European Journal of Science, Innovation and Technology
ISSN 2786-4936
Vol. 2 No. 3 (2022)

The Effect of Movement Pattern in Flight Phase for Long Jump Performance

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Abstract. During the execution of long jump, three different air dynamics are being used, each with its own effect on performance. The purpose of this investigation was to examine the body surface area changes in the frontal plane with the time during the flight phase of long jump performances. The data that support the findings of this study were collected through six national senior male long jumpers at the national trial in Sri Lanka. Each three of the techniques was studied with two of its best performers. The performances were recorded in the frontal and sagittal planes employing two cameras (100 Hz). The coordinates of each athlete's center of gravity were analyzed for each frame starting from take-off to the landing phase utilizing the human movement analyzing software. The space calibration was completed from the frontal plane and sagittal planes separately. The changes of surface area and the performances of the three techniques were negatively correlated (p<0.05). Consequently, in order to optimize the performance of the long jumper, body surface area on the frontal plane need to minimize into 21 positions out of 50 frames in the execution of flight phase.

Key Words: aero dynamics, body surface area, frontal plane, training

Introduction

The long jump is a field event where the athletes combine their ability of speed, strength, power and balance to achieve the horizontal displacement in track & field athletics. Long jump athlete aims to achieve maximum horizontal displacement from take-off line to landing point on long jump pit. Long jump consists of four phases; they are approach run phase, take-off phase, flight phase & landing phase (Tsuboi, 2010). Flight distance of the jump is determined by take-off velocity, take-off angle, take-off height of the center of mass of athlete, and aerodynamics. Furthermore, the flight distance is dependent not only on the take-off parameter but also it's depended on the flight technique and landing technique used by athletes (Smith & Lees, 2005). There are three main techniques are widely used by long jump athletes, hang, hitch kick and sail/stride jump technique (Figure 1) (Kamnardsiria, et al., 2015). These three techniques act differently with angular momentum due to different movement of arms and legs (Hong & Bartlett, 2008, pp. 340-363; Wu, Wu, Lin, & Wang, 2003).

(a) (b) (c)

Figure 1: Long jump style a) Hand b) Sail/Stride c) Hitch kick
Source: Kamnardsiria, et al. (2015)

There is an impact of arm and legs motion in the flight on the long jump performance. The arm and leg swing used to enhance the leaping distance (Tsuboi, 2010).

There has to determine the excessive force generated by changing the body segments such as arm and leg swinging. Arm motion has various advantages; including increasing the velocity of the body's center of gravity (CG), acquiring a bigger peak magnitude of the

vertical ground response force, and creating an extra downward push on the body that allows for more muscular force development. When the body segments are changed, such as when arms and legs swing, an excessive force will be generated. A lot of advantages are associated with arm motion, including increasing the body's center of gravity (CG), bringing the vertical ground response force to a greater peak magnitude, and creating a push downward that can let muscles develop more powerfully.

The identified problem was, there are three techniques used in long jump and these styles have different air dynamics and also the air dynamics can be affected to the performances. The influence of wind and altitude on the aerodynamic drag during the approach and aerial phases has been assisted (Smith, 1985). Even in the same technique has different air dynamics and it also differs from player to player. The surface area changes always happen during their whole flight. The change of body surface area (frontal plane) depends on height of the body and the technique (movement of the body segments). The same technique may have different air dynamics and may differ among players. Throughout their entire flight, the surface area always changes. The changes in body surface area (frontal plane) are affected by the body's height and the technique used (moving the body segments).

Hang, sail, and hitch-kick are popular flying techniques employed by athletes for the perform enhancement. When athletes utilize various physical movements to regulate forward angular momentum, the forward angular momentum will not be conserved, and the path of the athlete's center of mass will change and the same time the frontal body surface area will change. This research is based on the space calibration in long jump flight phase. Pervious study on changes of mass during the long jump flight phase, Jasminan and Chandana (2021) started that Hitch and Sail technique is suitable to maintain the path of CG in a projectile path computed to other two techniques; from this findings, there is a possibility that external factors to affect the path of CG. Therefore, there was a gap to identify the facts behind that study and to ensure the validity of statement.

Material & Methods

This study enrolled national senior male long jumpers at the national trial (n=6). They were divided into three groups based on their flight technique (hitch-kick group, n = 2; hitch-sail group, n = 2; and hang group, n = 2). Body weight & height of all athletes were taken before the test has begun. The data was collected at Asian Trial in Sri Lanka 2022. The best jump from six attempts was taken for the data analysis. Two (02) video cameras were used to record the performance of each player's performances.

Setup of Apparatus

Two cameras were placed on sagittal & frontal planes as shown in Figure 2. The height of both cameras was 1.2m. A 1.5m rigid rod was used for the calibration. Two (02) Godox TT650 speed lights and Godox X1R-N TTL wireless flash trigger was used to synchronize the cameras (Thotawaththa & Arangala, 2021).

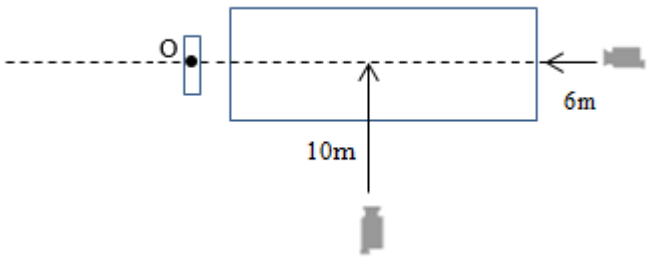


Figure 2: Experiment setup on around the long jump landing pit
(O is the origin of the coordinate system)

Space Calibration

Step 1: The square frame (S_{Sqaure} = 2025 cm^2) was moved on the sagittal plane and it was captured by two cameras.

Step 2: Fixed distance on sagittal plane was captured (Laksara & Chandana, 2019).

Calibration of Surface Area on Frontal Plane

Step 1: Retrieved the horizontal displacement (sagittal plane) of the CG in each time frame for every 6 players. Determine the corresponding position of the square frame (frontal frame) which travelled through the pit (on sagittal frame).

Step 2: Calculated body surface (on frontal frame) using the ratio between the number of pixels in the athlete and the square frame.

Results

The following plotted graphs show surface area changes against to the time in each technique.

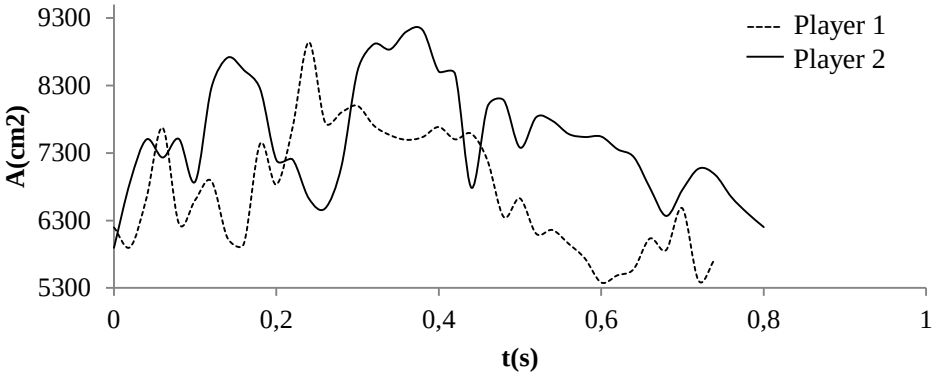


Figure 3

(Dashed line shows graph for Player 1 with technique (Hitch and Sail), m=81kg, h=1.78 m, flight time 0.75s, Performance-6.3 m and wind velocity -1.2 $m.s^{-1}$. Solid line shows graph for player 2 with Technique (Hitch and Sail), 2kg, h=1.81 m, flight time 0.8s, Performance- 5.87 m and wind velocity -1.5 $m.s^{-1}$)

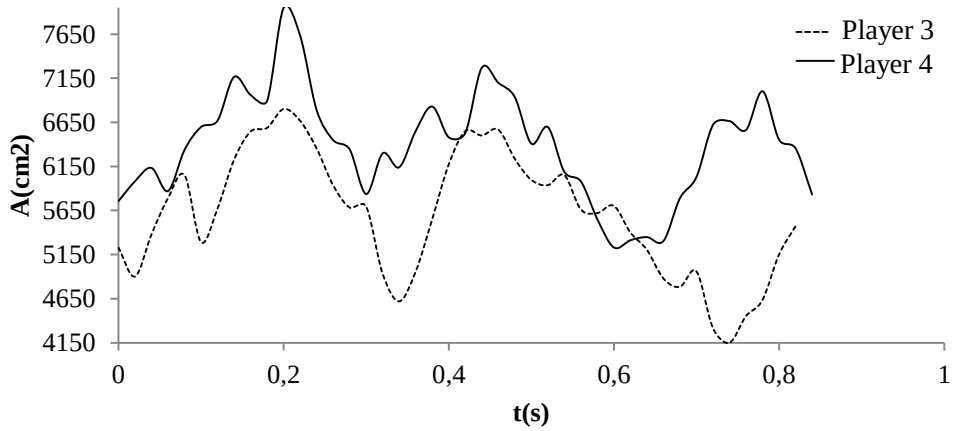


Figure 4

(Dashed line shows graph for Player 3 with Technique (Hitch Kick), m=83kg, h=1.84 m, flight time 0.84s, Performance- 6.68 m and wind velocity -0.9 $m.s^{-1}$. Solid line shows graph for player 4 with Technique (Hitch Kick), m=69kg, h=1.78 m, flight time 0.85s, Performance- 6.62 m and wind velocity -1.2 $m.s^{-1}$)

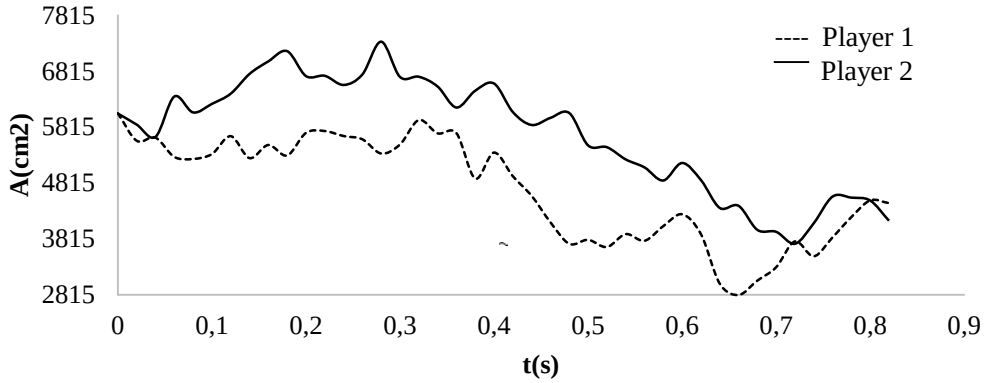


Figure 5

(Dashed line shows graph for Player 5 with Technique (Hang), m=80kg, h=1.82 m, flight time 0.8s, Performance- 6.93 m and wind velocity -1.1 $m.s^{-1}$. Solid line shows graph for player 6 with Technique (Hang), m=72kg, h=1.79 m, flight time 0.82s, Performance 6.87 m and wind velocity -1.2 $m.s^{-1}$)

According to all plotted graphs, flight times of the players (3, 4 and 6) are higher than other long jumpers. Comparing all three techniques, the last phase is starting from jerk and players try to minimize the surface area before landing. If the knee extended with good hip flexion cause to decrease the surface area and it helps to reach more distance in the air.

Correlation between Surface Area and Performance

Table 1: The correlation between surface area and performance (pearson correlation)

Control variables	V1		
	Correlation	Significance (2-tailed)	df
V1	1	.	0
V2	-0.918	0.032	4
V3	-0.89	0.017	4
V4	-0.875	0.023	4
V5	-0.815	0.048	4
V6	-0.864	0.027	4
V7	-0.866	0.026	4
V8	-0.9	0.015	4
V9	-0.931	0.007	4
V10	-0.957	0.003	4
V11	-0.814	0.049	4
V12	-0.835	0.038	4
V13	-0.826	0.043	4
V14	-0.9	0.015	4
V15	-0.901	0.014	4
V16	-0.945	0.004	4
V17	-0.9	0.015	4
V18	-0.935	0.006	4
V19	-0.92	0.009	4
V20	-0.897	0.015	4
V21	-0.839	0.037	4
V22	-0.858	0.029	4

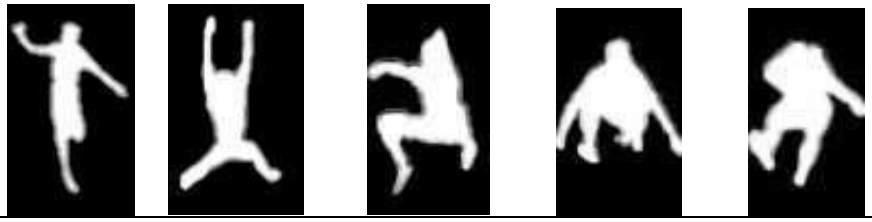
Note: V1 indicates performance and V23 are representing surface areas

Discussion

The negative correlation ($r>0.5$, $p<0.05$) corresponds to performances and surface area changes shows in Table 1. According to Table 2, the surface area changes and performances which were showed that there were the significant difference between to each ($p<0.05$) in all 21 positions. It clearly explored that there is an impact in different surface areas to the athlete's performances. Therefore, the performance increase when the surface areas decrease in 21 positions among 50 frames. These 21 positions can be derived in terms of flight time (T): 0.06T, 0.11T, 0.17T, 0.26T, 0.43T, 0.51T, 0.54T, 0.57T, 0.6T, 0.66T, 0.71T, 0.74T, 0.77T, 0.8T, 0.83T, 0.85T, 0.88T, 0.91T, 0.94T, 0.97T, 0.98T.

Those are emphasized for all three techniques in their same position in the air. The 1st position, 2nd position, 3rd position, 4th position, and 5th position is chosen from 0.17T, 0.51T, 0.71T, 0.8T, and 0.94T respectively in traveling through the air just after the take-off.

Table 2: Surface area changes for each technique (5 positions from 21)

Technique	Position				
	0.17T	0.51T	0.71T	0.8T	0.94T
Hitch and Sail					
Hitch Kick					
Hang					

The arm and leg movements contribute to minimizing the body surface area even if the upper body is fully extended. In the position of 0.17T, the upper body extended in hitch and sail but minimizes the body surface area by moving the lower extremities. A wide backward movement of the lead leg can be seen and same time take-off leg bent forward with the movement. This position in hitch kick has a slightly hip rotation and one arm extending to the side parallel to the ground and the opposite leg bent at the knee. In the hang technique, both arms are extended parallel to the ground and one leg bent by the knee.

The 2nd and 3rd positions are representing the air paddling in each technique. The 2nd position was chosen from the 0.51s traveled through the air by the athlete just after the take-off. Their hitch and sail technique performs showed that the hip rotation to the side and one leg fully extended to the forward and the other leg bent slightly by the knees. The arms are extended over the head and one arm is stretched backward. In hitch kick, the upper body is in the upright position in moreover and arm and leg movements are changed. In the hang

technique, both arms are extended upward and the upper body starts to bend forward to minimize the body surface area.

The jerk was started each of three techniques at the 3rd position (0.71T) of mentioned 21 positions. In hitch and sail, both legs were bent from knees apart to the side and the upper body slightly bent to the forward to minimize the body surface area. The hang technique performs the same action as hitch and sail but both arms are positioned in front of the body. Compared to the hitch and sail and hang technique; the hitch kick technique remains the upper body straight in trivial. To minimize the surface area, the hip rotates slightly to the side.

The 4th position was chosen from the traveled position of 0.8T. In this position, player starts to perform the landing. The player who performs the hitch and sail technique; both arms and legs are extended forward and the body is bent the forward sufficiently ($<45^0$ to the longitudinal axis). The CG is remaining close to the body and keeping the balance to reach more distance. In the hitch kick position, the player's both arms are placed above the head level and start to rotate the arm forward. One leg is bent from the knees and the other leg extends in the moving direction. The hip rotates slightly to the side. In the hang technique, both arms freely move downward. Hip bent forward than upper body lumpish (Chandana & Xubo, 2021). Hence the CG is much close to the body in the hitch kick and the hang techniques. In this position, all the body segments are stretched forward and it will assist to reduce the body surface area.

In the 5th position (0.91), is the landing and the athlete prepares for landing at the end of the flying phase by raising their legs and stretching them in front of the torso. The purpose of the landing is to generate as much horizontal distance as possible between the take-off line and the sand mark made by the heels. Both heels touch the pit and ready to land in hitch and sail technique. And the angle of the hip-knee-ankle is $\sim 135^0$. For the hitch kick technique; the upper body is bent forward and one leg fully extended to the moving direction. The other leg is bent from the knees and perpendicular to the ground. Both arms are rotating the forward and the body surface area is minimized by extended leg and bent of the upper body. In the hang technique; the upper body is fully stretched to the forward and, at the same time arms and legs are fully extended to the forward and backward respectively to minimize the frontal body surface area.

According to the results in Table 2, in Hitch Sail and Hitch kick techniques have maximized surface area in their maximum height than in other positions. If the player split the legs maximally, it will help to minimize the body surface and to achieve more distance. In the hang technique, the body surface area is maximum just after the takeoff. In the jerk position, it takes a minimum value. Hip flexion, knee extension, and hip angle differ for each position in each technique in the above images. By splitting the legs maximally, a player can minimize the body surface and maximize distance. During the takeoff phase of the hang technique, the body surface area is at its maximum. When performing the jerk position, it is at the minimum value. As shown in the above images, hip flexion, knee extension, and hip angle vary by technique.

The results revealed that even in the same position in the air, different surface areas were appropriate for hip flexion. The surface area depends on the motion of body segments like hip flexion, knee extension, and hand and leg movements. There the maximum surface area was observed just after the takeoff, and the minimum surface area was observed in the jerk position. In comparison to all three techniques, the last phase, starting with a jerk, took the least amount of surface area before landing. By extending the knee, and decreasing the hip in flexion, more distance is reached in the air.

Conclusions

Three long jump styles have different air dynamics, which also affects the performance. The present study identified the relationship between performance and surface area changes in each time frame during the flight phase of the long jump. The performance of a long jump is affected by specific movements of body segments. To optimize an athlete's performance, the surfaces of the athlete in the aerial phase need to be minimized in 21 frames (frontal frames) out of 50.

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