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Kinovea-based Video Content Analysis of Elite Men's High Jump

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Abstract – *High jump is popular track and field sport event in international competitions. The ability of the athlete to jump and reach maximum height with respect to ground level is tested here. There are numerous analyses methods available to investigate the performance or to find the reasons behind one's successful jump. Video-based analysis is promising way to get deeper insight into many sports. To find and understand the relationship between performances of successful athletes, this research work performs a video analysis on three elite men's high jumpers who were the top three contestants of Rio 2016 summer Olympics. The video from YouTube was undertaken for the study. We used kinovea video motion analysis freeware to perform different kinds of studies. The analysis revealed many significant performance differences between the Gold, Silver and Bronze medalists in the final event which may be non-observable by bare vision or simply looking at the video. These minor differences are crucial in deciding the medal winning ability. The insight of our work will provide useful technical guidelines for the new high jump practitioners and coaches.*

Key Words: Video analysis, Kinovea, High jump, Performance analysis, fosbury, winning differences.

1. INTRODUCTION

With the introduction of new software and systems, the analysis of a sport or game has become common to get more knowledge about it. The knowledge gained will be helpful for athletes, teams and coaches to train in a systematic way. High jump is less video-analysed track and field event as compared to other events. Getting in-depth information about this sport will pave way for new comers to get trained without complexity and fear. Different styles of jump were practiced in olden days and Fosbury technique of 1960s is consistently followed till now. The high jump can be sub divided into three phases: approach, take-off and bar clearance or flight [2]. Many studies had earlier quantified high jump in any one or combination of these jump phases.

1.1 Related Works

Several works from literature were found showing the possibility of high jump sport analysis with video as a medium and are briefed in this sub section.

Video is used as a feedback method in [1] to analyze the high jump performance. Performance of players with and without vision or visual feedback is applied here to test their performance. Statistical analysis was performed to find the relationship between a player who had video feedback and who has not. Group of players who had visual feedback had outperformed the players without visual feedback. Also the possibility of self motivation of athletes from video is discussed here.

The biomechanical analysis of the world championship high jump was studied in [2]. The dependency of centre of mass of the high jumpers depending on different kinematics variables during the takeoff is studied. Centre of mass and velocity together determining the height of the flight was shown. They used three cameras to quantify the centre of mass locations of athletes. 8 best finalists were analyzed in this study with the height of their centre of mass during the last two contact were plotted. The physical capacities of individual player, the vertical velocity and height of the centre of mass at the end of take-off phase together determine the height of the flight.

The author of [3] proposed 3D biomechanical analysis of women's high jump techniques. The purpose of this study is to compare the performance of women participants with that of the elite level. Three digital video cameras were used to capture the 18 body anatomical parts via jumping video of women. The Kinematic parameters of the last two strides, the takeoff and the bar clearance were extracted for the analysis through software. Their results indicated kinematics parameters of the approach such as horizontal velocity stride length, angle, height of the body centre of mass being similar for some athletes and poor transformation of horizontal approach velocity to vertical takeoff velocity was observed.

An image-based and video-based analysis was performed on east African high jumpers as compared to the Olympic medalists. To check the validity and reliability of the claim of East African high jumpers jumping higher than Olympic medalist were investigated by [4] and found the claim to be false and also indicated that these novices can jump up to 135% of their height showing the ability of them participating in Olympics. The centre of mass height during the jump is calculated by [5] and the height of the jump is dependent on centre of mass, takeoff velocity and the takeoff angle. The high jump Kinematic parameters and its variability in longitudinal follow-up are analyzed in the paper [6].

Six competitions were video recorded using two digital cameras. For the purpose of kinematics analysis, it is necessary to take into account the subject's body height and body weight and with regard to the height of the jump. Video

recordings of 92 high jumpers for 48 kinematics characteristics were analyzed by [7]. They used fuzzy neural network to develop an interactive system based on the analysis of kinematics characteristics of high jump. All stages of high jump are analyzed in detail and also improve the technique through the targeted correction of specific motions and achieve the optimal combination of kinematic values for the best possible result.

The relationship between the running speed and the radius of the curve was investigated by [8]. Relationship between the final directions of the paths of the centre of gravity and the footprints were made. The use of the takeoff leg during the elite high jump is analyzed in [9]. The purpose of this study was to evaluate kinematics and kinetics of jumpers. They used 19 infrared cameras and ground reaction forces to analyze the performance of elite high jumpers. The authors of [10] founded effects of initial conditions and take off technique on running jump for height and distance. National level analysis during the take off phase in fast Fosbury flop high jump technique is analyzed by [11] with respect to biomechanical characteristics of centre of mass height. The takeoff phase in high jump was analyzed by [12] in terms of biomechanical of kinematic parameters.

1.2 Rio 2016 Men's High Jump Finals

The elite men high jumpers from different countries were participated in the final event of Rio 2016 Olympics. The event had 15 participants initially and reduced to final three contestants. Their details, trail ranges and final achieved heights are shown in the Table -1 for reference.

Table -1: Summary of Medalists

Athlete Name / Country	Range of Height of Trials in Meters							Final Height & Medals Secured
	2.20	2.25	2.29	2.33	2.36	2.38	2.40	
Derek Drouin (Canada)	o	o	o	o	o	**o**	x	2.38 (Gold)
Mutaz Essa Barshim (Qatar)	o	o	o	o	**o**	xxx	NA	2.36 (Silver)
Bohdan Bondarenko (Ukraine)	-	o	-	**o**	-	xx-	x	2.33 (Bronze)

o = Height cleared, **x** = Height failed, **–** = Height passed, NA = Not Available

The video from YouTube is 12 minutes and 48 seconds long, showing the three toppers performing several times followed by slow motion video of the same performance after each trial.

1.3 Motion Analysis Using Kinovea

Kinovea is a popular video/motion analysis tool frequently used to study the kinematic and biomechanical characteristics of different sport activities. Recently the use of kinovea in sports and games applications has increased due to the validity, reliability and feasibility that it provides. Works related to measure vertical jumping height and tracking of leg's key points while jumping was already successfully carried out. A relative angle of drop Jump movement is analyzed using kinovea by [13]. The study revealed that kinovea is more reliable as compared to a 3D motion analysis system. Extensive study was made by [14] on validity, reliability and usefulness of smartphone and kinovea motion analysis software combination for direct measurement of vertical jump height as compared to costlier motion analysis system. This work uses facilities of kinovea depending on the nature of video shot during the event.

2. VIDEO ANALYSIS

The video was downloaded from YouTube and is of 1080p quality. The camera positions changes from athlete to athlete and with varying zoom level. The nature of obtained video does not allow us to measure all angle variations of body parts since it needs the camera to be in a fixed place and at right angles to object under study. So we take angle measurements only on body with respect to ground level and perform frame rate/ duration measurements. This section further elaborates on how the analysis was performed.

2.1 Dataset Creation

Firstly, the whole video was split into 32 small portions of variable duration videos. These videos contain the performance of all three finalists having normal speed and slow motion videos. Secondly, we created a dataset of 18 normal speed videos and 14 slow motion videos for the purpose of comparison and analysis. Thirdly, we noted the starting time, duration and frame numbers of each small video as shown in the Table -2. As the videos are obtained from a public web source, we cannot demand all the athletes having equal proportion of video duration. Hence, we used only small videos that were very useful to get some useful information and interpret the meaning of the content. All other portions of this dataset are ignored.

2.2 Video Comparison

From the dataset created, we extracted key frames with crucial measurements and compared the performance of three contestants by further simplifying the analysis via sub-division of the videos into three phases: approach, take-off and flight. Several parameters were extracted in all the three phases. Some of the examples include body inclination with respect to ground, number of running steps, running type, hand movement during running, hand position, angle measurements on CM (Centre of Mass) point and knee, jump position, flight details and timing details.

Table -2: Details of Dataset

Athlete Name / Country	Video Clip Type	Time & Frame Details	Range of Height of Trials in Meters						
			2.20	2.25	2.29	2.33	2.36	2.38	2.40
Derek Drouin (Canada)	Normal	Start Time	1:15:11	2:43:44	4:10:92	5:20:64	6:17:64	7:44:32	11:11:36
		Duration/ No. of Frames	7:40/ 186	6:00/ 151	6:40/ 161	6:56/ 165	6:40/ 161	6:96/ 175	7:00/ 176
	Slow Motion	Start Time	1:30:92	2:55:28	4:24:52	5:32:44	6:37:96	8:08:96	-
		Duration/ No. of Frames	7:07/ 177	6:44/ 162	5:20/ 131	6:04/ 152	5:84/ 147	7:58/ 190	-
Mutaz Essa Barshim (Qatar)	Normal	Start Time	1:43:32	3:24:76	4:38:32	5:45:84	6:51:88	8:35:08 & 8:48:16	-
		Duration/ No. of Frames	2:92/ 74	6:04/ 152	2:68/ 68	5:28/ 133	4:52/ 114	4:96/ 125 & 4:88/ 123	-
	Slow Motion	Start Time	2:00:20	3:36:68	-	6:01:40	7:08:64	9:11:72 & 9:19:20	-
		Duration/ No. of Frames	5:12/ 129	5:84/ 147	-	3:92/ 99	5:68/ 143	3:96/ 100 & 10:36/ 260	-
Bohdan Bondarenko (Ukraine)	Normal	Start Time	-	2:08:72	-	4:50:80	-	7:29:80	10:35:16
		Duration/ No. of Frames	-	6:08/ 153	-	5:77/ 145	-	5:24/ 132	4:88/ 123
	Slow Motion	Start Time	-	2:19:96	-	5:04:64	-	-	-
		Duration/ No. of Frames	-	3:80/ 96	-	3:54/ 89	-	-	-

2.2.1 Approach Phase

The videos of three players are synchronized so that we got a simultaneous time of approach phase. This phase has running and the lifting point with one leg. We observed the approach angle, number of steps of running before jumping, the running type and hand movement during this phase. Fig -1 shows the readings of approach body angle.

Fig -1: Approach Body Angles

We observed the unique running style of gold medal winner, having a flying type of running during the stride period. Also his hands were behind his body to create enough pace of his body before jumping. The silver medalist on the other hand, used a very short step in the beginning and the end of the stride period. The comparison between the gold and bronze medalists was shown as a composite image in Fig -2 for understanding. Note that the fly type running found in gold medalist (Running athlete's image in the behind)

Fig -2: Composite Running Style Comparison

The height of the legs from ground while running is very high for gold medalist and very low for the bronze medalist. Furthermore, the enormous swing of the hand was noticed in the topper and these factors together may contribute to his

power to cross the bar in a smooth and curved position during the last phase of the jump.

Table -3 lists some important recordings during this analysis.

Table -3: Approach Quantities

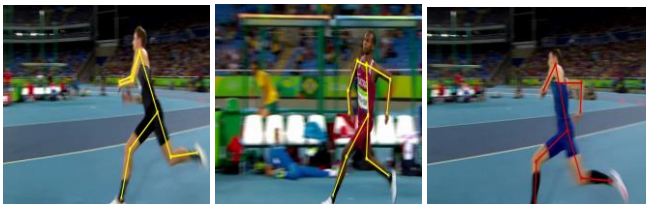
Quantities	Derek Drouin	Mutaz Essa Barshim	Bohdan Bondarenko
Approach Angle	77°	65°	70°
Running Type	3 to 5 short steps initially & unique Fly Running	4 short steps- (Includes one short step in start and end)	3 to 4 short steps and then normal
Hand Movement	For short instance, both hands behind the body	Normal (Alternate hands w.r.to legs)	Normal (Alternate hands w.r.to legs)

The number of steps was quantified for available dataset of different heights of jumping. Table -4 shows the comparison of stride length in terms of number of steps observed from the slow motion videos of the dataset.

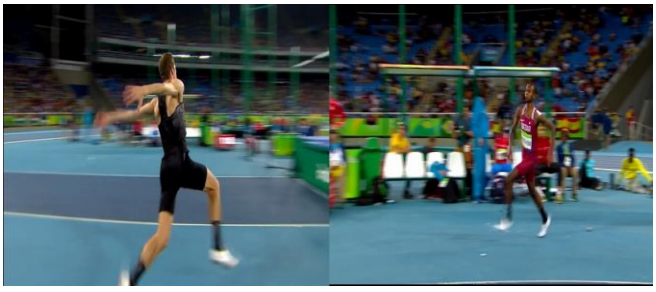
Table -4: Number of Running Steps

Trials of Different Heights	Derek Drouin	Mutaz Essa Barshim	Bohdan Bondarenko
1	11	-	-
2	12	14	15
3	12	-	-
4	13	14	16
5	12	12	-
6	14	13	13
7	14	13	14

The run type and the hand position of different athlete are also shown in Fig -3 (a) and (b) respectively.



(a) Run Type (Gold, Silver & Bronze Medallists in Order)



(b) Hand Positions (Gold & Silver Medallists)

Fig -3: Running Style Comparison

2.2.2 Take-off Phase

In this phase, the body position near the bar, hand position reaching towards bar, Angles of Centre of Mass (CM) and knee were analyzed. Table -5 summarizes these findings.

Table -5: Number of Running Steps

Quantities		Derek Drouin	Mutaz Essa Barshim	Bohdan Bondarenko
Body position near bar/ Reaching Hand		Left side/ Left	Right Side/ Right	Left side/ Left
Hand Position type		Other hand Bended	Other Hand Straight	Both Hands Reaching
Angles	∠CM	148°	160°	163°
	∠Knee	156°	150°	116°

Fig -4 shows the angle variations and positions of all the athletes.

Fig -4: Take-off Positions and Angles

2.2.3 Flight Phase

This is the most important phase that decides the medals. The other two phases of high jump accumulates here to perform and cross the bar. In the analysis, we found many crucial parameters for the successful high jump. The body shape features were noted and found the curved body position for the gold medallist as against flat body for both silver and bronze medallists. These body positions are not made consciously and it is the type of flight which is unique to each athlete. However, new trainees of high jumpers must take this factor importantly to succeed. Fig. -5 show the complete analysis.

Fig -5: Flight Body Shape

The height of the body from the bar is very important for each trial, as this will ensure the athletes to jump higher heights every time. In the performance comparison shown in Fig -6, it is very clear that the ability of maintaining higher height is depending on the talent level.

Fig -6: Body Height from Bar

The leg and hand positions of the athletes during flight were shown in Fig -7. Gold and silver medallists used scissor leg position but the bronze medallist used a combined leg position. And the hand position also played a vital role in gold medallist by bending the right hand (other than the reaching hand) during the flight.

Fig -7: Hand & Leg Positions During Flight

Then, we tracked one leg of all the players to understand about the flight type. For a better result, we should have tracked the centre of mass of the body. But due to the unavailability for a tracking marker, we tracked the individual shoe of the athletes and saw the variations as shown in the Fig -8.

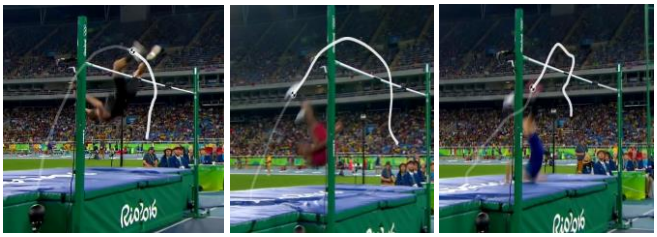


Fig -8: Tracking Results

The tracking results show some interesting facts. The leg tracking of the players showed a smooth to irregular foot flight while crossing depending on the player's calibre. For example, the foot tracking of gold medallist is very smooth and perfectly curved. The silver medallist's was slightly curve with minor irregularities and the bronze medallist's was distorted. This together yields some understanding about the superior performance.

Finally, we also noted the typical time duration/ frame numbers of running to jump, jump to reaching bar and jump to crash land for all athletes to get a insight into total time taken by the athletes and was tabulated in the Table -6. The tabulated values are randomly taken from different heights.

Table -6: Start to End of Jumping Timing Details

Duration	All Measurement in (s:ms)/ No. of Frames		
	Derek Drouin	Mutaz Essa Barshim	Bohdan Bondarenko
Running to Jump	5:56/ 140	3.84/ 97	5:76/ 145
Jump to Reaching Bar	0:44/ 12	0:32/ 9	0:24/ 7
Jump to Crash Land	1:08/ 28	1:44/ 37	1:28/ 33

3. CONCLUSIONS

In this paper, we have performed kinovea-based video analysis on three top high jump performers during final game of Rio Olympics 2016. The analysis was made on three phases of high jump yielding the results to understand the medal winning abilities of these athletes. We performed angle measurements, side by side comparisons, height calculations, timing calculations etc., The purpose was not to quantify the parameters, but to understand the major and minor factors contributing the success. The bare vision capabilities of human cannot observe these parameters. Hence, these findings will be helpful for the coaches as well as the new high jump practitioners during practice.

This work suffers from few drawbacks. The video was taken from YouTube, which do not allow us to set the angle positions exactly from right angled view. The video seems to be moving in some places, which introduced some difficulty during analysis. We don't have facility to place markers in body parts of athletes to measure crucial parameters. A systematic analysis using own video setup and inclusion of professional high jumpers in real-time, would be a great advantage to get deeper understanding. The same analysis can also be extended to other sports and games as well.

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REFERENCES

[1] D. S. Sethu, 'International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS) www.iasir.net', p. 5, 2014.

[2] Juha Isolehto *et al.,* 'Biomechanical analysis of the high jump at the 2005 IAAF world championships in athletics' New studies in athletics, 22:2, pp 17-27, 2007.

[3] Vassilios Panoutsakopoulos and Iraklis A. Kollias, '3D biomechanical analysis of women's high jump technique' New studies in athletics, 27:3, pp 31-44, 2012.

[4] I. Van Caekenberghe *et al*, 'Traditional high jump Gusimbuka Urukiramende: Could early 20th century African athletes beat Olympic champions?', *Journal of Sports Sciences*, pp. 1–7, Mar. 2021, doi: 10.1080/02640414.2021.1898175.

[5] U. Kersting, A. Arampatzis, and G.-P. Brüggemann, 'Biomechanical analysis of the high jump at the VIth WCA IN Athens', p. 4.

[6] I. Blažević *et al*, 'Variability of high jump kinematic parameters in longitudinal follow-up', p. 9, 2006.

[7] I. Y. Krivetskiy and G. I. Popov, 'Innovative Modeling Method in Technical Training of High Jumpers: Innovative high jump technique modeling', *Polish Journal of Sport and Tourism*, vol. 19, no. 4, pp. 253–255, Dec. 2012, doi: 10.2478/v10197-012-0024-z.

[8] Jesus Dapena *et al,* ' A closer look at the shape of the high-jump run up' Track coach 4406, 1997.

[9] J.-P. Goldmann *et al.*, 'Joint work of the take-off leg during elite high jump', p. 3, 2015.

[10] C. Wilson *et al* 'The effects of initial conditions and takeoff technique on running jumps for height and distance', *Journal of Biomechanics*, vol. 44, no. 12, pp. 2207–2212, Aug. 2011, doi: 10.1016/j.jbiomech.2011.06.010.

[11] C. R. Rao, Y. Kishore, and D. J. R. Rao, 'Biomechanical Analysis of Centre of Mass Height during the Takeoff Phase In Fosbury Flop High Jump of National Level Participants', vol. 2, no. 10, p. 3, 2014.

[12] D. Z. A. Swedan, 'Biomechanical of kinematic parameters at take off phase in high jump', p. 26.

[13] N. M. Nor Adnan, M. N. A. Ab Patar, H. Lee, S.-I. Yamamoto, L. Jong-Young, and J. Mahmud, 'Biomechanical analysis using Kinovea for sports application', *IOP Conference Series: Materials Science and Engineering*, vol. 342, p. 012097, Apr. 2018.

[14] B. Pueo, A. Penichet-Tomas, and J. M. Jimenez-Olmedo, 'Validity, reliability and usefulness of smartphone and kinovea motion analysis software for direct measurement of vertical jump height', *Physiology & Behavior*, vol. 227, p. 113144, Dec. 2020