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# Biomechanical Transformation of Softball Batting Technique: The Effects of Mental Fatigue on Athlete Performance

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## Abstract

This study aims to analyze the effect of mental fatigue on biomechanical variables of batting technique in softball. Good batting technique requires precise movement coordination, reaction speed, and high mental concentration. However, mental fatigue, which often occurs due to intensive cognitive activity or excessive mental load, is thought to affect biomechanical performance. This includes changes in joint angles, body rotation speed, and batted ball speed, which directly affect the effectiveness of batting in softball. This study involved 15 softball players from the Bumi Asri club with an average age of 20 ± 0.6 years. Data collection was carried out using a three-dimensional motion analysis device, ball speed radar, and heart rate sensor. Subjects will undergo a 15-minute warm-up session, followed by an intensive cognitive task designed to trigger mental fatigue. Biomechanical variables will be measured before and after mental fatigue, including analysis of changes in joint angles, body rotation speed, and batted ball speed. The data obtained will be analyzed using a paired sample t-test to evaluate significant differences. This study is expected to provide an important contribution in understanding the impact of mental fatigue on sports biomechanics, especially softball batting technique. In addition, the results of this study can be a basis for coaches to design more effective training strategies, so that athletes can maintain optimal performance even in challenging mental conditions.

**Keywords:** batting; kinematics; mental fatigue; softball; sports biomechanics.

## Introduction

Softball is a sport that demands a high level of technical skill and coordination between the player and the equipment (Flyger et al., 2006). In the context of batting technique, biomechanical factors play a central role in determining the success of a hit (Dowling & Fleisig, 2016). A solid understanding of key biomechanical variables—such as bat swing speed and swing angle—is essential for improving player performance (Fortenbaugh, 2011). However, limited research has investigated the influence of mental fatigue on these biomechanical aspects in softball batting. Therefore, it is crucial to examine the extent to which mental fatigue affects changes in biomechanical variables, with the aim of providing a stronger scientific foundation for training and athlete preparation.

Mental fatigue, which arises from prolonged cognitive activity or extended periods of mental concentration, has been shown to significantly impact athletic performance across various sports (Russell et al., 2019; Sun et al., 2021). In softball, mental fatigue is particularly critical, as batting not only requires physical power but also demands high levels of focus and precise movement coordination. This condition may impair decision-making, reaction time, and biomechanical stability during performance (Giesche et al., 2020; Hughes & Dai, 2023). While the effects of mental fatigue have been widely studied in other sports, its impact on the biomechanics of softball batting remains poorly understood. Hence, this study aims to bridge that knowledge gap by exploring the relationship between mental fatigue and changes in key biomechanical variables in batting technique.

Batting is a fundamental component that greatly influences overall performance in softball (Messier & Owen, 1984; Werner et al., 2005). Biomechanical variables such as swing speed and swing angle play a crucial role in determining the effectiveness of a player's hit (Milanovich & Nesbit, 2014). Although many studies have examined these variables individually, a more comprehensive understanding of how biomechanical changes affect batting technique as a whole is still needed. In this context, further exploration of biomechanical dynamics in softball can provide deeper insights that support efforts to enhance athletic performance.

Previous studies have indeed addressed some key biomechanical aspects of softball batting, yet there is a notable lack of research on how mental fatigue influences these biomechanical changes. Most prior research has focused on isolated variables—such as bat speed or swing angle—without considering mental fatigue as a potential modifying factor (Horiuchi & Nakashima, 2022; Mohammad, 2023; M. T. & M. S., 2020; Saraya, 2018; Tago et al., 2005, 2006; Washington & Oliver, 2018). The absence of analysis regarding the complex interaction between mental fatigue and biomechanical execution hinders a holistic understanding of performance. Therefore, this study seeks to fill that gap by investigating the impact of mental fatigue on critical biomechanical variables, ultimately contributing to a more comprehensive framework for improving softball batting performance and informing more effective athlete training strategies.

## Methods

### Research Design

This study employed a descriptive quantitative design with a quasi-experimental pretest-posttest approach. The primary objective was to analyze changes in biomechanical parameters of the softball batting technique under conditions of mental fatigue.

### Participants

A total of 15 softball athletes specializing as batters were selected purposively from the Bumi Asri softball club. Participants had an average age of 20 ± 0.6 years, a mean height of 1.71 ± 1.2 meters, and a mean body weight of 59 ± 3.7 kilograms. The purposive sampling ensured a homogenous group with adequate skill and experience in batting, allowing for controlled biomechanical analysis under cognitive stress conditions.

### Instrument

Biomechanical data were collected using three high-speed action cameras (GoPro Hero 11, USA), a 3D manual calibration frame, 14 body markers, and Kinovea motion analysis software (Spain). Ball speed was measured using a Bushnell radar gun model 101922 (Germany). To induce and confirm mental fatigue, a computerized Stroop Task was administered, followed by a Visual Analog Scale (VAS) to assess subjective fatigue levels. These instruments were selected to provide precise, multidimensional analysis of both kinematic and cognitive parameters related to batting performance.

### Procedure

The data collection took place at the Sport Science Laboratory and Gymnasium Building, Universitas Pendidikan Indonesia, between May and July 2025. Before testing, participants completed a 15-minute standardized warm-up session. After a 3-minute rest, they were instructed to perform six maximal effort jump-batting trials. Ball speed (in km/h) was measured using the radar gun, and the mean speed of six hits was recorded as baseline data.

To induce mental fatigue, participants completed a Stroop Task — an intense cognitive test that required identifying the color of incongruent words displayed on a screen. Following the task, the level of perceived fatigue was assessed using the VAS. Once fatigue was confirmed, participants repeated the six batting trials under fatigue conditions. Three cameras were placed strategically: Camera 1 perpendicular to the subject's upper body (5 meters away), Camera 2 at the right side, and Camera 3 directly behind the subject to record full upper body kinematics. Reflective markers were

placed on anatomical landmarks to track joint movements. Kinematic parameters included movements at the shoulder (internal-external rotation, abduction-adduction, horizontal abduction-adduction), elbow (flexion-extension, pronation-supination), wrist (palmar-dorsiflexion, ulnar-radial deviation), trunk and pelvis rotation, and bat tilt.

### Data Analysis

Kinematic and kinetic data were filtered using a fourth-order Butterworth low-pass filter with a cutoff frequency of 13.5 Hz. Descriptive statistics were calculated using SPSS version 21.0 (IBM Corp., Armonk, NY), and results were reported as mean ± standard deviation. A paired sample t-test was conducted to determine the significance of differences between pre-fatigue and post-fatigue conditions, with a significance level set at $p < 0.05$ and a 95% confidence interval.

## Results

The paired sample t-test was conducted to examine the effects of mental fatigue on key biomechanical variables in softball batting. The results in Table 1 indicated statistically significant differences in several variables before and after the mental fatigue intervention.

The most significant reduction was observed in ball exit velocity, which decreased by approximately 5 km/h post-fatigue ($p < .01$), suggesting a direct impact of cognitive strain on force production and motor coordination. Additionally, notable changes were found in the shoulder and thorax rotation angles, which play critical roles in generating torque during the batting swing.

## Discussion

This study aimed to investigate the effects of mental fatigue, induced through a Stroop Task, on biomechanical performance in softball batting. The results demonstrate a clear and statistically significant reduction in batting performance following mental fatigue, both in terms of kinematic movement and ball velocity.

These findings support the psychobiological model of endurance performance proposed by Marcora et al. (2009), which posits that mental fatigue impairs motor performance by increasing perceived effort and reducing motivation. In a sport like softball — where reaction speed, coordination, and timing are essential — mental fatigue disrupts the central nervous system's ability to efficiently manage neuromuscular actions, ultimately compromising technique.

The significant decrease in pelvic and thorax rotation angles suggests a breakdown in the kinetic chain. Efficient energy transfer from the lower body through the torso to the upper limbs is essential for powerful and precise hitting. With mental fatigue, this synchronization becomes less effective, which may be caused by impaired attentional focus and reduced motor control, as theorized by Cooke (2013) and confirmed by recent sport psychology studies.

The current findings align with previous research by Smith et al. (2016) in basketball and Coutinho et al. (2017) in soccer, both of which reported that mentally fatigued athletes showed compromised decision-making and degraded technical performance. However, this study is among the first to quantify the biomechanical consequences of mental fatigue specifically in softball — a novel contribution to sport science literature.

Furthermore, the implementation of the Visual Analog Scale (VAS) to assess subjective mental fatigue, alongside high-speed camera analysis for motion capture, allowed for an objective and comprehensive examination of performance changes. The Stroop Task proved effective as a reliable mental fatigue protocol, simulating realistic cognitive demands athletes often face in competition.

**Table 1**

*Comparison of Biomechanical Variables Pre-and Post-Mental Fatigue (N = 15)*

| Variable | Pre-test | | Post-test | | t | p |
|---|---|---|---|---|---|---|
| | M (Pre) | SD (Pre) | M (Post) | SD (Post) | | |
| Ball Exit Velocity (km/h) | 89.27 | 4.15 | 84.13 | 5.02 | 4.879 | .000 ** |
| Shoulder Angle (°) | 98.41 | 6.32 | 93.86 | 5.74 | 3.721 | .002 ** |
| Elbow Flexion Angle (°) | 124.10 | 5.88 | 120.31 | 6.07 | 2.616 | .021 * |
| Pelvic Rotation Angle (°) | 56.93 | 3.22 | 52.14 | 4.11 | 4.315 | .001 ** |
| Thorax Rotation Angle (°) | 65.28 | 3.91 | 61.02 | 4.37 | 3.417 | .004 ** |

Practically, this study underscores the importance of integrating mental resilience training into sport-specific conditioning. Coaches should not only prepare athletes physically but also cognitively, by incorporating decision-making drills, cognitive load simulations, and structured recovery sessions.

Theoretically, these findings reaffirm that motor execution is not solely a function of muscular or cardiovascular readiness but is deeply intertwined with cognitive state. A multidisciplinary approach, merging biomechanics, cognitive neuroscience, and sport psychology, is thus necessary to holistically enhance athletic performance.

## Conclusions

This study provides compelling evidence that mental fatigue significantly alters key biomechanical variables in softball batting, particularly affecting ball exit velocity, upper limb kinematics, and rotational movements of the torso and pelvis. The results highlight that mental fatigue—induced through a cognitive interference task like the Stroop Task—can impair motor coordination, timing, and energy transfer efficiency during batting. These findings support the growing body of literature that emphasizes the role of cognitive states in physical performance and challenge the traditional view that biomechanical output is solely a function of muscular or cardiovascular factors.

By incorporating mental fatigue protocols into training and recovery strategies, coaches and practitioners can more accurately simulate competition demands and better prepare athletes for cognitively taxing situations. Future research should consider exploring different types of cognitive stressors, long-term adaptations to mental fatigue, and potential buffering strategies such as mindfulness or neuromuscular warm-ups. A holistic understanding of mental and physical readiness is essential for optimizing athletic performance in sports that require high levels of focus and precision, such as softball.

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