting the findings. The absence of a control group prevents causal conclusions, as improvements may have been influenced by biological maturation, regular technical training, testing effects, regression to the mean, or other uncontrolled factors. The large observed effects should therefore be interpreted cautiously because non-randomized, single-group designs are known to overestimate intervention effects. In addition, the small sample from a single club limits statistical precision and the generalizability of the findings, while the absence of follow-up assessments prevents evaluation of whether the observed improvements were sustained over time. The lack of an independent test-retest reliability assessment, assessor blinding, and manipulation checks for psychological variables further limits confidence in the measurement precision and the proposed mechanisms underlying the intervention. Finally, some outcome measures were based on study-specific reference values, limiting direct comparisons with other populations. Consequently, the findings should be considered

preliminary and require confirmation through larger randomized controlled trials with longitudinal follow-up trials and more comprehensive psychological assessment.

### **Directions for Future Research**

A primary priority for future research is replication using a randomized controlled design with an attention-matched control group, allowing the specific effects of mental training to be disentangled from the effects of attention and maturation. When sample sizes are constrained, a viable alternative involves a single-case experimental design utilizing repeated assessments across study phases, particularly a multiple-baseline design across participants, which permits causal inferences through the temporal replication of effects without necessitating an untreated control group (Kratochwill et al., 2013). Furthermore, future studies should incorporate psychological measures as a manipulation check, follow-up assessments to evaluate the retention of effects, and biomechanical analyses to determine whether increased speed is indeed accompanied by changes in kinetic chain efficiency, as hypothesized. Research across a broader range of ages and skill levels is also necessary to identify the developmental stage at which this intervention is most effective.

### **CONCLUSION**

An integrated mental training program, incorporating relaxation, goal setting, self-talk, and imagery within a pre-performance routine, was associated with significant improvements in both the pitching accuracy and velocity of youth baseball athletes. The proportional gain in accuracy was more than double the gain in velocity, aligning with theoretical predictions that fine motor tasks are more responsive to psychological interventions than tasks relying on force-production capacity. All athletes showed improvement in both metrics, with no evidence of a speed-accuracy trade-off.

The study makes both substantive and practical contributions. Substantively, it addresses a gap in the literature on youth pitching performance, historically dominated by physical and biomechanical determinants, by demonstrating that the psychological dimension warrants further investigation. Practically, mental training offers performance enhancement without increasing throwing load.

However, the pre-experimental design (lacking a control group) necessitates caution when interpreting the results, particularly regarding velocity, a variable highly sensitive to maturation and concurrent physical training. These findings are best viewed as preliminary evidence justifying further testing via controlled designs, rather than as definitive proof of the intervention's causal effectiveness.

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### **AUTHORS' NOTE**

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

## REFERENCES

- Bandura, A. (1997). Self-efficacy: The exercise of control. W. H. Freeman.
- Brown, D. J., & Fletcher, D. (2017). Effects of psychological and psychosocial interventions on sport performance: A meta-analysis. *Sports Medicine*, 47(1), 77-99.
- Campbell, D. T., & Stanley, J. C. (2015). *Experimental and quasi-experimental designs for research*. Ravenio books.
- Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. routledge.
- Dowling, B., McNally, M. P., Chaudhari, A. M., & Oñate, J. A. (2020). A review of workload-monitoring considerations for baseball pitchers. *Journal of athletic training*, 55(9), 911-917.
- Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of experimental psychology*, 47(6), 381.
- Fleisig, G. S., Andrews, J. R., Cutter, G. R., Weber, A., Loftice, J., McMichael, C., ... & Lyman, S. (2011). Risk of serious injury for young baseball pitchers: a 10-year prospective study. *The American journal of sports medicine*, 39(2), 253-257.
- Hatzigeorgiadis, A., Zourbanos, N., Galanis, E., & Theodorakis, Y. (2011). Self-talk and sports performance: A meta-analysis. *Perspectives on Psychological Science*, 6(4), 348-356.
- Holmes, P. S., & Collins, D. J. (2001). The PETTLEP approach to motor imagery: A functional equivalence model for sport psychologists. *Journal of applied sport psychology*, 13(1), 60-83.
- Kratochwill, T. R., Hitchcock, J. H., Horner, R. H., Levin, J. R., Odom, S. L., Rindskopf, D. M., & Shadish, W. R. (2013). Single-case intervention research design standards. *Remedial and Special Education*, 34(1), 26-38.
- Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Frontiers in psychology*, 4, 863.
- Lang, P. J. (1979). A bio-informational theory of emotional imagery. *Psychophysiology*, 16(6), 495-512.
- Locke, E. A., & Latham, G. P. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American psychologist*, 57(9), 705.
- Lyman, S., Fleisig, G. S., Waterbor, J. W., Funkhouser, E. M., Pulley, L., Andrews, J. R., Osinski, E. D., & Roseman, J. M. (2001). Longitudinal study of elbow and shoulder pain in youth baseball pitchers. *Medicine & Science in Sports & Exercise*, 33(11), 1803-1810.
- Manzi, J. E., Dowling, B., Wang, Z., Luzzi, A., Thacher, R., Rauck, R. C., & Dines, J. S. (2022). Pitching mechanics and the relationship to accuracy in professional baseball pitchers. *The American Journal of Sports Medicine*, 50(3), 814-822.
- Nakata, H., Nagami, T., Higuchi, T., Sakamoto, K., & Kanosue, K. (2013). Relationship between performance variables and baseball ability in youth baseball players. *The Journal of Strength & Conditioning Research*, 27(10), 2887-2897.
- Olsen, S. J., Fleisig, G. S., Dun, S., Loftice, J., & Andrews, J. R. (2006). Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. *The American journal of sports medicine*, 34(6), 905-912.
- Reinebo, G., Alfonsson, S., Jansson-Fröjmark, M., Rozental, A., & Lundgren, T. (2024). Effects of Psychological Interventions to Enhance Athletic Performance: A Systematic Review and Meta-Analysis: G. Reinebo et al. *Sports Medicine*, 54(2), 347-373.
- Sgroi, T., Chalmers, P. N., Riff, A. J., Lesniak, M., Sayegh, E. T., Wimmer, M. A., ... & Romeo, A. A. (2015). Predictors of throwing velocity in youth and adolescent pitchers. *Journal of Shoulder and Elbow Surgery*, 24(9), 1339-1345.

- Shitara, H., Tajika, T., Miyamoto, R., Hatori, Y., Ino, F., Nakase, K., ... & Chikuda, H. (2026). A combined logistic regression and decision tree analysis of factors influencing throwing velocity and accuracy in little league baseball players. *JSES international*, 101690.
- Stodden, D. F., Fleisig, G. S., McLean, S. P., & Andrews, J. R. (2005). Relationship of biomechanical factors to baseball pitching velocity: within pitcher variation. *Journal of applied biomechanics*, 21(1), 44-56.
- Werner, S. L., Suri, M., Guido Jr, J. A., Meister, K., & Jones, D. G. (2008). Relationships between ball velocity and throwing mechanics in collegiate baseball pitchers. *Journal of shoulder and elbow surgery*, 17(6), 905-908.