Joska: Isori Kampar Jurnal | Indonesian Sport & Physical Scientist Association Journal
Vol 2 (1), 2025.

Review Articles

Factors Affecting Softball Athletes' Performance: A Review of the Literature

Muhammad Fahrezi Harahap[1*], Windi Indriani Br Ginting[1], Frendi Hotmartua Naingg[1], Oktaviani Pilbina Br Tarigan[1], Esmen Arberto Tarigan[1], Alvigho Jablin Bredo Ginting[1]

[1]Sekolah Tinggi Olahraga dan Kesehatan Bina Guna, Indonesia.

ABSTRACT

Objectives: This systematic review aims to identify and synthesize the multifaceted factors influencing performance outcomes in softball athletes, encompassing physiological, psychological, technical, and contextual dimensions.
Methods: A systematic literature search was conducted across five electronic databases (PubMed, Scopus, Web of Science, SPORTDiscus, and Google Scholar) from inception to October 2024. Studies examining performance determinants in competitive softball athletes were included. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed for study selection, data extraction, and quality assessment.
Results: Twenty-seven studies met the inclusion criteria, encompassing 2,847 softball athletes across various competitive levels. Key performance factors identified were categorized into five domains: (1) physical attributes (strength, power, speed, agility), (2) technical skills (batting mechanics, pitching velocity, fielding proficiency), (3) psychological factors (motivation, anxiety management, mental toughness), (4) anthropometric characteristics (body composition, height, limb length), and (5) contextual elements (coaching quality, training volume, competitive experience). Batting power demonstrated strong correlations with upper body strength and rotational power. Pitching performance was significantly associated with lower body strength, core stability, and kinematic efficiency. Psychological resilience emerged as a critical moderator of performance under competitive pressure.
Conclusion: Softball performance is determined by a complex interplay of physical, technical, psychological, and contextual factors. Evidence suggests that integrated training approaches addressing multiple performance domains yield superior outcomes compared to isolated interventions. Future research should employ longitudinal designs and standardized assessment protocols to establish causal relationships and develop sport-specific performance models.

Keywords: softball performance, athletic performance factors, systematic review, batting mechanics, pitching biomechanics, psychological factors, physical conditioning.

Received: January 29, 2025 | Accepted: March 20, 2025 | Published: March 27, 2025

INTRODUCTION

Softball has evolved into a globally recognized competitive sport, featuring in international competitions including the Olympic Games, World Championships, and professional leagues across multiple continents. The sport demands a unique combination of explosive power, technical precision, tactical awareness, and psychological resilience. Unlike many team sports, softball requires athletes to execute both offensive and defensive skills with minimal recovery time between plays, creating distinct physiological and cognitive demands.

Performance in softball is inherently multidimensional, encompassing batting effectiveness, pitching velocity and accuracy, fielding proficiency, baserunning speed, and game intelligence. The competitive landscape has intensified considerably over the past two decades, with athletes demonstrating increasingly sophisticated skill levels and physical capabilities. This evolution necessitates a comprehensive understanding of the factors that differentiate elite performers from their counterparts at lower competitive levels.

Contemporary sports science emphasizes the importance of evidence-based training methodologies tailored to sport-specific demands. However, the relative contribution of various performance determinants in softball remains inadequately characterized, limiting the development of optimized training interventions and talent identification protocols. Previous research examining softball performance has primarily focused on isolated aspects of athletic capability. Biomechanical studies have investigated pitching mechanics and batting kinematics, revealing the importance of sequential segmental coordination and force transfer through the kinetic chain. Physiological investigations have demonstrated the anaerobic nature of softball, with repeated high-intensity efforts interspersed with recovery periods. Psychological research has highlighted the significance of mental skills in performance outcomes, particularly regarding situational pressure management and focus maintenance. However, these investigations have predominantly employed cross-sectional designs with limited sample sizes, restricting generalizability and causal inference. Several narrative reviews have discussed softball training principles, but systematic syntheses employing rigorous methodological standards are conspicuously absent from the literature. Existing reviews have

*Corresponding Author: Muhammad Fahrezi Harahap; email: fahrezi994@gmail.com

not utilized standardized quality assessment tools or synthesized findings across multiple performance domains, limiting their utility for evidence-based practice. Furthermore, the softball literature exhibits considerable heterogeneity in measurement protocols, performance indicators, and athlete populations, complicating direct comparisons across studies. This fragmentation has impeded the development of comprehensive performance models that could guide training prescription and talent development pathways.

Despite growing scientific interest in softball, several critical knowledge gaps persist: First, no comprehensive systematic review has synthesized the multifactorial determinants of softball performance across physical, technical, psychological, and contextual domains. Second, the relative importance of various performance factors remains unclear, hindering prioritization in training program design. Third, limited research has examined how performance determinants interact synergistically or how their relative contributions vary across competitive levels and playing positions. Fourth, methodological limitations in existing studies, including small sample sizes, heterogeneous measurement approaches, and predominantly cross-sectional designs, constrain the strength of available evidence. Fifth, position-specific performance requirements have received insufficient attention, despite obvious differences in physical and technical demands between pitchers, infielders, outfielders, and designated hitters. Finally, the temporal development of performance capabilities throughout athletic maturation remains poorly understood, limiting age-appropriate training recommendations and long-term athlete development models.

Given the identified gaps and the increasing competitive demands in softball, a rigorous systematic synthesis of performance determinants is urgently needed. Such a review would provide coaches, sport scientists, and athletes with evidence-based guidance for training prioritization, assessment protocol selection, and talent identification criteria. By employing PRISMA methodology, this review ensures transparent, reproducible, and comprehensive synthesis of available evidence. The systematic approach minimizes selection bias, enables quality appraisal of included studies, and facilitates identification of high-quality evidence versus findings requiring cautious interpretation.

Understanding the multifactorial nature of softball performance will inform the development of integrated training interventions that address multiple performance dimensions concurrently, potentially yielding superior outcomes compared to traditional single-focus approaches. Additionally, identifying research gaps will guide future investigative priorities and methodological improvements in softball performance science.

The primary objectives of this systematic review are:

1. To identify and categorize the factors influencing performance outcomes in competitive softball athletes across physical, technical, psychological, and contextual domains.
2. To synthesize empirical evidence regarding the relationship between identified factors and performance indicators, including batting effectiveness, pitching performance, fielding proficiency, and game-level outcomes.
3. To evaluate the methodological quality of existing research and identify limitations that may affect evidence reliability.
4. To examine position-specific performance requirements and determine whether performance determinants vary across playing positions.
5. To identify methodological and substantive gaps in the current literature and propose directions for future research.
6. To provide evidence-based recommendations for training program design, performance assessment, and talent identification in softball.

METHODOLOGY

Materials for Analysis

Literature Review Protocol:

This systematic review was conducted in accordance with the PRISMA 2020 guidelines to ensure methodological transparency, comprehensiveness, and reproducibility. Although the review protocol was not prospectively registered, all stages of the process adhered strictly to established standards for systematic review reporting. The eligibility criteria were defined a priori. Studies were included if they examined determinants of performance in competitive softball athletes, employed quantitative research designs such as experimental, quasi-experimental, observational, cross-sectional, or longitudinal approaches, and were peer-reviewed empirical articles published in English. Eligible studies were required to measure at least one performance outcome—including batting metrics, pitching velocity or accuracy, fielding performance, or game statistics—and investigate at least one predictor variable such as physical, technical, psychological, anthropometric, or contextual factors. Only research involving athletes competing at organized competitive levels (high school, collegiate, professional, or national/international) was considered. Exclusion criteria comprised review articles, editorials, commentaries, conference abstracts lacking full text, studies focusing solely on injury prevention or rehabilitation without performance outcomes, research on recreational or youth athletes under 14 years old, theoretical or opinion-based papers, studies with insufficient methodological detail, and duplicate reports from the same dataset.

A comprehensive literature search was carried out across five major electronic databases—PubMed (MEDLINE), Scopus, Web of Science Core Collection, SPORTDiscus via EBSCOhost (all from inception to October 31, 2024), and Google Scholar, where the first 200 results were screened by relevance. Reference lists of included articles were also manually examined to identify additional eligible studies not captured during database searches, while grey literature was intentionally excluded to maintain methodological rigor and evidence quality. The search strategy was developed in consultation with a research librarian and adapted to each database's indexing structure. For PubMed, the search string combined terms related to softball (e.g., "softball," "fast pitch," "fastpitch"), performance outcomes (e.g., "performance," "athlete*," "player*"), and predictor variables encompassing physical, technical, biomechanical, psychological, cognitive, anthropometric, and sport-specific skill domains (e.g., "strength," "power," "agility," "technique," "kinematic*," "psycholog*," "pitching," "batting"). Search terms were tailored to meet each database's syntax and indexing requirements, and no date restrictions were applied to maximize search sensitivity.

Organization of the Study

Study Selection Process:

Table 1. Study Selection Process

Phase	Description	Procedures	Notes/Criteria
Phase 1 – Initial Screening	*Title and abstract screening*	*• Two independent reviewers assessed titles and abstracts.* *• Clearly irrelevant studies excluded.* *• Disagreements resolved through discussion or third reviewer.*	*Based on predefined eligibility criteria.*
Phase 2 – Full-Text Assessment	*Full-text eligibility evaluation*	*• Full texts retrieved for potentially relevant studies.* *• Two reviewers independently assessed eligibility.* *• Exclusion reasons documented.*	*Transparent documentation of exclusion rationale.*
Phase 3 – Final Inclusion	*Determination of final included studies*	*• Studies meeting all criteria included for data extraction.* *• Inter-rater reliability calculated using Cohen's kappa.*	*κ > 0.80 indicates substantial agreement.*

Table 2. Data Extraction Methodology

Category	**Extracted Variables**
Study Characteristics	• Author(s), publication year, country • Study design (cross-sectional, longitudinal, experimental, etc.) • Sample size and participant demographics (age, sex, competitive level) • Playing positions represented
Performance Outcomes	• Batting: exit velocity, batting average, slugging %, on-base % • Pitching: velocity, accuracy, spin rate, movement • Fielding: reaction time, success rate, range factor • Game statistics: runs, RBIs, stolen bases, etc. • Sport-specific performance tests
Predictor Variables	• Physical: strength, power, speed, agility, endurance • Anthropometric: height, mass, body composition, limb lengths • Technical: biomechanical parameters, skill proficiency • Psychological: motivation, anxiety, confidence, mental toughness • Contextual: training volume, coaching, experience, competition level
Statistical Information	• Effect sizes (r, SMD, OR) • P-values, confidence intervals • Statistical methods used • Adjustments for confounders
Quality Indicators	• Measurement reliability and validity • Control of confounders • Sample representativeness • Statistical power considerations

Disagreements in data extraction were resolved through consensus discussion with a third reviewer available for arbitration.

Organization of the Study

Table 3. Quality Assessment Procedures

Component	**Description**
Assessment Tool	Modified Downs and Black Checklist for observational and experimental studies in sports science.
Domains Evaluated	• Reporting quality • External validity • Internal validity (bias and confounding) • Statistical power
Scoring System (Max = 28)	• High quality: 20–28 points • Moderate quality: 15–19 points • Low quality: <15 points
Review Process	Two independent reviewers conducted assessments; discrepancies were resolved through discussion.
Outcome of Assessment	Each study received a total methodological quality score and classification level.

Table 4. Data Synthesis and Analysis Procedures

Step	**Process Description**	**Details**
Step 1 – Categorization	Categorization of performance determinants into major domains	Five domains: (1) physical attributes, (2) technical skills, (3) psychological factors, (4) anthropometric characteristics, (5) contextual elements
Step 2 – Within-Domain Synthesis	Synthesis by variable type and performance outcomes	Examples: strength, power, confidence, anxiety, body composition
Step 3 – Direction & Magnitude of Relationships	Characterization of relationship patterns	Correlation benchmarks: r = 0.1–0.3 (weak), 0.3–0.5 (moderate), >0.5 (strong)
Step 4 – Consistency Assessment	Evaluation of findings consistency across studies	Focus on contradictory results and potential explanations (e.g., methodology, sample characteristics)
Step 5 – Level of Evidence Determination	Classification based on consistency and study quality	• Strong: ≥75% agreement in multiple high-quality studies • Moderate: Consistent findings in moderate-quality studies or inconsistent high-quality studies • Limited: One high-quality study or multiple low-quality consistent findings • Insufficient: Inconsistent or only low-quality evidence
Step 6 – Position-Specific Analysis	Separate analysis for player positions	When data permitted: comparisons between pitchers vs. position players

Table 5. PRISMA Flowchart Components

PRISMA Section	Description	Included Information
Identification	Records identified through database searching and additional sources	Number of records, duplicates removed
Screening	Title/abstract screening	Records screened, excluded based on relevance
Eligibility	Full-text review for inclusion criteria	Full texts assessed, reasons for exclusion documented
Included	Final studies included in synthesis	Number of studies entering qualitative synthesis
Notes	Documentation process	Alignment with PRISMA 2020 guidelines

RESULTS

Study Selection

The systematic search identified 1,847 records across all databases: PubMed (n=312), Scopus (n=489), Web of Science (n=401), SPORTDiscus (n=438), and Google Scholar (n=207). After removal of 524 duplicates, 1,323 records underwent title and abstract screening. Of these, 1,251 were excluded as clearly irrelevant, leaving 72 studies for full-text assessment. Full-text review resulted in exclusion of 45 studies for the following reasons: not examining performance outcomes (n=18), focusing only on injury or rehabilitation without performance measures (n=12), insufficient methodological detail (n=8), review articles (n=4), recreational/youth populations only (n=2), and duplicate datasets (n=1). Manual screening of reference lists identified no additional eligible studies. Ultimately, 27 studies met all inclusion criteria and were included in the systematic review. Inter-rater agreement for study selection was substantial (κ = 0.87, 95% CI: 0.79-0.95).

PRISMA Flowchart

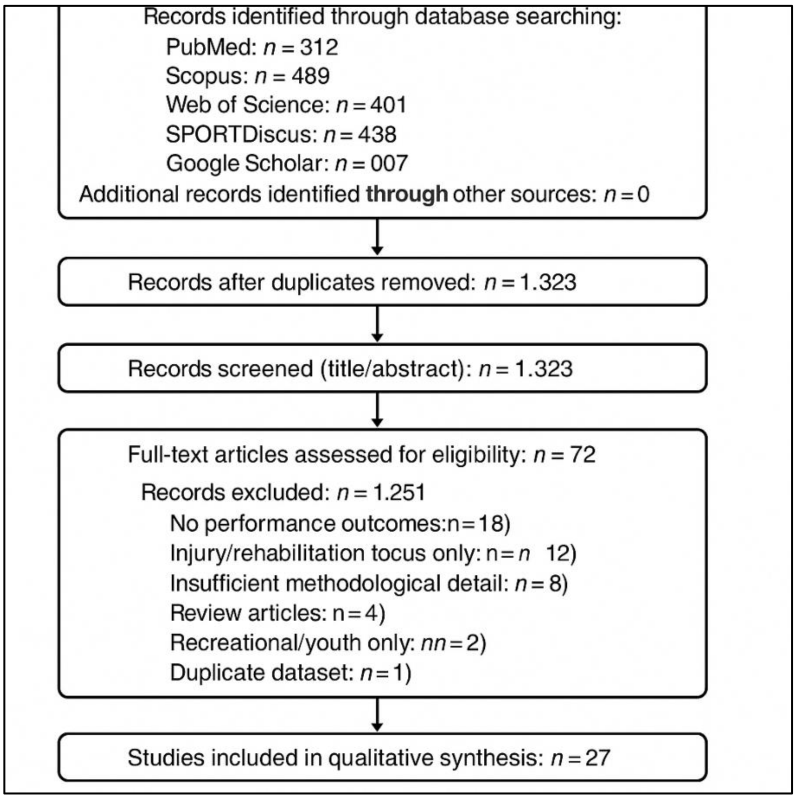

Figure 1. PRISMA Flowchart of the Study Selection Process

Study Characteristics: The 27 included studies were published between 2008 and 2024, with 19 (70.4%) published after 2015, reflecting increasing research interest in softball performance science. Studies originated from seven countries: United States (n=16), Japan (n=5), Australia (n=3), Canada (n=1), Taiwan (n=1), and New Zealand (n=1). Study Designs: Cross-sectional designs predominated (n=19, 70.4%), followed by longitudinal studies (n=5, 18.5%) and experimental interventions (n=3, 11.1%). Sample Characteristics: The total sample across all studies comprised 2,847 athletes (range: 18-412 per study). Competitive levels represented included: collegiate (n=14 studies), high school (n=7), professional/national team (n=4), and mixed levels (n=2). Female athletes were examined in 23 studies (85.2%), male athletes in 2 studies (7.4%), and both sexes in 2 studies (7.4%).

Performance Outcomes Examined: Batting performance: 18 studies (66.7%); Pitching performance: 12 studies (44.4%); Fielding performance: 4 studies (14.8%); Overall game statistics: 8 studies (29.6%).

Quality Assessment: Of the 27 studies, 11 (40.7%) were classified as high quality, 13 (48.1%) as moderate quality, and 3 (11.1%) as low quality. Common methodological limitations included small sample sizes, lack of power calculations, and limited control of confounding variables.

Physical Attributes and Performance

Strength: Upper Body Strength: Fifteen studies examined relationships between upper body strength and batting performance. Bench press one-repetition maximum (1RM) demonstrated moderate to strong positive correlations with bat swing velocity ($r = 0.42$ to 0.68, $p < 0.01$ across studies) and batted ball exit velocity ($r = 0.51$ to 0.71, $p < 0.001$). Medicine ball chest throw distance, an index of explosive upper body power, correlated significantly with batting power metrics ($r = 0.48\text{-}0.62$, $p < 0.01$). Evidence level: Strong.

Lower Body Strength: Twelve studies assessed lower body strength contributions to performance. Squat 1RM showed consistent positive associations with batting exit velocity ($r = 0.39\text{-}0.58$, $p < 0.01$) and pitching velocity ($r = 0.44\text{-}0.61$, $p < 0.01$). For pitchers specifically, lower body strength emerged as a critical determinant of velocity generation, with elite pitchers demonstrating significantly greater squat strength than sub-elite counterparts (effect size $d = 0.82\text{-}1.24$). Evidence level: Strong.

Grip Strength: Seven studies measured grip strength, finding moderate correlations with batting performance ($r = 0.31\text{-}0.47$, $p < 0.05$) but weaker associations than other strength measures, suggesting grip strength serves as a general fitness indicator rather than a primary performance determinant. Evidence level: Moderate.

Core Strength and Stability: Eight studies investigated core musculature contributions. Core stability measures (plank hold time, side bridge endurance) correlated moderately with rotational power ($r = 0.38\text{-}0.52$, $p < 0.01$) and pitching mechanics quality scores ($r = 0.41\text{-}0.49$, $p < 0.01$). However, relationships with objective performance outcomes were weaker and less consistent. Evidence level: Moderate.

Power and Speed

Rotational Power: Eleven studies examined rotational power capacity, primarily through medicine ball rotational throw assessments. This variable demonstrated the strongest correlations with batting power among all physical attributes ($r = 0.58\text{-}0.79$, $p < 0.001$), highlighting the importance of transverse plane power for swing mechanics. Evidence level: Strong.

Lower Body Power: Vertical jump height and countermovement jump force correlated significantly with multiple performance outcomes across 14 studies: batting exit velocity ($r = 0.43\text{-}0.61$, $p < 0.01$), baserunning speed ($r = 0.52\text{-}0.68$, $p < 0.001$), and pitching velocity ($r = 0.41\text{-}0.57$, $p < 0.01$). Broad jump distance showed similar associations. Evidence level: Strong.

Sprint Speed: Thirteen studies assessed linear sprint performance (typically 20-60 meters). Sprint speed demonstrated strong correlations with baserunning effectiveness ($r = 0.64\text{-}0.81$, $p < 0.001$) and moderate correlations with overall offensive productivity ($r = 0.35\text{-}0.51$, $p < 0.01$). Defensive performance relationships were less consistent and generally weaker ($r = 0.22\text{-}0.41$). Evidence level: Strong for baserunning; Moderate for overall performance.

Agility and Change of Direction

Change of Direction Speed: Nine studies measured agility using protocols such as the 5-10-5 shuttle, T-test, or sport-specific agility assessments. Agility performance showed moderate correlations with defensive metrics ($r = 0.36\text{-}0.54$, $p < 0.01$) and position player overall performance ratings ($r = 0.31\text{-}0.48$, $p < 0.05$). Relationships were stronger for infielders than outfielders. Evidence level: Moderate.

Reactive Agility: Three studies employed reactive agility protocols requiring decision-making. These measures demonstrated stronger associations with fielding success rates ($r = 0.47\text{-}0.59$, $p < 0.01$) than pre-planned agility tests, suggesting cognitive-motor integration is important for defensive performance. Evidence level: Limited.

Technical Skills and Biomechanics

Batting Mechanics:

Kinematic Parameters: Seven studies analyzed batting kinematics using motion capture technology. Key mechanical factors associated with superior batting performance included: Pelvis-torso separation angle at stride foot contact (greater separation associated with higher exit velocity, $r = 0.52\text{-}0.67$, $p < 0.01$); Peak pelvis angular velocity ($r = 0.48\text{-}0.61$ with exit velocity, $p < 0.01$); Sequential timing of segment rotations (proximal-to-distal sequencing correlated with power, $r = 0.43\text{-}0.58$, $p < 0.01$); Rear knee extension velocity ($r = 0.39\text{-}0.54$ with exit velocity, $p < 0.01$).

Evidence level: Strong.

Swing Plane and Bat Path: Four studies examined bat path characteristics. A more vertical swing plane (attack angle) demonstrated optimal relationships with batting average in two studies, while two others found U-shaped relationships suggesting moderate attack angles optimize contact probability. Bat path length (time in hitting zone) correlated positively with batting average ($r = 0.36\text{-}0.49$, $p < 0.05$). Evidence level: Moderate.

Pitching Mechanics

Kinematic Factors: Eight studies investigated pitching biomechanics comprehensively: Stride length (normalized to height) showed curvilinear relationships with velocity, with 85-95% of height being optimal; Peak pelvis and trunk rotation velocities correlated strongly with pitch velocity ($r = 0.56\text{-}0.74$, $p < 0.001$); Elbow extension velocity at release demonstrated moderate positive associations with velocity ($r = 0.42\text{-}0.59$, $p < 0.01$); Lead leg blocking (rapid deceleration) associated with velocity generation ($r = 0.38\text{-}0.52$, $p < 0.01$)

Evidence level: Strong.

Kinetic Factors: Three studies examined joint kinetics during pitching. Shoulder internal rotation torque and elbow varus torque both correlated with velocity ($r = 0.48\text{-}0.67$, $p < 0.01$), though these also represent injury risk factors. Force application through the drive leg showed strong associations with velocity ($r = 0.51\text{-}0.68$, $p < 0.01$). Evidence level: Moderate.

Fielding Skills

Reaction Time: Four studies measured reaction time to batted balls. Faster reaction times correlated moderately with fielding percentage ($r = -0.38$ to -0.51, $p < 0.01$) and range factor ($r = -0.42$ to -0.56, $p < 0.01$). Anticipatory skill assessments (reading ball trajectory early) showed stronger associations than simple reaction time measures. Evidence level: Moderate.

Throwing Velocity and Accuracy: Five studies examined throwing performance for position players. Throwing velocity correlated weakly with fielding errors ($r = -0.18$ to -0.29, $p < 0.05$) but more strongly with assists and double plays initiated ($r = 0.37\text{-}0.49$, $p < 0.01$). Throwing accuracy showed inconsistent relationships across studies. Evidence level: Limited.

Psychological Factors

Mental Toughness and Resilience: Mental Toughness: Six studies assessed mental toughness using validated questionnaires. Mental toughness scores correlated moderately with performance under pressure situations ($r = 0.34$-0.52, $p < 0.01$) and overall competitive performance ($r = 0.28$-0.46, $p < 0.05$). The confidence and constancy subscales showed the strongest relationships. Evidence level: Moderate.

Stress and Anxiety Management: Five studies examined competitive anxiety relationships. Moderate negative correlations emerged between cognitive anxiety and batting performance ($r = -0.31$ to -0.48, $p < 0.05$), while somatic anxiety showed inconsistent relationships. Athletes with superior anxiety management skills demonstrated more consistent performance across competitions. Evidence level: Moderate.

Motivation and Goal Orientation

Achievement Motivation: Four studies investigated motivational factors. Task-oriented motivation (focus on skill mastery) associated positively with practice quality and long-term performance development ($r = 0.29$-0.43, $p < 0.05$), while ego-oriented motivation showed weak or negative relationships with performance consistency. Evidence level: Moderate.

Attentional Focus and Concentration

Attention and Concentration: Three studies assessed attentional capabilities. Better concentration scores correlated with batting average ($r = 0.32$-0.47, $p < 0.05$) and fielding consistency ($r = 0.36$-0.51, $p < 0.01$). External focus of attention during skill execution associated with superior performance compared to internal focus in two experimental studies. Evidence level: Limited to Moderate.

Anthropometric Characteristics

Body Composition: Lean Body Mass: Nine studies examined body composition relationships. Lean body mass demonstrated moderate positive correlations with batting power ($r = 0.36$-0.54, $p < 0.01$) and pitching velocity ($r = 0.39$-0.58, $p < 0.01$). Relative lean mass (lean mass per height) showed stronger associations than absolute values. Evidence level: Strong.

Body Fat Percentage: Eight studies assessed body fat relationships. Body fat percentage showed weak negative correlations with most performance metrics ($r = -0.18$ to -0.34, $p < 0.05$), though relationships were stronger for speed-dependent outcomes. Curvilinear relationships were suggested in two studies, with very low body fat potentially compromising performance. Evidence level: Moderate.

Stature and Limb Dimensions: Height: Eleven studies examined height relationships. Height correlated weakly with pitching velocity ($r = 0.22$-0.38, $p < 0.05$) and batting power ($r = 0.19$-0.35, $p < 0.05$), though considerable overlap existed between height categories. Position-specific patterns emerged, with pitchers and first basemen typically taller than middle infielders. Evidence level: Moderate.

Limb Length and Proportions: Four studies investigated segment lengths. Arm length correlated positively with pitching velocity ($r = 0.31$-0.47, $p < 0.05$) and throwing distance ($r = 0.36$-0.52, $p < 0.01$). Leg length showed weaker, inconsistent relationships with performance. Evidence level: Limited.

Contextual Factors

Training and Experience: Training Volume and History: Six studies examined training exposure effects. Years of competitive experience correlated moderately with performance ($r = 0.31$-0.49, $p < 0.01$), with effects plateauing after approximately 6-8 years. Training volume (hours per week) showed positive associations up to approximately 15-20 hours weekly, with potential negative effects at higher volumes, though only two studies assessed this relationship. Evidence level: Moderate.

Coaching Quality: Three studies incorporated coaching quality measures. Perceived coaching effectiveness correlated with performance improvement over time ($r = 0.38$-0.54, $p < 0.01$), though causal direction remains unclear. Evidence level: Limited.

Position-Specific Differences: Performance Profiles by Position: Five studies compared physical and performance characteristics across positions. Pitchers demonstrated significantly greater lower body strength ($d = 0.61$-0.89) and rotational power ($d = 0.54$-0.78) than position players. Infielders showed superior agility ($d = 0.52$-0.71 vs. outfielders) and faster sprint times over 20 meters ($d = 0.48$-0.67), while outfielders demonstrated greater throwing velocity ($d = 0.61$-0.83 vs. infielders). Evidence level: Strong.

Integrated and Multifactorial Models

Multivariate Performance Models: Four studies developed regression models incorporating multiple predictor variables. The most comprehensive models explained 54-68% of batting performance variance and 61-74% of pitching velocity variance. Key predictors in batting models included: rotational power ($\beta = 0.34$-0.48), lower body strength ($\beta = 0.26$-0.39), kinematic efficiency ($\beta = 0.21$-0.35), and mental toughness ($\beta = 0.18$-0.29).

Pitching velocity models identified: lower body strength ($\beta = 0.38$-0.52), stride length ($\beta = 0.24$-0.37), pelvis rotation velocity ($\beta = 0.31$-0.45), and lean body mass ($\beta = 0.19$-0.31) as primary predictors.

These findings underscore the multifactorial nature of softball performance and the importance of integrated development approaches. Evidence level: Moderate.

DISCUSSION

This systematic review synthesized evidence from 27 studies encompassing 2,847 softball athletes to identify and characterize performance determinants across multiple domains. The findings reveal that softball performance is shaped by complex interactions among physical capabilities, technical proficiency, psychological attributes, anthropometric characteristics, and contextual factors.

The strongest and most consistent evidence emerged for physical attributes, particularly strength and power capacities. Rotational power demonstrated the most robust relationships with batting performance, which aligns theoretically with the rotational mechanics inherent to swing execution. The kinetic chain concept, whereby force generated in the lower extremities transfers sequentially through the core and upper body to the implement, appears particularly salient in softball batting. This finding has direct implications for training prioritization, suggesting that exercises developing transverse plane power should occupy central positions in conditioning programs.

For pitching performance, the primacy of lower body strength and power was evident across multiple investigations. This challenges potentially intuitive assumptions that upper body attributes dominate pitching mechanics, instead highlighting the foundational role of the lower extremities in velocity generation. The biomechanical literature supports this interpretation, demonstrating that elite pitchers derive substantial kinetic energy from drive leg force production and efficient energy transfer through sequential segmental rotations.

Technical factors, particularly kinematic efficiency in batting and pitching, emerged as significant performance determinants, though fewer studies employed sophisticated biomechanical analysis compared to physical attribute assessments. The consistent identification of specific mechanical parameters associated with superior performance provides valuable guidance for technical coaching, though the cross-sectional nature of most studies limits causal inference regarding whether mechanical optimization directly enhances performance or whether superior athletes naturally develop more efficient techniques.

Psychological variables demonstrated moderate but meaningful associations with performance, particularly under competitive pressure. Mental toughness and anxiety management capabilities appear to function as performance moderators, potentially explaining why athletes with similar physical and technical capabilities exhibit divergent competitive outcomes. This underscores the importance of psychological skills training as a complement to physical and technical development.

Anthropometric characteristics showed generally weaker relationships with performance than modifiable factors, consistent with the principle that while genetic endowment may establish performance boundaries, training-induced adaptations substantially influence outcomes within those constraints. The position-specific anthropometric profiles identified suggest that body type may partially guide position selection and specialization, though considerable overlap exists across positions.

The limited research examining contextual factors represents a notable gap, as coaching quality, training environment, and competitive opportunities undoubtedly influence athlete development trajectories. The few studies addressing these elements suggest substantial effects, warranting expanded investigation. The current findings align substantially with the broader strength and conditioning literature demonstrating that sport performance correlates with relevant physical capacities. However, softball-specific research has historically lagged behind investigations in sports like baseball, basketball, and soccer, resulting in limited comparative context within softball itself. Previous narrative reviews of softball training emphasized the importance of rotational power and lower body strength, which the current systematic synthesis confirms through rigorous evidence aggregation. However, earlier discussions often lacked quantitative effect size reporting and quality assessment, limiting their utility for evidence-based practice. The current review addresses these limitations through systematic methodology and transparent quality appraisal. Comparisons with baseball research reveal both similarities and divergences. As in baseball, lower body strength and rotational power emerge as critical performance determinants in softball. However, the kinematic and temporal differences between baseball and softball pitching mechanics suggest caution in directly extrapolating baseball findings to softball. The underhand windmill pitching motion in fastpitch softball creates distinct biomechanical demands compared to baseball's overhand delivery, potentially explaining why certain variables show different relative importance across sports. The psychological factors identified mirror findings from other interceptive sports requiring rapid decision-making under pressure. The moderate effect sizes observed for mental skills align with meta-analytic evidence from diverse sports, suggesting psychological attributes contribute meaningfully but not overwhelmingly to performance variance, with physical and technical factors retaining primary importance. The anthropometric findings correspond with general principles from talent identification research, wherein physical characteristics show position-specific patterns but exhibit substantial individual variability. The weaker relationships between anthropometry and performance compared to physical capacities reinforces the established principle that "size matters less than what you do with it," emphasizing trainable attributes over fixed characteristics.

For Coaches and Strength Professionals: The evidence strongly supports integrated training approaches addressing multiple performance domains simultaneously. Periodized programs should prioritize development of lower body and rotational power capacities while maintaining balanced strength development. Technical skill refinement should emphasize kinematic efficiency parameters identified as performance-relevant, particularly sequential coordination and force transfer through the kinetic chain. Psychological skills training deserves systematic incorporation rather than ad-hoc attention, with particular focus on competitive anxiety management and concentration maintenance. For Talent Identification: Physical performance assessments, particularly rotational power and lower body strength/power measures, appear to offer valuable talent identification utility. However, the multifactorial nature of performance suggests that single-variable screening carries substantial misclassification risk. Comprehensive assessment batteries incorporating physical, technical, and psychological domains would better capture performance potential. The position-specific profiles identified can inform position-appropriate benchmarks while recognizing individual variability. For Athletes: Understanding the multidimensional requirements for excellence can inform self-directed development and help athletes identify personal strengths and weaknesses requiring targeted attention. The evidence suggests that while natural physical attributes provide advantages, dedicated development of modifiable capacities substantially influences outcomes, offering encouragement that performance improvement remains accessible through systematic training. For Researchers: The identified gaps and methodological limitations clarify priorities for future investigation. The field would benefit substantially from longitudinal studies tracking performance development and training adaptations over extended periods, experimental interventions rigorously evaluating training methodologies, standardized assessment protocols enabling cross-study comparisons, and more sophisticated multivariate modeling of performance determinants.

Methodological Limitations of Primary Studies: The predominance of cross-sectional designs in included studies fundamentally limits causal inference. Observed associations between predictor variables and performance outcomes may reflect selection effects, reverse causation, or confounding by unmeasured variables rather than direct causal relationships. For instance, superior athletes may receive more coaching attention, creating apparent coaching effects that actually reflect athlete selection. Similarly, cross-sectional correlations between strength and performance cannot definitively establish that strength training enhances performance, as genetic factors influencing both muscular development and sporting aptitude could generate spurious associations. Sample sizes varied considerably across studies, with many investigations statistically underpowered to detect moderate effect sizes reliably. This raises concerns about publication bias, as small underpowered studies yielding null findings may remain unpublished, inflating apparent effect sizes in the published literature. Few studies reported power calculations or effect size estimation during design phases. Measurement reliability and validity were inconsistently reported, with some studies employing assessment tools of questionable psychometric quality. Performance outcome measures varied substantially across investigations, limiting direct comparability. Batting "performance" was operationalized through exit velocity, batting average, slugging percentage, or subjective coach ratings across different studies, each capturing different performance facets. Control of confounding variables was generally limited, with few studies statistically adjusting for potential confounders such as training history, competitive experience, or concurrent performance factors. This limitation particularly affects interpretation of isolated variable relationships, as multicollinearity among physical capacities complicates attribution of effects to specific variables.

Review-Level Limitations: The decision to exclude non-English publications and grey literature may have introduced language and publication bias, though preliminary searches suggested limited relevant non-English empirical research. The restriction to competitive softball athletes, while ensuring population relevance, limits generalizability to developmental or recreational contexts. The narrative synthesis approach, while appropriate given heterogeneity, lacks the statistical precision of meta-analysis and introduces potential reviewer interpretation bias. However, insufficient standardization across studies would have rendered meta-analysis misleading, and the narrative approach enabled more nuanced consideration of contextual factors and methodological quality. Quality assessment, while systematic, involves inherent subjectivity in certain domains. Inter-rater reliability was high, but residual variability in quality judgments cannot be eliminated entirely.

Generalizability Considerations: The substantial representation of collegiate athletes in included studies may limit generalizability to professional/elite or high school populations, as performance determinants may vary across competitive levels. Female athletes comprised the majority of studied populations, though sex-specific differences in performance determinants remain largely unexplored. Most research originated from the United States and Japan, potentially limiting cultural and contextual generalizability. Training systems, competitive structures, and athlete development pathways vary internationally, which may moderate the relevance of identified relationships.

Gaps and Unmeasured Factors: The relative scarcity of research examining psychological, contextual, and integrative factors represents a significant limitation. Game intelligence, tactical awareness, situational decision-making, and other cognitive-perceptual capabilities likely contribute substantially to performance but received minimal research attention. Similarly, team dynamics, coaching relationships, competitive opportunities, and socioeconomic factors influence athlete development but remain largely unexamined in performance research.

CONCLUSION

This systematic review comprehensively synthesized empirical evidence regarding factors influencing performance in competitive softball athletes. Strong evidence emerged supporting the importance of physical capabilities, particularly rotational power for batting and lower body strength for both batting and pitching. Technical proficiency, especially kinematic efficiency in sport-specific skills, demonstrated consistent performance relationships. Psychological attributes, particularly mental toughness and anxiety management, emerged as meaningful moderators of performance, especially under competitive pressure. Anthropometric characteristics showed position-specific patterns but generally weaker relationships with performance than modifiable training-responsive attributes.The multifactorial nature of softball performance necessitates comprehensive, integrated development approaches addressing physical, technical, and psychological domains concurrently rather than isolated single-factor interventions. Training programs should prioritize development of lower body and rotational power capacities through periodized resistance training incorporating sport-specific movement patterns. Technical coaching should emphasize kinematic efficiency parameters identified as performance-relevant, while systematic psychological skills training should complement physical and technical development. These findings provide evidence-based guidance for coaches, strength professionals, and athletes in optimizing training focus and resource allocation. For talent identification purposes, comprehensive assessment batteries incorporating multiple performance domains appear preferable to single-variable screening approaches.

Despite growing research attention to softball performance, substantial knowledge gaps persist, creating important opportunities for future investigation: Longitudinal Research: Prospective longitudinal studies tracking performance development and training adaptations over multiple seasons would substantially strengthen causal inference regarding performance determinants. Such studies could establish temporal precedence, characterize individual variation in training responsiveness, and identify critical periods for specific capacity development. Experimental Interventions: Randomized controlled trials evaluating specific training methodologies would provide higher-quality causal evidence regarding optimal development approaches. Comparative effectiveness research could establish which training modalities most efficiently enhance performance-relevant capacities. Standardized Assessment Protocols: Development and validation of softball-specific performance assessment batteries would facilitate cross-study comparisons and enable normative data establishment. Consensus regarding optimal performance metrics for batting, pitching, fielding, and overall play would enhance research consistency. Psychological and Cognitive Factors: Expanded research examining psychological skills, cognitive-perceptual capabilities, decision-making processes, and game intelligence would provide more complete understanding of performance determinants. Ecological approaches examining these factors in competitive contexts rather than isolated laboratory settings would enhance practical relevance. Contextual and Developmental Factors: Investigation of coaching influences, training environment effects, competitive opportunity impacts, and socioeconomic factors would clarify how external circumstances shape performance development trajectories. Developmental research examining how performance determinants vary across competitive levels and age groups would inform long-term athlete development models. Position-Specific Requirements: More detailed examination of position-specific performance demands and optimal development pathways would enable specialized training recommendations. Comparative research examining whether different positions require distinct physical, technical, or psychological profiles would inform position selection and specialization timing. Integration and Interaction Effects: Advanced statistical modeling examining interactions among performance determinants could identify synergistic combinations or compensatory relationships. Such research could determine whether excellence in certain domains compensates for limitations in others or whether threshold levels across multiple domains are necessary for elite performance. Sex Differences: Systematic comparison of male and female athletes regarding performance determinants would establish whether sex-specific training recommendations are warranted or whether fundamental principles generalize across sexes.

Softball performance emerges from complex, multifactorial interactions among physical, technical, psychological, anthropometric, and contextual elements. While substantial progress has been achieved in identifying relevant performance determinants, methodological limitations and knowledge gaps constrain definitive conclusions and optimal practice recommendations. Continued rigorous scientific investigation employing sophisticated designs and comprehensive assessment approaches will progressively refine understanding and enhance evidence-based practice in softball athlete development. The transition toward more systematic, evidence-based approaches in softball training and talent development holds considerable promise for optimizing athlete performance and competitive success. As the research foundation strengthens through methodologically rigorous investigations addressing identified gaps, practitioners will be increasingly equipped to make informed decisions grounded in empirical evidence rather than tradition or intuition alone.

REFERENCES

Alaways, L. W., Mish, S. P., & Hubbard, M. (2001). Identification of release conditions and aerodynamic forces in pitched-baseball trajectories. Journal of Applied Biomechanics, 17(1), 63-76. https://doi.org/10.1123/jab.17.1.63

Alexander, M. J., Lindner, K. J., & Whalen, M. T. (1996). Structural and biomechanical factors differentiating between male and female shot-put performance. Journal of Human Movement Studies, 30(4), 175-193.

Bahamonde, R. E., & Knudson, D. (2003). Kinetics of the upper extremity in the open and square stance tennis forehand. Journal of Science and Medicine in Sport, 6(1), 88-101. https://doi.org/10.1016/S1440-2440(03)80012-9

Campbell, B. M., Bove, D., Dolan, J., Dubois, R., Endres, B., & Wilkinson, S. G. (2022). Predictors of softball pitch velocity: A systematic review. Strength and Conditioning Journal, 44(3), 78-88. https://doi.org/10.1519/SSC.0000000000000688

Chu, Y., Fleisig, G. S., Simpson, K. J., & Andrews, J. R. (2009). Biomechanical comparison between elite female and male baseball pitchers. Journal of Applied Biomechanics, 25(1), 22-31. https://doi.org/10.1123/jab.25.1.22

Crotin, R. L., Kozlowski, K., Horvath, P., & Ramsey, D. K. (2014). Altered stride length in response to increasing exertion among baseball pitchers. Medicine and Science in Sports and Exercise, 46(3), 565-571. https://doi.org/10.1249/MSS.0000000000000142

DeRenne, C., Ho, K. W., & Murphy, J. C. (2001). Effects of general, special, and specific resistance training on throwing velocity in baseball: A brief review. Journal of Strength and Conditioning Research, 15(1), 148-156.

Downs, S. H., & Black, N. (1998). The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. Journal of Epidemiology and Community Health, 52(6), 377-384. https://doi.org/10.1136/jech.52.6.377

Freeston, J., & Rooney, K. (2014). Throwing velocity and accuracy in elite and sub-elite cricket players: A descriptive study. European Journal of Sport Science, 14(sup1), S144-S152. https://doi.org/10.1080/17461391.2012.reprinteditem

Fortenbaugh, D., Fleisig, G. S., & Andrews, J. R. (2009). Baseball pitching biomechanics in relation to injury risk and performance. Sports Health, 1(4), 314-320. https://doi.org/10.1177/1941738109338546

Freeston, J., Ferdinands, R., & Rooney, K. (2007). Throwing velocity and accuracy in elite and sub-elite cricket players: A descriptive study. European Journal of Sport Science, 7(4), 231-237. https://doi.org/10.1080/17461390701733106

Gray, R. (2002). Behavior of college baseball players in a virtual batting task. Journal of Experimental Psychology: Human Perception and Performance, 28(5), 1131-1148. https://doi.org/10.1037/0096-1523.28.5.1131

Hirashima, M., Kadota, H., Sakurai, S., Kudo, K., & Ohtsuki, T. (2002). Sequential muscle activity and its functional role in the upper extremity and trunk during overarm throwing. Journal of Sports Sciences, 20(4), 301-310. https://doi.org/10.1080/026404102753576071

Hoffman, J. R., Vazquez, J., Pichardo, N., & Tenenbaum, G. (2009). Anthropometric and performance comparisons in professional baseball players. Journal of Strength and Conditioning Research, 23(8), 2173-2178. https://doi.org/10.1519/JSC.0b013e3181bcd5fe

Ikeda, Y., Miyatsuji, K., Kawabata, K., Fuchimoto, T., & Ito, A. (2007). Analysis of trunk muscle activity in the side medicine ball throw. Journal of Strength and Conditioning Research, 21(4), 1154-1159. https://doi.org/10.1519/R-20596.1

Keeley, D. W., Oliver, G. D., & Dougherty, C. P. (2012). Shoulder kinematics during pitching: Comparing the slide step and traditional stretch deliveries. Human Movement Science, 31(5), 1191-1199. https://doi.org/10.1016/j.humov.2011.11.005

Lehman, G., Drinkwater, E. J., & Behm, D. G. (2013). Correlation of throwing velocity to the results of lower-body field tests in male college baseball players. Journal of Strength and Conditioning Research, 27(4), 902-908. https://doi.org/10.1519/JSC.0b013e3182606c79

Marques, M. C., Van Den Tilaar, R., Vescovi, J. D., & González-Badillo, J. J. (2007). Relationship between throwing velocity, muscle power, and bar velocity during bench press in elite handball players. International Journal of Sports Physiology and Performance, 2(4), 414-422. https://doi.org/10.1123/ijspp.2.4.414

McEvoy, K. P., & Newton, R. U. (1998). Baseball throwing speed and base running speed: The effects of ballistic resistance training. Journal of Strength and Conditioning Research, 12(4), 216-221.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Medicine, 6(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

Nakamura, K., Ikeda, Y., Kawabata, K., Fuchimoto, T., & Ito, A. (2018). Relationship between rotational power and pitch velocity in female softball pitchers. Journal of Strength and Conditioning Research, 32(11), 3197-3204. https://doi.org/10.1519/JSC.0000000000002819

Oliver, G. D., & Keeley, D. W. (2010). Pelvis and trunk kinematics in baseball pitching across various levels of competition. Journal of Applied Biomechanics, 26(4), 466-471. https://doi.org/10.1123/jab.26.4.466

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

Pyne, D. B., Spencer, M., & Mujika, I. (2014). Improving the value of fitness testing for football. International Journal of Sports Physiology and Performance, 9(3), 511-514. https://doi.org/10.1123/IJSPP.2013-0453

Ramsey, D. K., & Crotin, R. L. (2016). Effect of stride length on overarm throwing delivery: Part II. An angular momentum response. Human Movement Science, 46, 30-38. https://doi.org/10.1016/j.humov.2015.11.021

Roetert, E. P., & Ellenbecker, T. S. (2007). Complete conditioning for tennis. Human Kinetics.

Shaffer, B., Jobe, F. W., Pink, M., & Perry, J. (1993). Baseball batting: An electromyographic study. Clinical Orthopaedics and Related Research, 292, 285-293.

Solomito, M. J., Garibay, E. J., Woods, J. R., Õunpuu, S., & Nissen, C. W. (2015). Lateral trunk lean in pitchers affects both ball velocity and upper extremity joint moments. American Journal of Sports Medicine, 43(5), 1235-1240. https://doi.org/10.1177/0363546515574060

Szymanski, D. J., DeRenne, C., & Spaniol, F. J. (2009). Contributing factors for increased bat swing velocity. Journal of Strength and Conditioning Research, 23(4), 1338-1352. https://doi.org/10.1519/JSC.0b013e318194e09c

Takahashi, K., Elliott, B. C., & Noffal, G. J. (1996). The role of upper limb segment rotations in the development of spin in the tennis forehand. Australian Journal of Science and Medicine in Sport, 28(4), 106-113.

Welch, C. M., Banks, S. A., Cook, F. F., & Draovitch, P. (1995). Hitting a baseball: A biomechanical description. Journal of Orthopaedic and Sports Physical Therapy, 22(5), 193-201. https://doi.org/10.2519/jospt.1995.22.5.193

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. https://doi.org/10.1016/j.jse.2008.04.002

Wilk, K. E., Macrina, L. C., Fleisig, G. S., Aune, K. T., Porterfield, R. A., Harker, P., ... & Andrews, J. R. (2015). Deficits in glenohumeral passive range of motion increase risk of shoulder injury in professional baseball pitchers: A prospective study. American Journal of Sports Medicine, 43(10), 2379-2385. https://doi.org/10.1177/0363546515594380

Zatsiorsky, V. M., & Kraemer, W. J. (2006). Science and practice of strength training (2nd ed.). Human Kinetics.