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Biomechanical Analysis of Slingshot Grip dan Pull in Traditional Game

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Abstract
Slingshot is a traditional game that has several basic techniques that must be mastered. Some of the basic techniques in the traditional slingshot game have not been fully understood by some players. This study aims to analyze the biomechanical grip and pull of slingshot in traditional games. This quantitative study used a sample consisting of 10 traditional slingshot game players in Semarang Regency. Kinematic data were obtained from the slingshot shooting video analysis using Kinovea software version 0.9.5. The kinematic data consisted of three phases: preparation, release, and followthrough. This study found that the ideal grip is a straight hand position that is parallel to the arm pull until an angle of 90^{o} is formed. Effective and efficient pulling techniques are carried out by pulling and anchoring the rubber in the preparation phase right on the cheekbone as a support point. Hence, the rubber pull is consistent in the same position. Further study needs to be conducted to discuss the analysis of the length of the pulling and shooting accuracy.

Keywords: Biomechanics analysis; grip; pull; slingshot; traditional games

1. Introduction

Traditional games are one of the cultural evidences of ancestral heritage in Indonesia that has inherent cultural characteristics; they are in the form of games and sports activities that grow from the habits of certain populations (Handoko & Gumantan, 2021). Traditional games are original Indonesian sports that are the legacy of ancestors with inherent cultural characteristics. Traditional games are closely related to the cultural heritage of society because they teach life values (Irawan, et al., 2023). This culture can train children's skills in socializing in society, and no less important in socializing with their peers (Puspitasari, 2022). Traditional games are very necessary to be maintained and preserved. Through traditional games, the culture and identity of a society can be preserved and passed on from generation to generation (Himawan & Pujihartati, 2020).

According to Hayati & Hibana (2021), traditional games in each region have different rules and concepts according to the region's origin and the times. Some may have undergone changes in the rules or equipment used. Traditional games are classified as traditional sports because the activities carried out contain real physical elements involving large muscle groups and contain elements of play, so they are said to be traditional sports. The scope of sports includes various types such as achievement sports, recreational sports, sports as education, and traditional sports (Soendari & Agustia, 2012). Of the many types of traditional games that people know today, there are many that contribute to having a positive impact on the players, one of which is the traditional slingshot game (Irawan & Permana, 2019). Slingshot is a traditional sport that involves gross motor skills because it performs activities using its large muscles (Rahmawati & Afifulloh, 2022). Gross motor skills are very important and must be possessed by children as a basis for mastering further, more complex movements. Motor skills that work properly will make children do activities by moving their hands and feet without feeling stiff and will become agile (Santoso & Setiabudi, 2020).

Traditional slingshot sports are also known as slingshot games and have been played for centuries in various cultures around the world (Kurniaziz et al., 2022). Based on Rahesti et al. (2023), playing slingshot is not just about shooting until the bullet reaches the target. However, there are several things to consider, such as playing techniques ranging from body positioning, installing, frame holding, rope pulling (drawing), anchoring, aiming techniques, bullet release techniques (release), and the last one the continuous motion until the bullet hits the target (follow through). Traditional slingshot sports are included in the accuracy branch, where calmness, balance, and accuracy are needed in order to aim the target correctly (Irawan & Ghassani, 2022). The speed of the bullet will not be straight with the target if the shooter stands unsteadily. Therefore, each of these complex stages must be studied in detail and supported by science and technology.

In traditional sports, biomechanical motion analysis is necessary for coaches and teachers, particularly to know the movements and muscles that can improve the ability and perfect movements (Wibisona et al., 2019). The urgency of this research is to find out the problems in traditional games through motion analysis in slingshot game through sports science studies to improve the performance of slingshot players in Semarang. According to (Prastiwi & Irawan, 2022), biomechanics is a special science that studies motion in living things. In the field of sports, biomechanics has a role in providing evaluation of every movement that is considered to achieve the process of improving athlete performance (Rahesti et al., 2023). In addition, sports biomechanics can be useful in preventing injuries. Biomechanical analysis in sports can prevent injuries to athletes while providing recommendations for effective and efficient movements (Irawan & Long-Ren, 2019). With the advancement of technology that continues to grow, biomechanical analysis can be done easily to analyze movements through videos or images and then will be processed in video analysis software (Billah & Irawan, 2022). Kinovea video analysis application is one of the video analysis applications (Irawan, Permana, et al., 2023) that is often used to analyze a valid movement.

Based on the results of observations that have been made by researchers at the Semarang Regency Elementary Level Folk Games Festival event held on November 17, 2022, at Bung Karno Ungaran Square, it was found that when performing the slingshot techniques, 60% of players executed it incorrectly, such as incorrect position of the grip and incorrect alignment of the pull. This can be seen from the incorrect shots of the target. Related to the study by Prastiwi & Irawan (2022), the biomechanical aspects of the body influence the results of a movement. Their study showed that kinematic data were used to analyze the movements of each body segment.

Santoso and Setiabudi (2020) discovered that a physical analysis of the pull carried out with a mathematical model based on existing physical phenomena suggested that the angles of the ankles, knees, and waist simultaneously affect the maximum pulling force. Furthermore, there is a very strong relationship between holding the rope and the pulling force, then there is a negative relationship between body angle and the pulling force. So that the angle of the ankle, knee, and waist simultaneously encourage maximum pulling force.

Although there are differences between slingshots and tug-of-war in traditional games, slingshots have some similar techniques to the tug-of-war method. There is a very strong connection and relationship between holding the rope and the strength of the pull performed when connected to the findings in the current study where the rope pull will also affect the shot's direction, speed, and strategy. This is in accordance with the performance concept of the traditional slingshot sport, where the body angle also affects the slingshot pulling force, which will impact the result of the bullet shot taken. Rarely are studies that analyze traditional sports through biomechanical aspects. This makes researchers interested in analyzing the movement of grip and pull in traditional slingshot sports in biomechanical aspects. The purpose of this study is to analyze the biomechanical grip and the pull of slingshot in traditional sport. The results of the data in this study could be useful for developing training and providing input to coaches and players of traditional slingshot games. Researchers also hope this study can be used as a reference for further study.

2. Method

This study used quantitative research that was explained in detail using descriptive analytics (Purnomo & Irawan, 2021). Research data were obtained using a one-shot case study method (Cendra & Gazali, 2019). The data collection technique using the one-shot case study (Soendari & Agustia, 2012) is done by one video recording of a slingshot performance, which is then analyzed. This study used a quantitative descriptive method to analyze the biomechanics of slingshot grip and pull in traditional games. The sample in this study was 10 players of traditional slingshot games in Semarang Regency, and all players completed an informed consent as a willingness to participate in the research. The analysis focused on the angle of the grip and pull (Irawan, Sutaryono, et al., 2021), the foot's distance in the stance, and the time in performing a series of slingshot movements. Quantitative data in this study is kinematic data consisting of 3 phases: the preparation phase, the release phase, and the followthrough phase. Several tools supported this research, including 1) a Nikon digital camera type D5200, 2) a camera tripod, 3) stationery, and 4) a laptop with Kinovea application version 0.9.5. This study also was approved by the Health Research Ethics Committee of Universitas Negeri Semarang, Indonesia.

The present study used survey methods, observation, and analysis in the form of video analysis from which kinematic data was taken, including time, distance, and angle. The research procedures were as follows: (1) explaining to the subjects about the test, (2) giving the subjects some time to prepare and try the slingshot stool, (3) preparing equipment such as cameras, tripods, and stationery, (3) placing the camera perpendicular to the subject and recording when the subject starts playing the slingshot, (4) shooting of slingshot by the subjects with a predetermined number of bullets.

3. Result

The study used several indicators, including height, overall movement time, standing leg distance, grip angle, pull angle, aiming angle, torque angle, and bullet velocity to the target, which was provided with a distance of 7 meters. The motion analysis in this study is divided into 3 phases: preparation, release, and followthrough. Table 1 explains the motion analysis results.

Table 1. Motion analysis results

N=10		Mean ± SD	Min	Max
Body height (m)		1.449 ± 0.119	1.268	1.674
Time (s)		4.93 ± 0.786	3.28	6.12
Stride Leg (m)		0.264 ± 0.124	0.128	0.565
Preparation Phase	Time (s)	2.17 ± 0.996	0.88	4.08
	Grip Angle (°)	99.08 ± 5.995	92.9	112.9
	Pull Angle (°)	98.11 ± 22.956	44	137.2
Release Phase	Time (s)	1.988 ± 0. 957	0.56	3.48
	Grip Angle (°)	99.66 ± 4. 977	93.1	109.9
	Pull Angle (°)	103.76 ± 26.22	33	137.1
	Shot Angle (°)	5.01 ± 1.563	2.4	7.5
	Torso angle (°)	169.8 ± 10. 316	140.9	178.8
	Arm length (m)	0.485 ± 0.165	0.353	0.956
	Pull length (m)	0.726 ± 0.362	0.515	1.788

N=10		Mean ± SD	Min	Max
	Speed (m/s)	30.667 ± 11.628	17.5	58.33
Followthrough Phase	Time (s)	0.512 ± 0.333	0.08	1.04

Based on Table 1, the results of kinematic data analysis of a series of slingshot movements of 10 persons in Semarang Regency are as follows: the average total time obtained of 4.93 ± 0.786 second, with a division of time in the preparation phase with an average of 2.17 ± 0.996 second, time in the release phase 1.988 ± 0.957 second, and time in the followthrough phase 0.512 ± 0.333 second. From the existing data, the preparation phase has an average grip angle of 99.08 ± 5.995° with a pull angle of 98.11 ± 22.956°, and the release phase has an average grip angle of 99.66 ± 4.977° and a pull angle of 103.76 ± 26.22°. The average angles of grip and pull in the preparation and release phases differ significantly because the data on one of the samples is at a very small angle of pull of 44° in the preparation phase and 33° in the release phase.

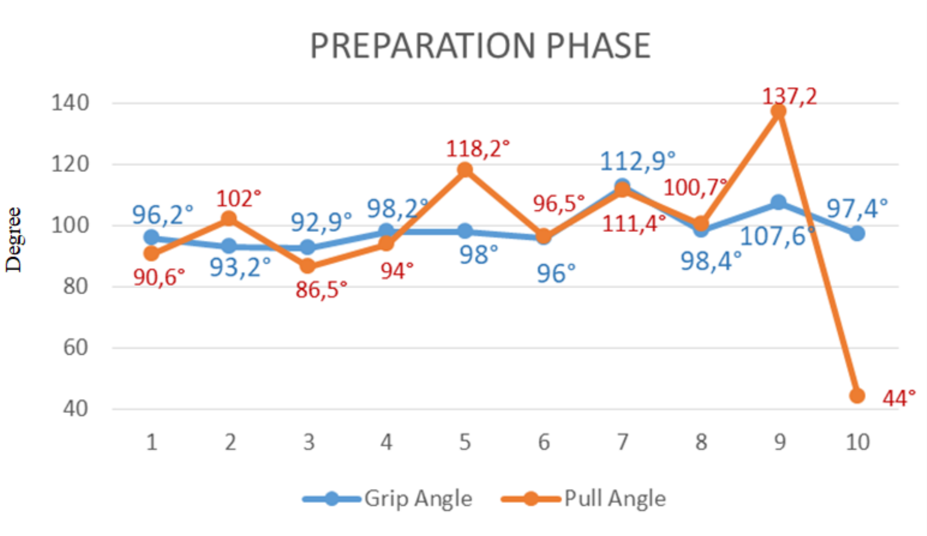

Figure 1. Grip and Pull Angles of the Preparation Phase

Figure 1 presents data from the grip angle in the preparation phase, with the smallest angle formed at 92.2° by subject number 3 and the largest angle at 112.9° by subject number 7. While in the pull angle, the smallest angle formed at 44° was produced by subject number 10, and the largest pull angle was at 137.2° by subject number 9. The grip angles that were too large or too small occurred because the grip arm was not strong enough to withstand the pull. Then, the small angle of pull, or less than 90°, was produced by the subject due to the arm being less stretched and the body position being too bent, while the subject who produced a grip angle exceeding 90° was due to the position of the elbow being too raised.

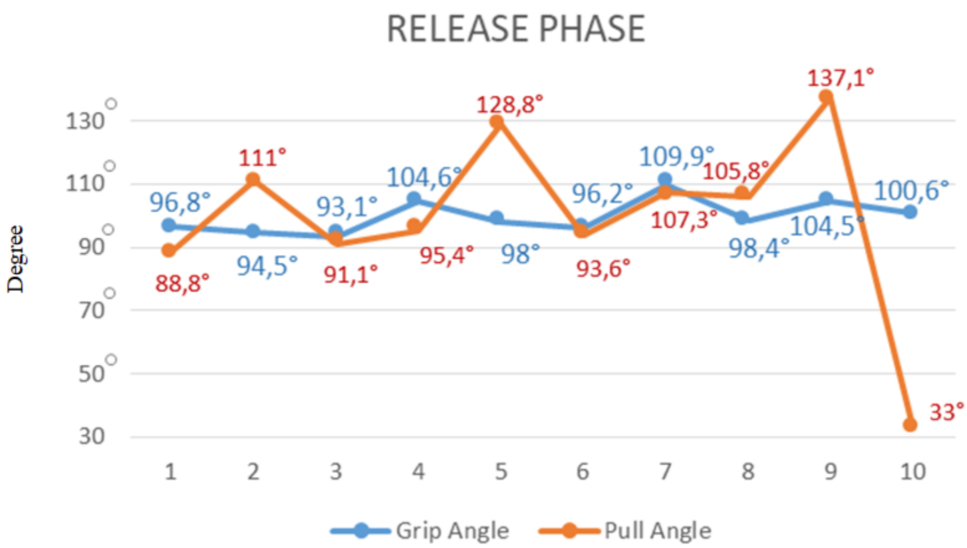

Figure 3. Grip and Pull Angle of The Release Phase

Figure 3 presents data on the release phase of the smallest angle formed from the grip angle of 93.1° produced by subject number 3 and the largest grip angle of 109.9° by subject number 7. On the other hand, at the pull angle, the smallest angle of 33° was produced by subject number 10, and the largest pull angle of 137.1° was produced by subject number 9. The grip angle must form approximately 90° with the goal of making the grip arm straight toward the target. The pull angle must form an angle of 90° by placing the right anchor point, namely on the cheekbone, every time players pull the rubber slingshot.

4. Discussion

Based on the results of this study on the analysis of slingshot motion analysis, each subject shot using 5 bullets at a 7-meter distance. The best data from each sample per indicator will be taken as data per sample. Body height measurement is needed because the height of the players will affect the final result of a shot. Body height is useful in making slingshot shots because a person's height is influential in helping to improve shooting abilities such as balance, eyes, elbows, and followthrough abilities (Ramadhan & Irawan, 2022). This shooting ability is the initial capital of slingshot players to support the level of accuracy because accuracy is the most important thing in playing slingshot.

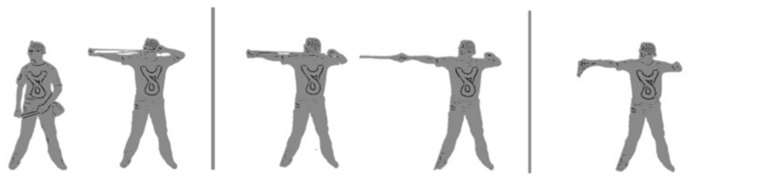

Figure 4. Slingshot Phase

The movement technique in each phase must be done correctly to get the optimal final result; the essential technique in traditional slingshot games is the grip and pull technique. There are four types of different ways of holding slingshots, namely the ancient handle, the gangster handle, the hammer handle, and the finger handle. Of the four handles, the common one that is used by many is the gangster grip. The gangster grip or side grip technique is a way of holding the slingshot vertically by turning the wrist 90° inward so that it is parallel to the pulling arm. Using the gangster grip eases slingshot players to aim at targets using the rubber tip of the upper slingshot; besides that, the gangster grip is considered quite stable compared to other types of grips. The grip and pull in the traditional slingshot game must be considered; the angle formed by the shoulder as a puller and the arm that must be straight as a handle can affect the final result of the shot, namely the intended target.

The preparation phase begins when the position of the feet is already on the shooting line with an open stance with the feet shoulder-width apart, the body position is parallel to the target direction, and the position of the head turns to face the target, all parts are positioned in such a way as to achieve the correct biomechanical attitude. Balance at the time of shooting will be influenced by the standing position, especially the distance between the two legs to support the body's weight. The data show that the smallest foot distance was 0.128 meters, and the largest was 0.565 meters. The ideal leg length is shoulder-width apart, where the distance will be adjusted to the shooter's height. In the data, the average foot distance was 0.264 meters with a standard deviation of ± 0.124 meters. When most of the subjects were standing, their legs were less open, which caused the stance of the legs to be not strong. This position, in turn, caused the body to vibrate easily and become unstable. A better position would be a standing position with both feet shoulder-width apart, as done by subject 1, which resulted in a foot distance of 0.565 meters with the appropriate foot position, which was shoulder-width, intending to have a strong stance so that is stable in aiming at the target. An anchoring movement where the rubber-pulling hand that clamped the bullet was placed right on the cheekbone.

The standing position is followed by installing the bullet by placing it on the rubber pad and pulling the rubber after the bullet is installed. In the preparation stage, the angle of the hand grip and the angle of the arm pull will be formed; in the results of the subject data in Table 1, the hand grip angle had an average of 99.08 ± 5.995^o. The average value of the arm pull angle was 98.11 ± 22.954^o. The grip and pull angles had the smallest angles produced, 92.9^o for the grip and 44^o for the pull. The difference in the smallest angle produced was significant, leading to different standard deviation results. In the slingshot game, anchoring is a movement to anchor the pulling hand on the cheekbone; some things that must be considered in anchoring include the hand pulling the rope must remain attached to the cheekbone as a benchmark.

The release phase begins with a smooth release of the bullet cushion pull by relaxing the fingers. As soon as the bullet pad is released, the bullet will be ejected forward. Before releasing, the previous pull will go through the aiming technique or aiming; the aiming technique is done by inserting the shadow of the aiming device into the target point. When aiming, the body position is not expected to change; this is done so that the player is more focused on the target. The body position, slingshot grip, arm pull, and length of the shot must be considered because it will affect the final result of the bullet shot. Based on the observation of every world championship in archery, athletes only take 3-4 seconds on average from anchoring to release (Vanagosi, 2015). In the present data, 10 subjects had an average time of 1.988 seconds with a standard deviation of ± 0.957 seconds, the fastest time record was 0.56 seconds and the longest was 3.48 seconds, a total of 5 subjects with a record time below 2 seconds were considered too hasty to release the bullet. As for the grip and pull techniques, the average grip angle was recorded at 99.66^o with a standard deviation of 4.977^o. The average pull angle was 98.11^o with a standard deviation of ± 22.956^o. The grip and pull angles in the release phase were the same as in the preparation phase, where the minimum data between the grip angle data of 93.1^o and the pull angle of 33^o caused a difference in standard deviation. Previous studies found that kinematic data with different standard deviations were due to the minimum data that has much difference (Irawan, Raharja, et al., 2021).

The error that caused the grip angle to be less or more than 90^o was that the elbow arm did not rotate straight resulting in the movement of the slingshot sight located at the upper end of the slingshot to determine the direction of the shot. The correct elbow rotation will keep the slingshot handle straight. The pull angles produced by some subjects were not close to 90^o because the anchor point was not right on the cheekbone. If the angle formed is too small, the bullet will shoot far below the target. On the contrary, if the angle formed is too large, the bullet will shoot far above the target. Similar to archery where the angle and position of the elbow play an important role in the force at the shoulder, slingshot games are also influenced by both the angle of the pulling arm and the perpendicular hand holding the slingshot (Mukhtar & Rubiono, 2020). The stages of the correct grip and pull technique are: the arm holding the slingshot at shoulder level and tilted inward so that the slingshot sight is tilted and the pulling hand is ready to pull the slingshot rubber. There will be a shoulder abduction movement (the left arm as the slingshot holder); the pulling arm is raised to shoulder height and then positioned to touch the cheekbone. Furthermore, the neck rotates to the left or neck rotation to the left (if pulling rubber with the right hand). In the right hand, there is elbow flexion and shoulder abduction of the upper arm. The last phase is followthrough or continued motion after the release phase occurs. The followthrough technique can affect the shot's success and facilitate the control of the bullet release motion in the release phase to remain stable.

The angle formed from the data in the grip and pull in the preparation phase to the release phase had a different amount. This was because, in the release phase, it passed the aiming technique where the shooter had ensured that when the bullet was released it would hit the target correctly. The difference in angles formed in the preparation phase to the release phase should not have too much different because it will provide many changes in movement which will ultimately disrupt the balance of the shooter. In order for the resulting angle to be stable, the shooter must have arm muscle endurance and perform proper grip and pull techniques starting from the preparation phase so that during the aiming technique or aiming there are not too many changes in the resulting movement (Yachsie, 2019). Grip and pull movements will become proportional with automation in order to produce shots with accuracy and constancy (Hita et al., 2022). Automation in the slingshot is carried out mainly during the pull of the slingshot rubber, precisely during the anchoring technique. When the rubber is pulled, the arm will be anchored until the pull is straight with the cheekbone. This anchoring process must be the same pattern and firmly attached to the cheekbone as a help point so that the pull remains in the same position, the goal is for the rubber rope to be in a straight line with the slingshot handle. The grip and pull will be assisted by the correct posture, which is upright, with the collarbone aligned with the slingshot pull. The hips should not bend forward, backward, left, or right with an upright position with the angle of the back strength *(togok)*. In the sample, the average *togok* angle was 169.8 ± 10.32 degrees with a note that subject number 7 had a body angle of 140.9^{o} due to the position of the body hunched backward, making it difficult in the aiming technique.

The mechanics of motion in slingshot are the same as in archery, which has two movements of shoulder position and the arm position when holding the slingshot frame in a straight line (Suntoro et al., 2021). In playing the slingshot when the rubber starts to lift the shoulder must be kept in a low position because in biomechanics this position is an efficient position. When pulling the rubber, the shoulder position must be low with the arm straightened to the target. The position of the shoulder in pulling the rubber needs to be considered. The elbow must be straight with the slingshot frame. According to Irfan (2018), the technique in shooting, namely the pulling arm and the grip arm, must be in a balanced 50/50 state. Grip and pull techniques that are performed correctly will allow consistent slingshot shooting movements so that when done continuously, the players will get high achievement (Vanagosi, 2015).

The purpose of slingshot biomechanical analysis is to understand motion correction, improve performance, technique, training methods, and reduce the risk of injury. Through biomechanics, athletes will get used to doing activities or movements in an effective and efficient way (Irawan et al., 2021). Effective and efficient means performing movements with proper coordination and timing, moving proportionally with automation. If a movement is done ineffectively and inefficiently, it will waste energy and excessive tension. The result of inefficient slingshot grip and pull would cause people to be physically fatigued quickly and psychologically nervous due to instability. In addition, improper movement will make the shot off target.

Some previous research findings that support the biomechanical analysis of motion include the results of research by Santoso & Setiabudi (2019) which states that physical analysis of the pull carried out with a mathematical model based on existing physical phenomena suggested that the angle of the ankle, knee, and waist simultaneously affects the maximum pulling force. Research by Irawan et al., (2016) states that the correct and proper technique will help shooters develop and improve control over the ball's flight pattern. Moreover, according to Irawan & Prastiwi (2022), the biomechanical aspects of the body, namely each body segment, can affect the results of a movement. Their research shows that the angle of the shoulder formed can affect the results in the release and followthrough phases. The correct technique is needed, and concentration and coordination are also needed in the traditional slingshot game. This is revealed by Irawan & Long-Ren (2019) that having eye, hand, and high concentration coordination is needed by athletes to control a match. Similarly, this study uses biomechanical analysis technology through video analysis Kinovea and focuses more on angles that can potentially affect the shot. Based on these reviews, it can be concluded in this study that mastery of techniques and body segments in each movement such as foot distance, *togok* angle, shoulder angle, arm angle, coordination, and concentration are elements that must be considered to get optimal slingshot shot results.

5. Conclusion and Recommendation

The angle formed by the arm as a handle and the shoulder as a puller can affect the final result of the shot. The ideal grip is a straight hand position that is parallel to the arm pull until an angle of approximately 90^o is formed. An effective and efficient pull is done by anchoring the rubber pull during the anchoring technique right on the cheekbone so that the rubber pull remains consistent. The shooter's height is also important in making effective movements. The height of the shooter's body that is parallel to or higher than the target, whose height is 1.5 meters, will make it easier for the shooter to handle and pull parallel to the target. The correct pulling grip technique is obtained from repeated practice so that good automation movements occur.

The data results in this study are useful for developing training and providing input to trainers and players or activists of traditional slingshot games for the future to be better. The limitation of this study is that there is still a lack of understanding among athletes regarding shooting techniques in slingshot games. Moreover, competition also needs to improve shooter skills and correct shooting techniques in every single shoot. Further study can discuss similar topics related to the analysis of the length of the pull and shooting accuration.

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