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Original Article

Biomechanical measurement with motion analysis system via software (Kinovea): A case studies on motion and degree of joint in hurdles athletes

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Abstract:
Problem Statement. The use of proper and maximum exercise requires good and targeted training. Proper and maximum training is believed to boost athletes' performance. Before providing targeted training, it was necessary to conduct an in-depth analysis related to the lack of movement by athletes when running and jumping over obstacles in the athletics hurdles number. ***Purpose.*** To conduct an in-depth analysis related to the performance of hurdling athletes through sports technology with the help of Kinovea software so that it can find out the weaknesses and shortcomings of athletes' movements. ***Methods.*** The type of research was a descriptive analysis with survey methods with samples of local, national and international athletes. The research implementation phase included recording training on local athletes using high-resolution cameras and video analysis of national and international athlete recordings. The analysis used Kinovea software, new version 0.9.5, with two-dimensional cinematography analysis. ***Results.*** The results of the obtained research showed that some differences can be seen in speed, movement when star, movement when jumping, and movement when in the air. Local runners altered acceleration and tended to experience a decrease in acceleration when passing obstacles. As for national runners, there was a slight change in acceleration that is slightly consistent. International runners had a very striking acceleration with the consistency of acceleration over obstacles, and it was also seen that at some stages, the joint angle of international runners tended to be more effective as a reference source in determining joint angles for training. ***Conclusions.*** The analysis showed that a striking difference in the athlete's acceleration and joint angle when passing the goal.
Keywords: athletics, running, hurdles, software, acceleration

Introduction

Appropriate and maximum exercise is expected to provide good results as well (Elnaga & Imran, 2013). However, to support this, it is necessary to analyze the performance that athletes have owned. Hurdles not only rely on running speed but also must pass some obstacles that require good strength and explosive power (Mullins, 2012). In addition, leg muscle strength will majorly affect one's jumping ability (Yendrizal et al., 2023). Therefore, before providing targeted training, it is necessary to conduct an in-depth analysis of the shortcomings of athletes' movements when running and jumping over obstacles (Lindberg et al., 2016).

The implementation of hurdling is closely related to various physical components such as speed and strength (de Villarreal et al., 2015). Movement speed is influenced by the physical elements of athletes or muscle performance abilities and reflexes of the nervous system (Hrysomallis, 2011). Mastery of motion is one of the essential elements (Sepdanius et al., 2023). Improving the speed of running is a complex process because, in addition to improving muscle quality, speed is also controlled by the brain and nervous system. Mastery of efficient hurdling techniques will have an impact on maximum results (Brničević, 2020). Four basic techniques need to be mastered by hurdlers, namely: 1) starting techniques), 2) sprint techniques towards goal I and between goals, 3) sprint techniques through the goal and 4) sprint techniques entering the finish line (Husbands, 2013). In addition, the explosive power of leg muscles has a vital role in various sports (Ihsan et al., 2022). The relative importance of these elements depends on the competition. Different race distances and goal heights placed different demands on hurdles.

Several solutions have been provided by athletic trainers, such as running ABC exercises that are believed to break athletes' achievements (Trowell et al., 2022). However, based on time data obtained from regional and national hurdles, it is still very far behind international runners. Various types of training have been given, such as speed training and explosive power training specifically for hurdling athletes, but zero results have still been obtained (Fischetti et al., 2018). The researchers try to provide a solution by conducting an in-depth analysis related to the performance of athletes today. The analysis to be carried out is an in-depth analysis using Kinovea

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software that can analyze related to star techniques, speed, strength, foot swing angle, hand swing angle, landing technique, and jumping height and distance (Amara et al., 2019). By doing this analysis, it can be illustrated the shortcomings possessed by athletes so that the coach can provide unique training for some movements that are still very lacking.

Based on several research results, in terms of the concepts of technique, exercise, and physical formation, there are still things that can be developed to improve even better results (Thomas et al., 2022). Technical ability can make a significant difference to an athlete's running ability (Purwanto et al., 2021). Therefore, the trainer must emphasize the appropriate training elements related to technique. For this reason, an in-depth analysis needs to be done in detail and related to the movement techniques carried out by athletes. Along with the development of science and technology, almost all sports have used and utilized technological developments to prepare the best athletes (Mali & Dey, 2020). Various kinds of software have been developed to analyze match results as well as to analyze forms of training. Software technology is used as a reference to understand the movement patterns and body kinematics of an athlete (Clermont et al., 2017). Another thing that can be done is to make a comparison between elite and non-elite athletes so that the disadvantages and advantages of each movement made during competition and training can be known (Stöggl & Wunsch, 2016).

In recent years, there have been many studies related to the analysis of hurdling movements. Previous research has conducted studies on proprioception training in the optimization of 110 m obstacle event techniques (Alecu & Ionescu-Bondoc, 2018). In addition, other related research related to analysis is the analysis of sports biomechanics and motor learning at the start of hurdling squats (Kridasuwarso, 2016) and research on aerobic and anaerobic running analysis from various angles and their components (Budi & Listiandi; n.d., 2020). The study (Rata et al., 2011) only discusses the dynamics of the results of hurdles of male and female athletes at a distance of 60 meters. Another study discusses how vital technology is in changing world sports so that it is growing (Ráthonyi et al., 2018). Technological innovations were developed and utilized to improve exercise techniques (Ratten, 2019).

A new study will be made that is different from before, and this latest study will analyze in detail the process of running a goal, starting from the star technique to the finish line. In addition, what also distinguishes this study is the use of Kinovea software to analyze thoroughly, where the level of difficulty of analysis in hurdles is much more complex than just analyzing speed. In hurdles, the techniques used are very complex (Singh & Shalini, 2016), ranging from start techniques, speed, explosive power when repelled, and hovering attitude in the air and when landing. Each movement will be analyzed in detail to see how much angle the joint can create from each stage of an athlete's movement. The angle analysis of the joint will be related to the acceleration that occurs at each stage and the final result of the athlete's speed. The advantage of this analysis is the use of targeted technology with a high level of analytical capabilities that cannot be done only with the naked eye (Nor Adnan et al., 2018). With the help of software analysis can facilitate the performance of coaches in observing every movement of athletes during training (Wilson, 2008). The results of this analysis were beneficial as a reference in providing a form of training to athletes (Graubner & Nixdorf, 2009).

The benefits of the results of this study can be used as a basis for determining the athlete's training program. The proper analysis results will make it easier for trainers to provide the right portion of exercise on target. Targeted training will improve the performance of athletes, especially hurdles athletes. That analysis with Kinovea software technology needs to be done as soon as possible to get the results of the ability of current hurdling athletes to determine the best training in the future. In addition, the use of software as an analytical tool will have a significant impact on various lines, such as improving athletes' techniques (Osipov et al., 2017). From such analysis, it can identify technical weaknesses or movement patterns that can be improved. The most important thing is also that a good analysis can help optimize athlete performance so that it has an impact on injury prevention. The use of software can also help athletes and coaches gain a deep understanding of the interaction of the body and environment during physical activity.

Materials and Methods

Study design and participants

The type of research to be carried out was quantitative descriptive analysis with non-test techniques using survey methods with samples of regional, national and international athletes, as many as 1 person each in athletics, with the use of purposive sampling techniques where the sample criteria were athletes with the best records in various competitions. The research design used an evaluative descriptive design.

Procedures and instruments

The stages of research implementation started from the preparation of tools and materials, the process of taking videos during training for regional athletes, uploading videos during national and international athlete matches, installing Kinovea software version 0.9.5, conducting movement analysis which included star technique components, repulsion when going through the goal, hovering attitude in the air, and acceleration that occurs when running. Furthermore, two-dimensional cinematography analysis was carried out by displaying data and qualitative elaboration associated with theories related to the ideal movement of each component.

Data analysis

Data were analyzed using the statistical software Kinovea version 0.9.5. Here is one example of the analysis performed.

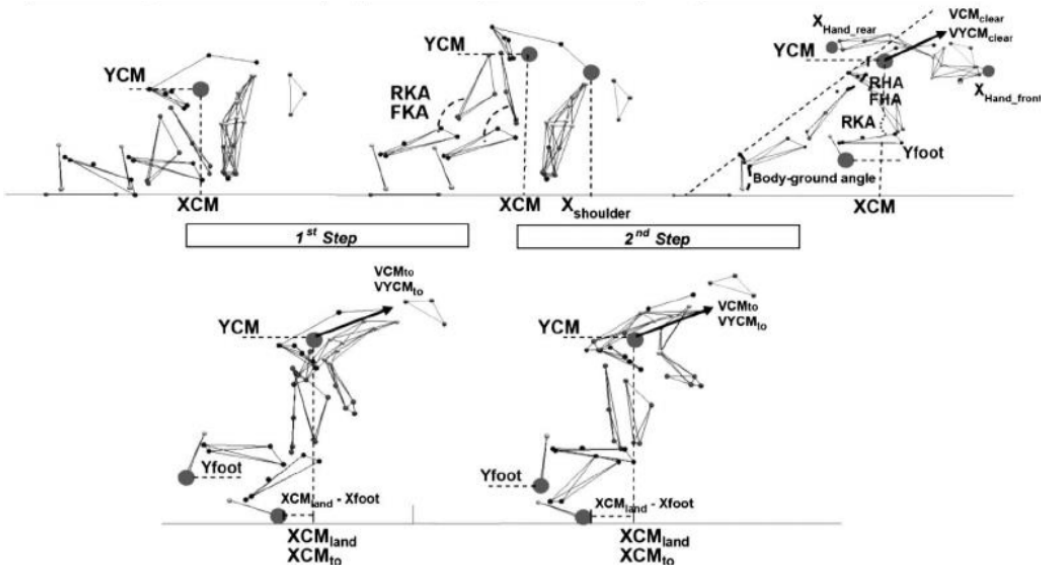

Figure 1. Forms of analysis

Results

Product Description

The results of the research obtained some data analysis results with the use of Kinovea software. The data analyzed starting techniques, repulsion stages, body position when in the air past obstacles, and acceleration. All of these data were analyzed by looking at the comparison of the speed travel time of each athlete. Here is the complete data of the results of the research that has been done:

Table 1. Comparison

Analysis	Area	National	International
Technical Start	Hind limbs 134,6° Front Limbs 103.9° Arm 139,4°	Hind limbs 132,2° Front Limbs 105.8° Arm 141,5°	Hind limbs 135° Front Limbs 107,6° Arm 144,9°
Push Process	Hind limbs 171,5° Front Limbs 71.5° Arm 101.4°	Hind limbs 175,4° Front Limbs 76,1° Arm 85.7°	Hind limbs 155,8° Front Limbs 77,2° Arm 111,5°
Position in the air	Hind limbs 124,6° Front Limbs 143° Arm 150,9°	Hind limbs 125,9° Front Limbs 142,5° Arm 160°	Hind limbs 149,8° Front Limbs 158,3° Arm 167,9°
Acceleration	Acceleration Resistance 1 (13m) 1.15 m/s Acceleration Resistance 5 (45m) 1.37 m/s Acceleration Resistance 10 (100m) 1.42 m/s	Acceleration Resistance 1 (13m) 1.08 m/s Acceleration Resistance 5 (45m) 1.25 m/s Obstacle Acceleration 10 (100m) 1.20 m/s	Acceleration Resistance 1 (13m) 0.95 m/s Acceleration Resistance 5 (45m) 1.25 m/s Obstacle Acceleration 10 (100m) 1.05 m/s
Speed (Distance 110m)	15,50 s	13,73 s	13,05 s

Extensive comparative analysis of the angle of the joint

Analysis was carried out to see the amount of joint angle of each runner so that more effective movements can be compared. Every angle formed in each stage has an impact on the speed and acceleration carried out by athletes. The following is a comparison of the results of the analysis that has been done:

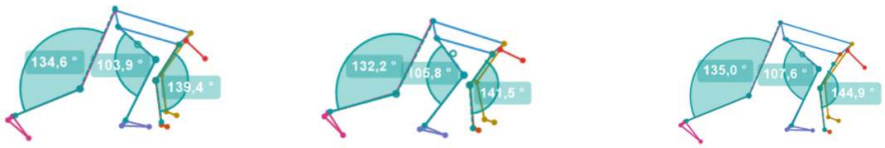

Figure 2. Starting position

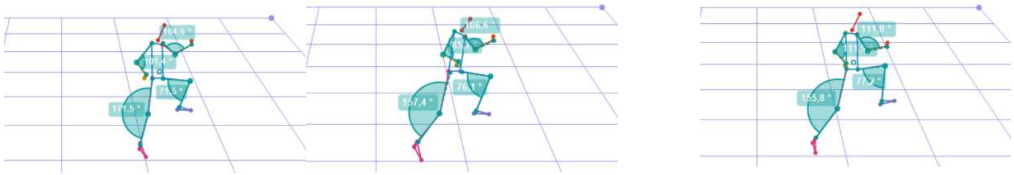

Figure 3. Repulsion when passing obstacles

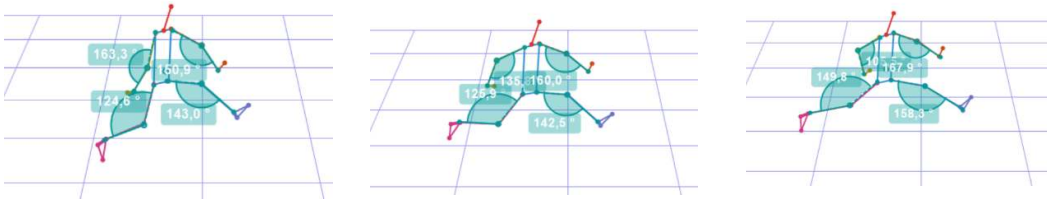

Figure 4. When hovering over obstacles

Discussion

An athlete should do things that will help them achieve speed and the ability to run well (Solheim, 2015). Changes in running methods are possible only by undergoing regular exercise (Ross et al., 2019), supervision from experienced trainers, and using biomechanical studies. With new developments in biomechanical analysis technology, it can be done using computer systems through various existing software (Phinyomark et al., 2018). One of the software used is Kinovea (Bandara et al., 2022) to analyze the results of the running ability of regional hurdling athletes, who will be analyzed and compared with national and international runners.

Biomechanical analysis used recordings of training sessions and athletes' matches. This analysis collects data such as the speed, acceleration and angle of the athlete's joints while running. The results of this analysis determine whether the athlete has an excellent running technique or not (Moore, 2016). The results of the study provide an overview of the analysis of ongoing Kinovea software applications. This analysis explained how hurdling techniques were carried out based on footsteps, running speed, and the ability to pass obstacles. The 110-meter hurdling speed measuring instrument, made using Kinvea analysis software, can calculate the time and speed of a 110-meter hurdle at each distance (line) (Ho et al., 2019). In addition to the functions mentioned above, this instrument also has several additional functions, specifically to analyze the speed of a 110-meter hurdle (Hafez et al., 2023), such as measuring running speed, joint angle, and acceleration.

One of the most commonly contested athletics is hurdles, more commonly called hurdles. A hurdling runner must have good performance and mastery of technique (Pavlenko et al., 2020). Like other short-distance running, the squat start is used as a star technique. The use of squat starts will make the legs do greater repulsion and forward push, so this can increase speed when running. The knees of the legs that are in front should form an angle of 90 to 110 degrees (Cotter et al., 2013). As for the hind legs form an angle of 120 to 140 degrees (Zulkifley et al., 2019). In research that has been conducted from three samples used as analysis material, the angle of the lower leg joint of the hind legs is at 135°, 134°, and 132°. It indicated that the three athletes had performed excellent starting techniques on the hind legs.

Furthermore, on the front limbs of the three athletes analyzed had angles of 107°, 103°, and 105°, respectively. At the same time, the angle of the joints on the hands form angles 144°, 139°, and 141°, which adjust to the anatomy of the athlete's body. The longer the athlete's limb, the greater the angle formed. Conversely, the shorter the athlete's limb, the smaller the angle formed (Pappas & Carpes, 2012).

In the position of repulsion when going through the first obstacle or goal, runners will form certain angles on their legs (Araújo et al., 2006). The results of each athlete will be described from three athletes who are the analysis sample, namely the hind limbs forming angles of 171°, 155°, and 157°. The angle of the front limb is at an angle of 71°, 77° and 76°. The greater the angle formed by the front limb, the more prepared it is to pass the obstacles it will pass through (Taylor et al., 2016). The hand swing itself forms angles of 101°, 111°, and 85° on

the arm behind, while for the front arm, each 104°, 111°, and 106°. This means that arm swings also have an influence on repulsion or jumping (Yulianti, 2017).

Furthermore, at the stage when one is floating in the air, past obstacles or goals are significant to analyze because they greatly determine the ability to run (Peng et al., 2018). If there is a collision between the legs and obstacles, it will have a significant effect on the ability to run (Larsen et al., 2016). The greater the angle formed on the leg, the less likely it will be friction or collision between the leg and the goal. From the results of the analysis carried out, data on the angle of the front and hind limbs of each athlete were obtained, namely 124° and 143°, 125° and 142°, and 149° and 158°. From these results, which are associated with the speed of athletes, data is obtained that the one who has the fastest time is the athlete who has the most significant angle on his legs when passing obstacles. This means that joint angle is very influential on jump and speed (Dos Santos et al., 2018).

The difference in travel time of the three athletes was 15.50s, 13.73s, and 13.05. From the previous discussion, it has been proven from a practical angle that it will have a significant impact on the speed of athletes in the running to pass obstacles or goals (Rabita et al., 2015). At each stage, it is crucial to pay attention to the effective movements to be carried out so that the process of training can be maximized. In addition, the acceleration carried out by the analyzed athletes has differences for each athlete. It can be seen that the most significant difference is in the acceleration at a distance of 45m for the 5th goal/obstacle with a decrease in acceleration at 1.37m/s, 1.25ms, and 1.25m/s which previously the acceleration carried out before passing the goal was better, namely with accelerations of 1.15m/s, 1.08m/s, and 0.95m/s, respectively. It means that the technique used by each athlete in passing the goal is very impactful to speed up travel time (Liu et al., 2023). However, in the final goal, two athletes made changes in acceleration for the better by being able to increase their speed at times of 1.42m/s, 1.20m/s and 1.05m/s, respectively. Changes in acceleration that slow down at the point approaching the finish line also have an effect in increasing the speed of travel time.

Conclusions

The results of the research produced analysis results in the form of joint angle data and the speed and acceleration of athletes. The results of the analysis showed that joint angle had an impact on changes in running acceleration made by athletes. The results of the study compared the stages of each movement between elite athletes and national athletes, who seemed to have a very significant difference. The most striking difference in joint angle occurs at the stage of repulsion to pass obstacles. It can be seen that the world's elite athletes are able to reach 171° compared to national athletes, still around 155° on the hind limbs that perform repulsion. The comparison of acceleration that occurs is related to elite athletes 1.05 m / s and 1.42 for national athletes. It indicated that the angle of the joint at the time of repulsion is directly proportional to the acceleration that occurs. The faster the repulsion forms, the more significant the angle the faster the acceleration will be. The more effective the movement made by the athlete, the higher the increase in acceleration performed.

Conflicts of interest

The authors report that there is no potential conflict of interest.

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