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Original article

La biomecánica aplicada a la técnica de pitcheo en lanzadores de béisbol

Biomechanics applied to throwing technique in baseball throwers

Biomecânica aplicada à técnica de arremesso em arremessadores de beisebol

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ABSTRACT

Sport as a social phenomenon, currently develops simultaneously with the advances of science and technology; in this context, biomechanics plays an important role that ensures the bases for true technical training; hence the work is directed to the use of biomechanics in throwing technique. To respond to this issue, the objective is to apply biomechanical studies to the throwing technique in the throwers of the La Isla de la Juventud baseball team.

Document analysis, bibliographic review, scientific observation, interview and the technique of video analysis with the help of a drone were used as methods; this made it possible to measure magnitudes and assess the behavior of the characteristics of the movements executed by the throwers under study. Also, two measurement techniques were used, one through filming and the other by kinematic processing with the use of software such as Tracker and Kinovea. The sample consisted of eight subjects, divided into three athletes, two coaches and three researchers; this allowed to determine the characteristics of the throw distance, the angle formed by the throwing arm with respect to the head, the height of the ball, and the speed of the ball executed by the investigated throwers.

Keywords: Biomechanics, throwers, throwing, technique.

RESUMEN

El deporte como fenómeno social, se desarrolla en la actualidad simultáneamente con los adelantos de la ciencia y la tecnología; en este contexto, juega un papel importante la biomecánica que asegura las bases para un verdadero entrenamiento técnico, de ahí que el trabajo está dirigido al uso de la biomecánica en la técnica de pitcheo. Para dar respuesta a esta temática se concibe como objetivo aplicar estudios biomecánicos a la técnica de pitcheo en los lanzadores del equipo de béisbol La Isla de la Juventud. Se utilizaron como métodos el análisis de documentos, la revisión bibliográfica, la observación científica, la entrevista y la técnica del análisis de video con ayuda de un Dron; ello permitió medir magnitudes y valorar el comportamiento de las características que poseen los movimientos ejecutados por los lanzadores objeto de estudio. También, se emplearon dos técnicas de mediciones, una a través de la filmación y otra por procesamiento cinemático con el uso de los softwares como Tracker y Kinovea. La muestra estuvo conformada por ocho sujetos, distribuidos en tres atletas, dos entrenadores y tres investigadores; esto permitió determinar las características de la distancia de paso, ángulo que forma el brazo de lanzar con respecto a la cabeza, altura de la pelota y la velocidad de la pelota ejecutados por los lanzadores investigados.

Palabras clave: Biomecánica, lanzadores, pitcheo, técnica.

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RESUMO

O esporte, como fenômeno social, está se desenvolvendo simultaneamente com os avanços da ciência e da tecnologia; nesse contexto, a biomecânica desempenha um papel importante para garantir a base de um verdadeiro treinamento técnico, portanto, o trabalho visa ao uso da biomecânica na técnica de arremesso. Para responder a essa questão, o objetivo foi aplicar estudos biomecânicos à técnica de arremesso nos arremessadores do time de beisebol La Isla de la Juventud. Os métodos utilizados foram a análise de documentos, a revisão bibliográfica, a observação científica, a entrevista e a técnica de análise de vídeo com a ajuda de um drone, o que permitiu medir as magnitudes e avaliar o comportamento das características dos movimentos executados pelos arremessadores em estudo. Além disso, foram utilizadas duas técnicas de medição, uma por meio de filmagem e outra por meio de processamento cinemático com o uso de softwares como o Tracker e o Kinovea. A amostra foi composta por oito sujeitos, distribuídos em três atletas, dois técnicos e três pesquisadores, o que nos permitiu determinar as características da distância de arremesso, do ângulo do braço de arremesso em relação à cabeça, da altura da bola e da velocidade da bola executada pelos arremessadores investigados.

Palavras-chave: Biomecânica, arremessadores, arremesso, técnica.

INTRODUCTION

Sport as a social phenomenon, currently develops simultaneously with the advances of science and technology, which has made the sport practice acquire greater strength and concurrence than years ago. The competitive activity is not alien to the scientific and technological advances that take place in the 21st century society, which is why in all sports modalities, the increasing introduction of technology and science for the improvement of sports technique is a reality.

Today, where it is getting bigger and bigger the number of competitions, levels so high have been achieved in the different aspects of preparation of athletes, that their increase becomes

a complex task and the vertiginous development becomes tangible in the competitive results that impose degrees unsuspected of perfection in their preparation.

For this reason, it is necessary to search for updated information, assess options and make decisions in an increasingly complex and variable universe, as well as reviewing and improving competitive strategies. Also, the management and driving game process should be constantly evaluated, hence, it is important to use in a rational way the human and material resources.

This decision is made based on achieving the best results and properly applying the sports technique with the minimum energy consumption, to avoid injuries to athletes. At present, work is required in search and creation of resources and means what allow to develop new training methods, correctly manage the information that is available and, at the same time, organize the sports activities with harmony and effectiveness.

Baseball, due to the characteristics of its actions, is considered a sport of variability in its efforts and rapid execution; these actions must be carried out in an unexpected and dynamic way in a short period of time and must be variables of reaction, coordination, mutual cooperation, communication and predominate during the whole game Reynaldo Balbuena, (2006). In this sport, during each game, the strategy can be divided into two important moments: offensive and defensive. In the particular case of defense, the performance of the throwers plays a very important role.

In baseball, to achieve victory in a competition at any level, it is necessary to have a group of throwers capable of minimizing the offense, that is, the hitting, of the opposing team. To achieve this goal, throwers have to master many technical and tactical elements, so coaches must pay special attention to their preparation and control Cañizares & Pérez, (2015). Although the act of throwing can be considered a continuous movement in baseball, it can be divided into different phases to better understand the behavior of the biokinematic chains at each instant, Fleisig, (2010).

As is known, the performance of the thrower or launcher is essential for a good defense, which establishes a solid foundation for his team. (Suárez Doval, 2014) Beyond this, the thrower's role is so relevant that it could make the difference between winning or losing a match, Conde, (2016). For this reason, the execution of this technique is vital, since it not only seeks to throw the ball, but also to prevent the batter from connecting. To do this, the throwers carry out movements that allow them to reach incredible speeds in their throwes.

The energetic biomechanical movements of translation and rotation manifested in the thrower's technical movement require a logical, uninterrupted, synchronized and dependent sequence until releasing the ball as the final product. These are based on the laws of Newton's classical mechanics and the conservation of mechanical energy or kinetic momentum and angular momentum, Young *et al.* (2013).

It is in agreement with what was referred to by the aforementioned author, however, it is considered necessary to take into account the principle of the coordination of partial impulses that establishes that when it is intended to impress a body with great speed, all the parts of the athlete´body, employed as agents of acceleration, must reach their maximum speed at the same instant. The velocity vectors, of the centers of gravity of all the parts of the biokinematic chain that intervene in the execution of the movement, must point in the same direction at that instant.

Thus, in order to achieve optimal sporting results or performance, motor learning or technique training must be systematic, based on a referential model of efficient, effective and effective movement, guaranteed with the support of biomechanics, Camacaro *et al.*, (2021).

Biomechanical studies have become essential for many reasons, among them are the importance of sports results in various areas of life and the increasing difficulty of improving brands; but mainly, they are applied to prevent injuries. The improvements in results are increasingly related to the increase in anthropometric parameters of athletes that are of a biological type, especially related to muscular strength and of a technical type, in addition to the control of other variables such as psychological ones.

Estrada (2018) considers that "Biomechanics studies the movement of living beings from a trend supported by mechanics (mechanical physics), which seeks relationships between magnitudes and explanations of behaviors and observations" (p. 16). Later, this same author defines Biomechanics as:

> (...) the interdisciplinary area of knowledge that studies the models, phenomena and laws that are relevant for the explanation of movement (including situations of static equilibrium of bodies). It is a scientific discipline that aims to study the mechanical structures that exist in living beings, mainly the human body (p.17).

By the composition of the word biomechanics (bio, means life and mechanics, part of physics dedicated to the study of the movement of bodies), it can be established that biomechanics is the science that applies mechanics to explain the laws that govern mechanics movement of living systems, Pérez *et al.*, (2021). It is then assumed, in principle, that biomechanics is a science and that it applies the fundamentals of mechanics to the study of the mechanical movements of living systems. Sports biomechanics is the science applied to sports that allows us to understand the kinetics (forces), kinematics (movements) of the body and their interaction with respect to displacements, static balance and dynamic activity that characterize gymnastic and acrobatic sports actions, Nyman, (2020).

For the improvement of the sport, the effective application of the fundamentals of biomechanics and its research methods is required. Currently, in the control of the technical elements, the biomechanical analysis plays a fundamental role, which has as one of its purposes "(...) the evaluation and diagnosis of movements and identification of technical faults (errors) and their limiting factors" (Pilotos, 2012).

The biomechanical analysis of the motor actions, related to the execution of the technique in any sport, is fundamentally based on the registration of the biomechanical characteristics or indicators of the movements. These characterize the skill under study, from the biomechanical control of the appropriation of the technique by determining the behavior of these characteristics. A movement analysis system (SAM in Spanish) is used and the technique control by expert (CTE in Spanish) methodology is applied (Zatsiorsky, 1989 and Perdomo Manso, 2018) in which their work plays a fundamental role.

> In view of the human being, many fast and involuntary movements can hinder the execution of different techniques that are intended to improve, the importance of biomechanical control through indirect observation applying a videographic analysis, can facilitate the correct execution of unnecessary techniques and movements. (Toledo *et al.*, 2020).

The use of the video-analysis technique is nowadays an appropriate technology for the scientific and academic environment. This technology allows the study of real phenomena to be developed and offers the unique opportunity to obtain, with low consumption of resources, a wide spectrum of information on the different magnitudes that allow a better characterization of the mechanical movement of bodies.

Video-analysis technology is also used with great effectiveness in the development of sports research, especially in biomechanics. Different software such as: Kinovea, Motion Analysis Tool (MAT), Pro-Trainer, SkillSpector, WINanalyze and Tracker, among others, are frequently used in the study of sports movements because they provide a volume of information that allows the orientation of athletes. and coaches in relation to the improvement of sports technique.

For these reasons, the fundamental objective of the work presented is to apply biomechanical studies to the throwing technique in the throwers of the Isla de la Juventud baseball team.

MATERIALS AND METHODS

In order to comply with the objectives outlined in this research, a total of 20 participants were taken as a population, distributed among 13 throwers belonging to the Isla de Juventud baseball team, four throwing coaches and three researchers who considered that the chosen throwers met the necessary physical and technical characteristics , depending on the objectives of the proposed research, that is, those that best fit the selection criteria, from these a sample of eight participants was chosen, which represented 40 % of the population, distributed in three throwers who represented 37.5%.

As selection requirements were established:

- Years of experience.
- Function, role or specialization within the throwing staff (openers).
- Stay on the team during the research.
- Not having presented any type of discomfort or major injuries with sequelae.

Two throwing coaches representing 25 % of the population were selected. The inclusion requirements were established:

- Have more than ten years of performance in the preparation of baseball throwers.
- Have experiences in preparing athletes for the National Baseball Series.

In addition, three researchers who represented 37.5% of the population.

The methods and techniques that were used to respond to the scientific problem were the analysis of official documents that were reviewed with the purpose of knowing the existing elements for work with baseball throwers and the bibliographic review for the consultation of scientific materials that addressed topics related to the object ofresearch and allowed the pertinent analyzes to be carried out.

The scientific observation was carried out during several training sessions of the first category baseball team, with the purpose of verifying how the throwers executed the throwing movements and determining the subjects that were finally selected as a sample. The interview was used with the objective of exploring the current information they have about the mechanics of throwing and was aimed at throwing coaches.

The video analysis technique was used in the study of the sports movement of the throwers and provided information for the orientation of the athletes and coaches in relation to the improvement of the sports technique.

The Kinovea and Tracker software have similar features that allow them to be within the reach of most users. Among these characteristics, according to Pérez *et al.* (2021, p. 500-501) the following stand out:

- They belong to the free software group and can be purchased free of charge from the www.kinovea.org and www.opensourcephysics.org sites, respectively.
- They have a user-friendly work environment.
- They offer different tools for the measurement and processing of variables during the study of mechanical movement. They integrate powerful tools for tracking trajectories, measuring time, lengths, speed, angles, and others.
- hey facilitate manual and automatic tracking of object trajectories.
- They promote the monitoring of certain phases of the movement and control the speed of observation of the movements.
- They allow incorporating stopwatches to measure the duration of the phenomena.
- They allow data to be exported to new videos and to spreadsheets for statistical processing and also have built-in mathematical tools for curve fitting and statistical analysis.
- The studies can be carried out with the presence of an appropriate computer in any environment (home, school, scientific center, etc.) and do not require other special conditions.
- They allow the study of a sequence of images (videos) or of a particular isolated image.

The fact that Kinovea and Tracker are used interchangeably is due to the ease of tools that both applications have to develop the video analysis technique. On the one hand, Kinovea has certain tools that facilitate the measurement of times, distances, angles, and the graphics it proposes have better definition than Tracker. As for Tracker, this application, in addition to having tools similar to Kinovea, facilitates a greater number of variables that favor

mechanical studies and allows manual trajectory monitoring; in addition, it allows the adjustment of curves for a better theoretical approach to the description of the behavior of the variables under study and thus compare the results obtained with the use of Kinovea.

The means and material and human resources necessary for the study were selected: the baseball field of the "Cristóbal Labra" stadium on the Isla de la Juventud; a Nikon (DX 5100) HD NTSC video camera, with a shooting frequency of 32 frames / second and its accessories; a Pentium IV computer, for data analysis and the Kinovea (ver 0.9.1 of 2019) and Tracker (ver 6.0.1 of 2022) applications for movement study; three throwers, two coaches and three teacher-researchers from the Physical Culture Faculty of the territory.

The throwers who were studied together with the collaborators were prepared. Ten film shots were taken for each thrower (three shots from the right position, four from the center, and three from the left of the throwing board, respectively).

It was proceeded as follows:

1. Of the ten throws executed by each thrower, the film was taken which, in the opinion of the coaches and researchers, was the best executed.

2. Preparation of the videos, in such a way that they were compatible with the analysis software (Kinovea and Trackers) and the TMPGEnc4XP, version 4.3.1.222 was used.

3. Analysis with the software Kinovea and Trackers (programs for the analysis of human movement) of the filming already prepared; The elements to be evaluated in the athletes studied were taken into account.

4. Qualitative assessment of the execution of the studied movement, from the video recording.

For this, a drone and two cameras were used, one located above the studied throwers to be able to capture the throw in all phases of the action and the other, in a lateral position with respect to the throwers to capture the execution of the throwing movement.

The measurement provided the possibility of expressing, through numbers, the biomechanical characteristics of the throwing technique in the throwers of the baseball team of La Isla de la Juventud.

RESULTS AND DISCUSSION

Results of the interview with the throwing coaches

As answer to the indicators selected, the following results were obtained. In question one, referring to the distance of the stride length, 100% of the coaches stated that this measurement should have been slightly less than the height of the thrower and it was established as a range normal, between 82% to 93 %, in relation to the height of the thrower; this allowed an adequate transfer of energy to the upper extremity, due to the increase in the distance and the time in which the trunk can rotate.

In question two, referring to the angle of output of the ball with respect to the head, 100% of the coaches agreed that this action should have been closest to the head, to avoid injuries to the throwers and seek that the throw be done overhead.

In question 3, about the height that the ball reaches before reaching the receiver's pet, 100% of the coaches stated that it must pass through a point between 50 and 100 centimeters.

Results of the biomechanical analysis from the different locations. To do this, the following parameters were taken into account used in the analysis from the different launcher locations:

- Step length.
- Angle of output of the ball with respect to the head.
- Height of the ball before reaching the catcher mascot.
- Average throw speed.

Results of the biomechanical analysis of the stride length from the center of the box. The length of the step is one of the indicators to consider in the thrower's throws, since it plays an important role in the quality of the delivery to the plate. This parameter is described as the horizontal distance that separates the calcaneus of the foot of the driving leg from the calcaneus of the support foot, at the instant of contact with the ground (Figure 1).

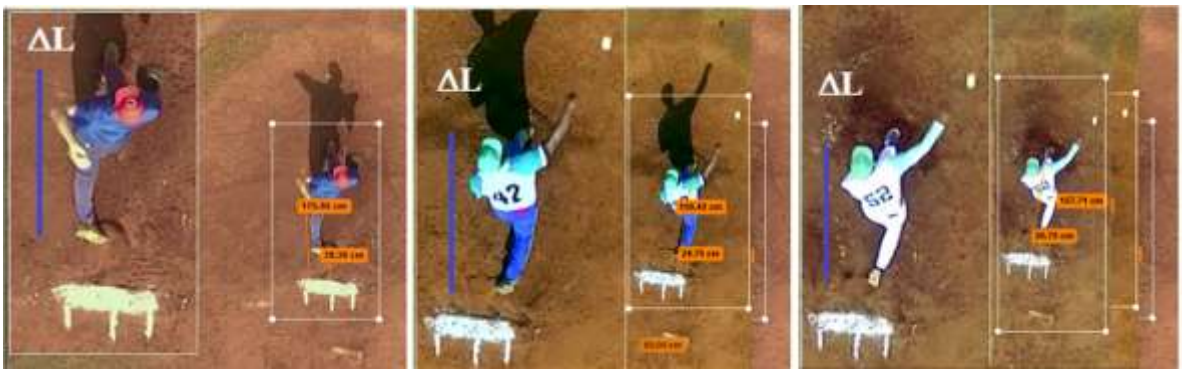

Fig. 1. - *Step length*

From the video analysis, the application of sports biomechanics to the throwing technique, the throwers' stride length was obtained:

- Thrower 1: 137.19 cm.
- Thrower 2: 133.67 cm.
- Thrower 3: 131.01 cm.

Considering that this measurement should be slightly less than the height of the thrower, it was established as a normal range, from 82 % to 93% in relation to height.

The height of the throwers is as follows:

- Thrower 1: 1.80 m
- Thrower 2: 1.78 m.
- Thrower 3: 1.82 m.

From determining the distance of the stride length and the height, it was possible to obtain the range that represented the stride length of each thrower, by using the following formula:

Stride range = (step length x 100/height)

- Thrower 1: 76 %.
- Launcher 2: 75 %.
- Thrower 3: 72 %.

The results obtained by each thrower allowed to affirm that the range of the stride was lower than that established in the literature, therefore it was deduced that a short stride can reduce the potential development of force, through a potentially reduced trunk rotation; z shorter strides (less than 75 % of body height) were less effective in the action of the knee during the transfer phase and by altering the correct transmission of intersegmental forces, from the ground to the throwing hand, the speed decreased release.

Results of the biomechanical analysis of the angle of output of the ball with respect to the head (Figure 2).

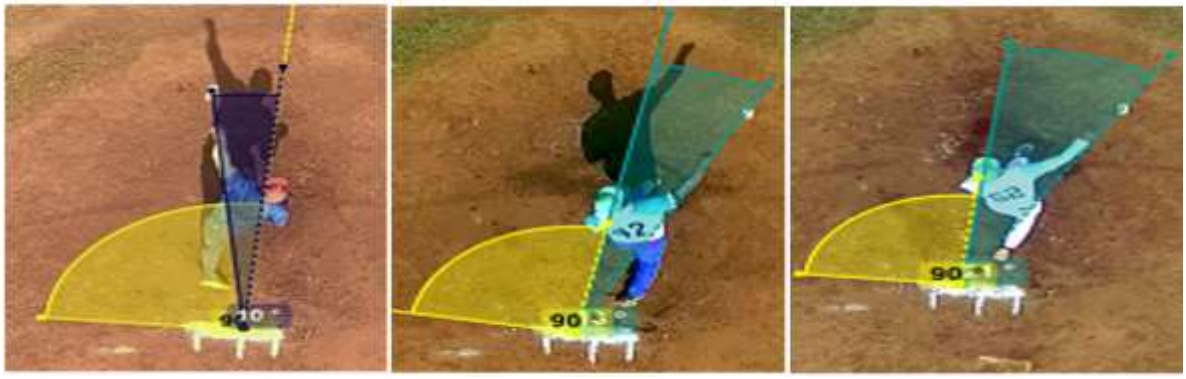

Fig. 2. - *Angle of output of the ball*

Regarding the angle of output of the ball with respect to the head of thrower number 1, a distance of 10 degrees was obtained, so that the arm that held the ball and executed the movement was close to the head. The angle of output of the ball with respect to the head of thrower number 2 obtained a distance of 13 degrees, the arm that held the ball and executed

the movement was separated with respect to the head. In thrower number 3, a distance of 21 degrees was obtained, the arm that held the ball and executed the movement was separated from the head. As a conclusion, it was arrived at that there were no differences between thrower number 1 and 2, but with respect to thrower number 3, when verifying 8 degrees of distance with the angle of output of the ball.

Results of the biomechanical analysis of the height of the ball before reaching the receiving mascot (Figure 3).

Fig. 3. - *Height of the ball*

Regarding the height of the ball before reaching the catcher's mascot, thrower number 1 obtained a distance of 88.63 cm with respect to the ground. This is understood as the ball at this point was located in a favorable zone for the thrower. Regarding the height of the ball before reaching the catcher's mascot, thrower number 2 obtained a distance of 87.56 cm with respect to the ground, which is understood as the ball being located in a favorable zone for the thrower.

By using the Kinovea program, a timer was inserted into the video; in this way, it was possible to measure the time and estimate the average speed. Without a speed gun this would be impossible to do during a training session. The result of these measurements for this work is presented in Table 1.

Table 1. *- Estimation of the speed of a ball. Source: Own elaboration*

Distance (m)	Time (s)	Speed (m/s)	Speed (m/s)	Speed (m/s)
0	0			
1.3236	0.042	32	115	72
1.3906	0.041	3. 4	122	76
1.3537	0.042	32	115	72
Distance (m)	Time (s)	average speed values		
4.0679	0.125	33	119	74

Regarding the height of the ball before reaching the catcher's mascot, thrower number 3 obtained a distance of 45.97 cm from the ground, so the ball at this point was in an unfavorable zone for the thrower.

The documentary analysis and the bibliographical review allowed to reveal the foundations of the investigation for the treatment of the existing problems in the mechanics of the throwers.

CONCLUSIONS

With the use of biomechanical software, the characteristics of the passing distance, the angle formed by the throwing arm with respect to the head, the height of the ball when approaching home plate and the speed of the ball executed by the studied throwers were determined.

The biomechanical analysis of the throwing mechanics in the throwers of the Isla de la Juventud team was taken into account and the two measurement techniques used, one through filming and the other through kinematic processing with the use of Tracker software, it is considered opportune to extend and apply biomechanical studies to other baseball categories of La Isla de la Juventud.

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Conflict of interests:

The authors declare not to have any interest conflicts.

Authors' contribution:

The authors have participated in the writing of the work and analysis of the documents