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Kinematic Analysis on Biomechanical Parameters of Hop Phase among Inter University Level Triple Jumpers

Santhosh. R, Associate Professor, Sree Narayana College, Punalur

Dr. Ajesh. C.R. Assistant Professor, E.K.N.M. Government College, Elerithattu

Dr. Jiji Kurian, Associate Professor, Mar Ivanios College, Thiruvananthapuram

Abstract

The purpose of the study was to predict the distance of hop phase in triple jump with the selected kinematic parameters. For the purpose of the study 20 Inter university level triple jumpers were selected and their trials were recorded using digital cameras (Sony A7S2, lens: 24-105mm, 120 FPS). Each athlete's best legal trials were analyzed for the study. The analysis on each attempt was done using Kinovea motion analysis software. The data pertaining to the selected biomechanical variables of hop phase of triple jump were tested using Descriptive statistics, and Multiple Regression analysis. The level of significance was set at 0.05 for testing the hypothesis. The kinematic analysis of selected biomechanical variables of hop phase in triple jump revealed that average velocity and flight time have a large effect in predicting the hop distance.

Key Words:- Kinematics Analysis, Hop Phase

Introduction

The definition of the term hop insinuate certain tendencies that portray the mechanics of this phase and is of the utmost aspect in determining the ultimate distance of a jump. The hop begins with the athlete jumping from the take- off board on one leg, and landing on the runway with the same leg. Seeing as the jumper takes off from the ground on a designated leg, the progress includes a backward recovery of the same leg, then swings forward a second time, in order that the jumper lands on the take-off foot. It turns out to be more of a "cycling'' movement. The take-off angle in the hop is noticeably lower than in the long jump (12 -15°). The intention is to go forward and upward, not upward and forward as regards to long jump. This is accomplished by maintaining the body erect and rotating the heel of the hop leg up under the buttocks and then extending it as far forward as possible. The jumper must stab to stanch as little as possible in the take-off by pulling the take- off leg as close as possible beneath the body. Bearing in mind the mechanical importance of hop phase, the researcher made an endeavor to find out the relationship among the selected kinematic variables of hop phase of triple jump.

Materials and methods

Twenty Inter university level Triple Jumpers of age group 18-25 years were randomly selected as the subjects for the study. Distance, Flight Time, Average Velocity, Takeoff Velocity, Angle of Takeoff, Horizontal Velocity, Loss of Horizontal Velocity, Vertical Velocity, Duration of Support Phase, Minimal Knee Angle at Touch Down, Inclination Angle at Touch Down, Trunk Angle at Touch Down, Trunk Angle at Takeoff, and Maximum Height of CG at Takeoff were selected as the variables for the study. All the attempts were recorded using digital cameras (Sony A7S2, lens: 24-105mm, 120 FPS). The performance distance comprises of 25metres had been analyzed and divided the total distance in to 3 zones (9m,8m,9m). A 0.5m overlap occurred between zones 1and 2 and between zones 2 and 3. Each zone was covered by a single camera and an additional camera was used to record the total area in order to capture the whole sequence Camera (1), camera (2) and camera (3) covering the first second and third zones were positioned at the midpoint of each zones to the left side of the runway at a distance of 10 meter from the left edge near the approach path. The camera lens was oriented perpendicular to the plane of motion (sagittal) at a height of 1.35 meters which was approximately equal to one half of the height of the athlete when he was in the air after the take off. Each attempt was captured and saved in to a computer in AVI format. The analysis on each attempt was done using Kinovea motion analysis software. All the kinematics variables of hop phase were measured using Kinovea motion analysis software. The data pertaining to the selected biomechanical variables of hop phase of triple jump phase was tested using Descriptive statistics, and Multiple Regression analysis. The level of significance was set at .05 for testing the hypotheses.

Results of the Study

Table: 1 ***Analysis of the variables of hop phase of Triple Jump***

Variable	N	Mean	Std. Deviation
Distance	20	5.45	0.40
Flight Time	20	0.54	0.05
Average Velocity	20	10.20	1.13
Takeoff Velocity	20	8.84	0.41
Angle of Takeoff	20	12.85	2.52
Horizontal Velocity	20	8.61	0.39
Loss Of Horizontal Velocity	20	1.57	0.39
Vertical Velocity	20	1.97	0.41
Duration of Support Phase	20	0.13	0.01
Minimal Knee Angle at Touch Down	20	134.85	2.91
Inclination Angle at Touch Down	20	15.80	2.44
Trunk Angle at Touch Down	20	87.20	7.49
Trunk Angle at Takeoff	20	87.30	7.09
Max: Height of cg At Takeoff	20	1.17	0.05

The Hop phase showed a mean Distance of 5.45m with a standard deviation of 0.40m. The mean Flight Time was recorded as 0.54s and the standard deviation was0.05s. The results of mean Average Velocity and standard deviation of Hop phase of the subjects were 10.20m/s and 1.13m/s respectively. The mean Take off Velocity and standard deviation of Hop phase was recorded as 8.84m/s and 0.41m/s. The results of mean Angle of Take off and standard deviation of the Hop phase was 12.85 degree and 2.52 degree. The results of mean Horizontal Velocity and standard deviation of Hop phase was recorded as 8.61m/s and 0.39m/s respectively. The results of mean Loss of Horizontal Velocity and standard deviation of Hop phase was 1.57 m/s and 0.39 m/s respectively. The mean Vertical Velocity and standard deviation of Hop phase was recorded as 1.97m/s and 0.41m/s respectively. The mean Duration of Support phase and standard deviation was 0.13 s and 0.01s for Hop phase. The results of mean Minimal Knee Angle at Touchdown and standard deviation of the Hop phase was recorded as 134.85 degree and 2.91 degree, respectively. The results of the mean Inclination Angle at Touchdown and standard deviation of Hop phase was 15.80 degree and 2.44 degree respectively. The mean Trunk Angle at Touchdown and standard deviation of Hop phase was recorded as 87.20 degree and 7.49 degree. The results of mean Trunk Angle at Takeoff and standard deviation of Hop phase was 87.30 degree and 7.09 degree respectively. The Hop phase showed a mean Maximum Height of Center of Gravity at Take off with a standard deviation of 1.17m and 0.05m respectively.

Table: 2 Summary of Multiple Regression Models

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.880[a]	.775	.762	.19738
2	.915[b]	.836	.817	.17313
3	.997[c]	.994	.992	.03551
4	.996[d]	.993	.992	.03664

a. Predictors: (Constant), Loss of Horizontal Velocity
b. Predictors: (Constant) , Loss of Horizontal Velocity, Average Velocity
c. Predictors: (Constant), Loss of Horizontal Velocity, Average Velocity, Flight Time
d. Predictors: (Constant), Average Velocity, Flight Time

Model 1 includes only one variable, Loss of Horizontal Velocity, which predicts the Hop distance with an R square of 0.775 ie. 77.5% of variation in the Hop distance can be explained by the variable - Loss of Horizontal Velocity. Model 2 includes two variables (Loss of Horizontal Velocity and Average Velocity), which predicts the Hop distance with an R square of 0.836 ie. 83.6% of variation in the Hop distance can be explained by the variables- Loss of Horizontal Velocity and Average Velocity. Model 3 includes three variables (Loss of Horizontal Velocity, Average Velocity and Flight Time), which predicts the Hop distance with an R square of 0.994 ie. 99.4% of variation in the Hop distance can be explained by the variables - Loss of Horizontal Velocity, Average Velocity and Flight Time. Model 4 includes two variables (Average Velocity and Flight Time), which predicts the Hop distance with an R square of 0.993 ie. 99.3% of variation in the Hop distance can be explained by the variables- Average Velocity and Flight Time.

Table: 3 ***Significance of the regression models assessed by ANOVA***

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.415	1	2.415	61.989	0.000[b]
	Residual	.701	18	.039		
	Total	3.116	19			
2	Regression	2.607	2	1.303	43.484	0.000[c]
	Residual	.510	17	.030		
	Total	3.116	19			
3	Regression	3.096	3	1.032	818.674	0.000[d]
	Residual	.020	16	.001		
	Total	3.116	19			
4	Regression	3.094	2	1.547	1151.872	0.000[e]
	Residual	.023	17	.001		
	Total	3.116	19			

a. Dependent Variable: Distance
b. Predictors: (Constant), Loss of Horizontal Velocity
c. Predictors: (Constant) , Loss of Horizontal Velocity, Average Velocity
d. Predictors: (Constant), Loss of Horizontal Velocity, Average Velocity, Flight Time
e. Predictors: (Constant), Average Velocity, Flight Time

Table 3 reveals that the regression equation based on model 1 is significant (F = 61.989, P = 0.000). Therefore, the Hop distance can be significantly predicted using the variable - Loss of Horizontal Velocity. The regression equation based on model 2 is significant (F = 43.484, P = 0.000). Therefore, the Hop distance can be significantly predicted using the variables - Loss of Horizontal Velocity and Average Velocity. The regression equation based on model 3 is significant (F =818.674, P=0.000).Therefore, the Hop distance can be significantly predicted using the variables - Loss of Horizontal Velocity, Average Velocity and Flight Time. The regression equation based on model 4 is significant (F =1151.872, P= 0.000).Therefore, the Hop distance can be significantly predicted using the variables - Average Velocity and Flight Time.

Table: 4 ***Coefficients of regression models and their significance***

Model		Coefficients	t	Sig.
1	(Constant)	6.893	36.644	0.000
	Loss of H. Velocity	-.918	-7.873	0.000
2	(Constant)	5.767	12.151	0.000
	Loss of H. Velocity	-.820	-7.496	0.000
	Average Velocity	.095	2.529	0.022
3	(Constant)	-4.740	-8.744	0.000
	Loss of H. Velocity	-.064	-1.452	0.166
	Average Velocity	.512	22.739	0.000
	Flight Time	9.419	19.703	0.000
4	(Constant)	-5.455	-23.258	0.000
	Average Velocity	.540	47.542	0.000
	Flight Time	10.019	40.209	0.000

a. Dependent Variable : Distance of Hop

` The regression equation based on model 1 Hop Distance = 6.893-.918 x Loss of Horizontal Velocity. Here the coefficient of Loss of Horizontal Velocity was found statistically significant using t-test (P = 0.000). Hence, Hop distance has a negative effect with Loss of Horizontal Velocity. The regression equation based on model 2 Hop Distance = 5.767-.820 x Loss of Horizontal Velocity + 0.095 x Average Velocity. Here the coefficient of Loss of Horizontal Velocity and coefficient of Average Velocity were found statistically significant using t-test (P = 0.000 and 0.022). Hence, Hop Distance has a negative effect with Loss of Horizontal Velocity and a positive effect with Average Velocity. The regression equation based on model 3 Hop Distance = - 4.740 - 0.064 x Loss of Horizontal Velocity + 0.512 x Average Velocity + 9.419 x Flight Time. Here the coefficient of Average Velocity and coefficient of Flight Time were found statistically significant using t-test (P=0.000) and coefficient of Loss of Horizontal Velocity was found statistically insignificant using t-test (P=.166). Hence, Hop Distance has a positive effect with Average Velocity and Flight Time and also have a negative relationship with loss of horizontal velocity. The regression equation based on model 4 Hop Distance = -5.455 + .540 x Average Velocity + 10.019 x Flight Time. Here the coefficient of Average Velocity and Flight Time were found statistically significant using t-test (P = 0.000). Hence, Hop Distance has a positive effect with Average Velocity and Flight Time.

Selection of the Best Regression Model

Model 1 which contains one independent variable - Loss of Horizontal Velocity (F = 61.989, P = 0.000), Model 2 which contains two independent variables - Loss of Horizontal Velocity and Average Velocity - (F = 43.484, P = 0.000), Model 3 which contains three independent variables - Loss of Horizontal Velocity, Average Velocity and Flight Time (F = 818.674, P = 0.000) and Model 4 which contains two independent variables - Average Velocity and Flight Time (F = 1151.872, P = 0.000) were found significant. While the analysis of effect of independent variable on Distance of Hop, in Model 1, 2, 3 and 4, all the variables except Loss of Horizontal Velocity in Model 3 were found statistically significant using t-test (P<.05). Model 4 which include two variables (Average velocity and Flight time) which predicts the distance with an R square of .993 ie. 99.3% of variation in Distance of Hop can be explained by the variables - Average velocity and Flight time. Hence Model 4, can be selected as the best model to predict the dependent variable, Distance of Hop phase even though the prediction percentage of Model 3 (R square=0.994 ie.99.4%) was higher than Model 4.

Discussion of Findings

By analyzing the best regression model of Hop phase, Model 4 is selected as the best model because the dependent variables- Average Velocity and Flight Time are found statistically significant with an R square of .993 i.e 99.3% and both the variables show positive effect on Hop distance. Hence, the dependent variables-Average Velocity and Flight Time play a prominent role in determining the performance of Hop phase in Triple Jump. Among the 4 models, the difference is very minimal even though in model 3, one variable is insignificant.

When comparing with Iraqi model to world model, it was found that the independent variable Duration of Support phase and Loss of Horizontal Velocity have got an inverse relationship with the Hop distance, where as variable - Horizontal Velocity at Touchdown had a significant role in the performance of the World model (Hussein Mardan Omar & Mazen Anhir Lamy, 2015).

Average Velocity of the Hop phase of Triple jump and it is recorded as 10.20m/s. Average velocity of Hop phase can be defined as the displacement of hop phase by hop flight time. As Hop phase shows larger phase distance (5.45m) and moderate flight time (0.54s), hop average velocity perceives higher. Larger phase distance of Hop is inveigled by the consequential variables such as Angle of Take-off, Maximum Height of Center of Gravity at Take-off, Take-off Velocity, Duration of Support phase, Horizontal Velocity and Vertical Velocity. Among these variables, Take-off Velocity (8.84m/s) and Horizontal Velocity (8.621m/s) exhibit upmost values. This contributes to a larger phase distance because of the optimal trajectory which is relative to the speed at which the athletes take-off. Duration of support phase (0.13s) finds the lowest and the angle of take-off (12.85 Degree) shows optimum which held through an active take-off technique that ensures sufficient phase distance.

Flight Time of the Hop phase of Triple Jump and it is perceived as 0.54s. In order to conserve the high horizontal velocity acquired through the whole approach run for the henceforth phases (step and jump), the athlete follows a moderate flight curve.“The flight curve of a jump analogous to that of a projectile and the projectile with greater velocity will have a much higher trajectory during the flight phase which influences the phase distance". However in the case of Hop phase, the athlete up keep the flight curve at a moderate height by shifting the hip (CG) reasonably at take-off in order to preserve the horizontal velocity. This is swayed by the variables such as maximum height of center of gravity at take-off (1.17m) and vertical velocity (1.94m/s) and these values are seems modest. In view of the above facts, the hop flight time which is observed as modest has a close relation with the flight distance and average velocity. Hence, the variable hop flight time remains unchallenged in determining the performance of Triple jump.

Conclusions

1. The Average Velocity of the Hop phase of Triple jump and it is recorded as 10.20m/s. Average velocity of Hop phase can be defined as the displacement of hop phase by hop flight time. As hop phase shows larger phase distance (5.45m) and moderate flight time (0.54s), hop average velocity perceives higher. Larger phase distance of hop is inveigled by the consequential variables such as Angle of Takeoff, Maximum Height of Center of Gravity at Takeoff, Take off Velocity, Duration of Support phase, Horizontal Velocity and Vertical Velocity. Among these variables, Takeoff Velocity (8.84m/s) and Horizontal Velocity (8.621m/s) exhibit upmost values. This contributes to a larger phase distance because of the optimal trajectory which is relative to the speed at which the athletes take off. Duration of support phase (0.13s) finds the lowest and the angle of take off (12.85 Degree) shows optimum which held through an active take off technique that ensures sufficient phase distance. Maximum Height of Center of Gravity (1.17m) and Vertical Velocity (1.97m/s) shows moderate in the hop phase helps to sustain the horizontal velocity in the succeeding phases. Hence the variable -Average Velocity reveals a positive relationship and manifest an outstanding role in predicting the Hop distance

2. The Flight Time of the Hop phase of Triple Jump and it is perceived as 0.54s. In order to conserve the high horizontal velocity acquired through the whole approach run for the henceforth phases (step and jump), the athlete follows a moderate flight curve. ''The flight curve of a jump analogous to that of a projectile and the projectile with greater velocity will have a much higher trajectory during the flight phase which influences the phase distance''. However in the case of Hop phase, the athlete up keep the flight curve at a moderate height by shifting the hip (CG) reasonably at takeoff in order to preserve the horizontal velocity. This is swayed by the variables such as maximum height of center of gravity at take off (1.17m) and vertical velocity (1.94m/s) and these values are seems modest. In view of the above facts, the hop flight time which is observed as modest has a close relation with the flight distance and average velocity. Hence, the variable - Flight time exhibits a positive relationship and remains unchallenged in determining the performance of Hop phase.

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