JSSF (10) (1) (2024)

Journal of Sport Sciences and Fitness

http://journal.unnes.ac.id/sju/index.php/jssf

Kinematic Analysis of Hitting: Launch Angle and Swing Velocity Differences in Elite vs. Amateur Softball Swing

Nur Rika Hasanah[1]✉, Agus Rusdiana[2], Iwa Ikhwan Hidayat[3], Iman Imanudin[4], Syam Hardwis[5], Tono Haryono[6]

Sports Science Study Program, Faculty of Sports Education and Health, Universitas Pendidikan Indonesia, West Java, Indonesia[1,2,3,4,5,6]

Article's Info

Article's History:

Received December 2024

Accepted December 2024

Published January 2025

Keywords:
Swing, launch angle, exit velocity, swing velocity, softball

Abstract

Hitting is a basic technique that must be mastered in softball. Efficient hitting requires good coordination between the lower limbs, core, and arms. This study aims to analyze the launch angle and exit velocity characteristics of the hitting technique between elite and amateur softball athletes. This study used a quantitative descriptive method. The population consisted of 13 athletes, including 5 elite athletes and 8 amateur athletes, who were selected using purposive sampling. Data collection used documentation techniques by recording the batting movements of the samples which then the video results will be analyzed using Kinovea and SkillSpector software, and the data was analyzed using SPSS version 26.0 with Independent Sample T-Test. The results showed significant differences in launch angle (p=0.025), exit velocity (p=0.004), and swing speed (p=0.015) between elite and amateur athletes. However, there were no differences in elbow angle (p=0.904) and elbow velocity (p=0.123). This study concludes that there are significant differences in batting technique characteristics between elite and amateur softball athletes, with elite athletes showing better performance in launch angle, exit velocity, and swing speed. However, both samples were similar in elbow and elbow angle velocity.

Correspondence E-mail✉: nurrrika@upi.edu

ISSN 2252-6528

INTRODUCTION

Hitting is the most difficult technique to learn because of the complex movements that must be performed (DeRenne, 2007). According to research by Negara et al. (2021), attention is a crucial aspect of hitting, where a batter must be able to process visual information quickly and accurately as the ball approaches. Recent studies have underscored the importance of kinematic factors, such as the rotation angle and angular velocity of body segments, which are critical for achieving optimal swing mechanics (Buso, 2023; Washington & Oliver, 2018). The sequential rotational movements of the body, combined with coordinated muscle activity, are essential for generating swing speed, which is a key determinant of hitting performance (Williams et al., 2020; Oshikawa et al., 2020; Taniyama et al., 2021). The sequential kinetic chain theory posits that the swing involves a coordinated effort from the feet, hips, shoulders, and arms to produce maximum power (Friesen & Oliver, 2022). Research has demonstrated that muscle activity begins in the legs, with the hamstrings, hips, and trunk exhibiting the highest levels of activation. As the swing progresses, muscle activity in the trunk decreases, culminating in lower activation in the arms (Owen et al., 2020). This sequential activation pattern is vital for generating the force necessary for an effective swing.

Swing ability is expected to produce effective shots or what is known as barrel shots. A barrel shot is a shot where the ball hits the "sweet spot" of the bat (5-7 inches from the end of the bat and the center of the bat), resulting in the optimal rate and angle of launch to produce a long and effective shot (Andrew Gillingham Norman, 2019). Statcast defines a barrel shot as a ball that has a combination of a launch angle between 26-30 degrees and an exit velocity of at least 98 mph (MLB; Punchihewa et al,. 2021). These two parameters play an important role in determining the success of a barrel shot (Inkster et al., 2011; Nasu et al., 2020).

Many studies that have been conducted by researchers only focus on studying kinematics and EMG. While much of the existing literature has focused on kinematics and electromyography (EMG), which measures the electrical activity of muscles during contraction (Williams et al., 2020), there is a growing recognition of the need to explore additional factors that influence hitting performance.The motion of the object being analyzed is position, velocity, acceleration, and time, without the need to discuss the forces acting on the object (Serway & Jewett, 2018). This focus on motion analysis is crucial for understanding the dynamics of the swing, including position, velocity, and acceleration (Oshikawa et al., 2020). Studies on the kinematics of baseball swings have long been conducted on the importance of hip and trunk rotation in generating bat speed. However, research (Kidokoro & Morishita, 2021) emphasizes that bat angle and swing trajectory are very influential in optimizing hitting performance in softball. So it can be concluded that good kinetic quality does not guarantee that it will produce optimal shots if it does not pay attention to bat angle and swing trajectory.

This study aims to analyze motion kinematics based on the parameters of exit velocity, glide angle, and swing speed of elite and amateur softball athletes which are still rarely researched. although the difference in skills between elite and amateur athletes is clear as the results of research by Gumilar et al.

(2021) revealed that athletes with high skills have better batting speeds than beginners, which shows the importance of experience in improving performance. However, this comparative research will still be useful to identify specific areas where elite athletes outperform amateur athletes. Thus, amateur athletes can improve their deficiencies, help develop training development programs, and reduce the risk of injury. Oliver et al. (2019) showed that proper swing kinematics can reduce the risk of injury, which is often a problem for amateur athletes who may not have adequate knowledge or training.

METHOD

Participants

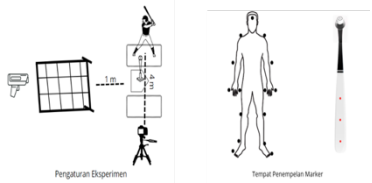
The participants in this study consisted of 13 softball athletes consisting of 5 elite athletes (average age 19.8 ± 1.09, height 161.8 ± 7.04, weight 57.44 ± 12.37) and 8 amateur athletes (average age 20.0 ± 0.75, height 158.62 ± 5.97, weight 56.10 ± 8.05) who were selected based on predetermined inclusion criteria. For the elite athlete category, participants had a minimum of 3 years of training experience and had been part of a national or provincial team. Meanwhile, for the amateur athlete category, participants must have a minimum of 2 years of training experience and have never been part of a national or provincial team. The age of participants is limited to between 18-25 years and is female. The participant sample consisted of West Java PON softball athletes for the elite athlete category and UPI UKM softball athletes for the amateur athlete category. Before the research was conducted, the participants were given an explanation regarding the objectives and procedures of the study so that the participants understood and agreed to the entire research process being carried out.

Kinematics

Kinematics parameters measured include launch angle, exit velocity, and swing velocity. Launch angle is measured using a motion capture system or high-speed camera Handycam Panasonic HC-V785 placed 4 meters in the sagittal direction of the bat to record the movement of the bat during swing and ball-bat impact. Exit velocity is measured using a radar gun or Bushnell speed sensor placed behind the net or target to measure the speed of the ball when it is hit. Measurements are taken when the athlete hits the maximum shot cause is crucial for enhancing a player's performance, as it directly correlates with the distance the ball travels (Stewart et al., 2021). Swing velocity is one of the factors that determine the strength and effectiveness of a player's swing with units of miles per hour (mph) or kilometers per hour (km/j). Penelitian telah menunjukkan bahwa meningkatkan kecepatan ayunan menghasilkan banyak manfaat: meningkatkan waktu pengambilan keputusan, mengurangi durasi ayunan tanpa mengubah mekanisme ayunan, dan meningkatkan kecepatan bola pada saat impact (Gilmore et al., 2019). Furthermore, the athletes' video data was analyzed using the Kinovea application for visualization and measurement of movement kinematics, and the Spektor skill for extraction and analysis of quantitative data related to position, velocity, and acceleration. The analysis can provide a more comprehensive picture of softball hitting techniques that differentiate elite athletes and amateur athletes.

Procedure

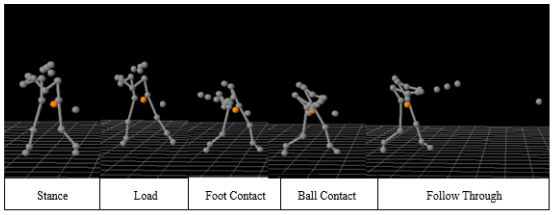
Swing data collection was carried out using the batting tee method. This condition is clearly different from the real game situation but one can see the athlete's ability more accurately because there is no external influence such as ball speed so it only focuses on swing techniques. In addition, Nasu et al. (2020) emphasized that the swing speed on a stationary ball is highly correlated with the output speed, After warming up, the participants will be given the opportunity to practice hitting using all the equipment that will be used in the study to familiarize themselves with the data collection situation. This is also to ensure proper positioning between the batting tee and the bat. Before the measurements are taken, reflective markers will be attached to certain anatomical points on the participants' bodies. The placement of these markers will facilitate the motion capture process in recording batting movements accurately. Markers will be attached to the forehead, shoulders, elbows, wrists, hips, knees, ankles, and toes (markers are attached to the right and left body parts). In addition, there were 4 reflective markers attached to the bat. After that, each participant was asked to hit the ball for 3 attempts with a maximum swing with the same type of bat, worth sick 454 FPSIC9 33/24. This aims to eliminate research bias, because based on research by Nesbit and Milanovich Nesbit & Milanovich (2021) showed that the inertial properties of the bat can affect the way athletes swing, which in turn has an impact on bat speed and effectiveness.



Picture 1. Field Setup and Marker Placement

Data Analysis

Statistical analysis was conducted to compare the kinematics parameters between the two groups. An independent samples t-test was used to determine if there were significant differences in the values of launch angle, exit velocity, swing velocity, elbow angle, and elbow angular velocity between elite and amateur athletes.



Picture 2. Swing Movement

RESULT AND DISCUSSION

Table 1. Average launch angle, exit velocity, and swing velocity

	Average Atlet Elit ± SD	Average Atlet Amatir ± SD	Signifikansi
Launch angle	-.74 ± 1.59	10.83 ± 9.77	.025
Exit velocity	116.42 ± 33.9	64.42 ± 19.34	.004
Swing velocity	94.5 ± 32.53	53.59 ± 18.94	.015

Based on the data depicted in Table 1, it shows that there are differences in launch angle, exit velocity, and swing velocity between elite athletes and amateur athletes. The data shows that elite athletes have an average launch angle of -.74 ± 1.59 much smaller than the average amateur athlete of 10.83 ± 9.77. So there is a significant statistical difference (p=0.025). This finding aligns with research by Lux et al. (2021), which suggests that a smaller launch angle can positively influence exit velocity. Specifically, Lux et al. (2021) found that a decrease in launch

angle can increase exit velocity. Therefore, the lower launch angle observed in elite athletes likely contributes to their higher exit velocities.

Furthermore, the average exit velocity of elite athletes is 116.42 ± 33.9 mph much greater than the average amateur athlete who has a value of 64.42 ± 19.34 mph. Thus, there is a significant statistical difference (p=0.004).

Based on several studies, a smaller launch angle can affect exit velocity (Kidokoro & Morishita, 2021) this is in line with research (Lux et al., 2021) which shows that every 0.57 decrease at the point of impact can result in an increase in exit velocity by 1 mph. In line with a smaller launch angle, Exit velocity will automatically be higher and produce a more effective and efficient shot.

Furthermore, the average swing velocity of elite athletes was 94.5 ± 32.53 mph, while amateur athletes had a much smaller average swing velocity of 53.59 ± 18.94 mph. The data showed a statistically significant difference (p=0.015).

In addition, higher swing velocity will produce faster bat swing movements, and produce hard hits. Studies have shown that increasing swing velocity yields multiple benefits: it enhances decision-making time, reduces swing duration without altering the swing mechanics, and increases the speed of the ball upon impact (Gilmore et al., 2019). Then, the higher the swing velocity, the batted-ball velocity, or the speed of the ball after being hit will increase and produce a long and hard hit.

Table 2. Average Angle Elbow and Angle Elbow Velocity

	Average Atlet ± SD	**Average Non-atlet ± SD**	**Signifikansi**
Angle elbow	115.56 ± 13.06	114.82 ± 8.60	.904
Angle elbow velocity	9.23 ± 4.27	5.19 ± 3.79	.123

From the data in Table 2, the data shows that the average elbow angle of elite athletes was 115.56 ± 13.06 degrees, while amateur athletes had a slightly smaller average elbow angle of 114.82 ± 8.60 degrees. However, this difference in elbow angle was not statistically significant (p=0.904). This finding aligns with existing literature that highlights the importance of elbow positioning in pitching and swinging mechanics, where slight variations may not necessarily translate into performance differences (Moeller et al., 2022).

Furthermore, the average elbow velocity of elite athletes was 9.23 ± 4.27 mph, while amateur athletes had a higher average elbow velocity of 5.19 ± 3.79 mph. However, the difference in elbow velocity between elite and amateur athletes was not statistically significant (p=0.123). This observation raises interesting questions about the mechanics of swinging and the potential for amateur athletes to optimize their elbow velocity through refined techniques and training. Previous studies have indicated that while elite athletes may have superior overall mechanics, the specific metrics of elbow velocity can vary widely based on individual technique and training backgrounds (West et al., 2019).

Other important factors that influence a shot are elbow angle, elbow angle speed, and arm coordination. A larger elbow angle can facilitate a wider range of motion, optimizing muscle contraction and contributing to more

powerful swings (Buso, 2023). Furthermore, a large elbow angle can also help optimize the contraction of the arm muscles which provides additional strength and promotes better control and coordination. This results in a more powerful and effective bat.

In addition, (Lux et al., 2021). emphasizes the importance of other factors such as lower limb coordination and the core of the body as the main source of power. The arm plays an important role in transferring that power efficiently to the bat. Therefore, an optimal combination of elbow angle, elbow angle velocity, arm coordination, as well as contributions from the lower limbs and core of the body are key to producing powerful and accurate hits in baseball and softball.

This study concludes that there are significant differences in batting technique characteristics between elite and amateur softball athletes, with elite athletes showing better performance in launch angle, exit velocity, and swing speed. However, both samples were similar in elbow and elbow angle velocity.

CONCLUSION

The results of research on the analysis of the characteristics of softball hitting techniques between elite athletes and amateur athletes show significant differences in the characteristics of launch angle, exit velocity, and swing velocity. These three variables play an important role that is interrelated with each other in producing the success of a stroke. Based on the findings, a smaller launch angle can increase exit velocity, while a higher swing velocity will produce a faster bat swing movement and a harder hit.

In addition, in this study, there was no difference between elbow angle and elbow angle velocity between the two samples. So that further research needs to be done to explore how these kinematic parameters influence overall performance regarding what causes differences in swing in other variables and analysis of strokes in real matches and athletes hitting from pitching machines or life pitches from pitchers so that they can produce a more comprehensive understanding of effective and optimal hitting techniques.

REFERENCES

Andrew Gillingham Norman, B. (2019). THE RELATIONSHIP BETWEEN BATTER'S EYES CHARACTERISTICS, THE HITTING PROCESS AND HIT QUALITY AMONG MAJOR LEAGUE BASEBALL PLAYERS.

Buso, D. (2023). Effects of medicine wall ball throws with whole-body vibration on bat swing performance in collegiate baseball players. The Journal of Strength and Conditioning Research, 37(10), 2071-2075. https://doi.org/10.1519/jsc.0000000000004584

DeRenne, C. (2007). The scientific approach to hitting: research explores the most difficult skill in sport. San Diego, CA: University Readers, 254-255.

Friesen, K. and Oliver, G. (2022). Softball pitching propulsion and performance differences according to body fat percentage. International Journal of Sports Medicine, 43(10), 895-901. https://doi.org/10.1055/a-1778-4359

Gilmore, S., Brilla, L., Suprak, D., Chalmers, G., & Dahlquist, D. (2019). Effect of a high-intensity isometric potentiating warm-up on bat velocity. The Journal of Strength and Conditioning Research, 33(1), 152-158. https://doi.org/10.1519/jsc.0000000000002855

Gumilar, A., Darajat, J., Ma'mun, A., Nuryadi, N., Hambali, B., Mudjihartono, M., … & Mulyana, D. (2021). Batting performance analisys of west java athletes. Jurnal Pendidikan Jasmani Dan Olahraga, 6(2). https://doi.org/10.17509/jpjo.v6i2.37215

Inkster et al. "Differences in the Kinematics of the Baseball Swing between Hitters of Varying

Skill" Medicine & science in sports & exercise (2011) doi:10.1249/mss.0b013e318203626a.

Kidokoro, S., & Morishita, Y. (2021). Relationship between impact characteristics and launch direction in softball hitting: A study involving elite players. PLoS ONE, 16(11). https://doi.org/10.1371/journal.pone.0260520

Lux, L., Larson, C. A., & Larson, C. (2021). The Biomechanics of the Softball Swing in Seven Stages: The Biomechanics of the Softball Swing in Seven Stages: Optimizing Exit Velocity Optimizing Exit Velocity The Biomechanics of the Softball Swing in Seven Stages: Optimizing Exit Velocity. https://lux.lawrence.edu/luhp

Major League Baseball. (2024, September 9). Glossary. MLB.com. https://www.mlb.com/glossary/statcast/barrel

Moeller, J., Swantek, A., Ziedas, A., Bazzi, A., Gasparro, M., & Makhni, E. (2022). Elbow stress in youth softball windmill pitchers: predictors of increased torque. Moj Sports Medicine, 5(3), 116-120. https://doi.org/10.15406/mojsm.2022.05.00130

Nasu et al. "Behavioral Measures in a Cognitive-Motor Batting Task Explain Real Game Performance of Top Athletes" Frontiers in sports and active living (2020) doi:10.3389/fspor.2020.00055.

Negara, J., Mudjianto, S., Budikayanti, A., & Nugraha, A. (2021). The effect of gamma wave optimization and attention on hitting skills in softball. International Journal of Human Movement and Sports Sciences, 9(1), 103-109. https://doi.org/10.13189/saj.2021.090114

Nesbit and Milanovich "Softball bat inertial considerations and their effects on female softball swing mechanics and estimated bat performance" Proceedings of the institution of mechanical engineers part p journal of sports engineering and technology (2021) doi:10.1177/17543371211063988.

Oliver, G., Friesen, K., Barfield, J., Giordano, K., Anz, A., Dugas, J., … & Andrews, J. (2019). Association of upper extremity pain with softball pitching kinematics and kinetics. Orthopaedic Journal of Sports Medicine, 7(8). https://doi.org/10.1177/2325967119865171

Oshikawa, T., Kaneoka, K., Morimoto, Y., & Akuzawa, H. (2020). Comparison of lumbar kinematics with a history of low back pain during baseball hitting. International Journal of Sports Medicine, 41(02), 119-127. https://doi.org/10.1055/a-1014-3041

Owen, M., Gambill, J., Damme, K., Byrd, J., & Jardins, J. (2020). Balance improvements and golf swing kinematic consistency with eight week balance intervention. Journal of Sports Research, 7(2), 50-62. https://doi.org/10.18488/journal.90.2020.72.50.62

Punchihewa, N., Arakawa, H., Chosa, E., & Yamako, G. (2021). A hand-worn inertial measurement unit for detection of bat–ball impact during baseball hitting. Sensors, 21(9), 3002. https://doi.org/10.3390/s21093002

Serway, R. A., & Jewett, J. W. (2018). Physics for Scientists and Engineers with Modern Physics (10th ed.). Cengage Learning.

Stewart, E., Stewart, M., Arachchige, S., Turner, A., Burch, R., Knight, A., … & Chander, H. (2021). Validation of a bat handle sensor for measuring bat velocity, attack angle, and vertical angle. International Journal of Kinesiology and Sports Science, 9(2), 28. https://doi.org/10.7575/aiac.ijkss.v.9n.2p.28

Taniyama, D., Matsuno, J., Yoshida, K., Pyle, B., & Nyland, J. (2021). Rotational medicine ball throw velocity relates to ncaa division iii college baseball player bat swing, batted baseball, and pitching velocity. The Journal of Strength and Conditioning Research, 35(12), 3414-3419. https://doi.org/10.1519/jsc.0000000000004148

Washington, J. and Oliver, G. (2018). Kinematic differences between hitting off a tee versus front toss in collegiate softball players. International Biomechanics, 5(1), 30-35. https://doi.org/10.1080/23335432.2018.1472038

West, A., Scarborough, D., McInnis, K., & Oh, L. (2019). Strength and motion in the shoulder, elbow, and hip in softball windmill pitchers. Pm&r, 11(12), 1302-1311. https://doi.org/10.1002/pmrj.12135

Williams, C., Donahue, P., Wilson, S., Mouser, J., Hill, C., Luginsland, L., … & Garner, J. (2020). Examining changes in bat swing kinematics in different areas of the strike zone in collegiate baseball players. International Journal of Kinesiology and Sports Science, 8(2), 1. https://doi.org/10.7575//aiac.ijkss.v.8n.2p.1