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Original article

RELATIONSHIPS BETWEEN HORIZONTAL VELOCITY VARIABLES AND JUMP PERFORMANCE IN THE TRIPLE JUMP

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Abstract

Aim. The aim of this study was to determine relationships between triple jump phases and velocity variables in Turkish athletes.

Methods. The research group was composed of 38 Turkish male triple jumpers. The findings were obtained during the official competitions. All trials of the athletes were recorded by two camcorders. The photocells which are used to determine running times of athletes have been established 1m, 6m and 11m distance from the take-off board. Velocities for 11m-6m section (V1), 6m-1m section (V2), total 10m (V10) and difference between V2 and V1 (V2-V1) were calculated for each jump. The official jump distances were recorded. Best performance of the athletes were analysed by the two dimensional analysis software. The official distance, actual distance, distance lost at take-off, hop distance, step distance, jump distance, hop percentage, jump percentage and step percentage, step length and velocity variables, contact time variables were measured and calculated. General characteristics of the participants were presented as means and standard deviations (±SD). Pearson correlation coefficients (r) were used to express the relationships between parameters. Linear regression analysis was used to find coefficients of determination (r2) for the relationships.

Results. It was found relationships between horizontal velocity variables and jumping distance. A strong correlation is between V10 and official distance ($r=0.88$, $p<0.05$, $r^2=0.78$). It was established a linear regression model to explain this relation[Predictive distance=(1.822*V10)-1.952]. Furthermore the technical effectiveness score can calculated with the measured distance divided by predictive distance during the competition or technical training.

Conclusion. This study has demonstrated that the approach velocity is highly related to jumping performance in triple jump. It can be suggested that the speed ability should be priority testing in talent identification in triple jump. In addition, the effectiveness score which is explained in this study can use by the athletic coaches to assess of their athletes' technical level.

*Keywords:*triple jump, hop, step, jump, velocity

Introduction

The triple jump is one of the jumping events in track and fields, and requires high levels of physical preparation and technical ability. It is technically divided into the approach run and three consecutive jumps which are named hop, step and jump.

The optimal distribution among hop, step and jump phases is set as an important affecting fact according to the triple jump performance. The hop-step-jump is indicated as a percentage of the triple jumps whole distance. The distances in its phases which are to do were known as the percentage of these phases. The ratio of this percentage is the ratio of these three phases and it is used as a measure for the distribution of the triple jump performance. The triple jump techniques were divided in three phases according to their hop-step-jump proportions: (a) Hop dominant technique: The hop rate is at least 2% bigger than the other step percentages; (b) Jump dominant technique: The jump rate is at least 2% bigger than the other step percentages; (c) The balanced technique: The rate between hop and jump is less than 2% (Hay, 1999).

Similar to long jump the approach run velocity is determining the jumping performance in triple jump.In addition to that the lost velocity during the three times performed jump action is effecting the jumping success. Hay and Miller (1985)found out that in the jump supporting phase 6%, in the support phase of step and jump loss of velocity is doubled. In the triple jump analyse of the Olympic Games in Athens 1996 it was found out, that almost the half of the male athletes using the hop dominant technique, and that those who used the balanced and jump dominant technique were as successful as those who used the hop dominant technique (Hay, 1999).

In a study investigating the competition performance of elite athletes (actual distance= 17.39 m), the speed for the approach run of the last 10 m(V10) were measured as a mean value of 10.10 m/s, the values of jump phases ratio mean 37:30:33

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(hop:step:jump, hop dominant technique), supporting time was 0.120, 0.150 and 0.170 s (hop, step and jump, respectively)(Hommel, 2009). In another study it was found out for (actual distance=17.46 m), that the athletes have a meanvelocity value of 10.18 m/s in their last step, their jump phases rate mean values were 36.0:29.9:34.1 (hop:step:jump, balanced technique), their supporting time was 0.130, 0.170 and 0.190 s (hop, step and jump, respectively)(Woo and Kim, 2011). Donley (1991) has declared that most male triple jumpers had horizontal velocity between 10.04 and 10.46 m/s.

It was found out that there is an important relation between triple jump performance and the values of the approach run velocity. For instance, Moura et al.(2005) found moderate correlation between approach velocity and performance ($r=0.58$, $p<0.02$). Fukashiro et al. (1981)have also declared that there was significant relationship between total jump distance and the velocity of run-up ($r=0.68$, $p<0.01$). Furthermore Fukashiro& Miyashita (1983)has revealed a strong significantly correlation between two component which are the approach velocity and jump distance ($r=0.91$, $p<0.001$). Whereas these studies which have found moderate or strong relationships between velocity and distance, Hutt (1988) has reported that the statistical correlation between final approach velocity and triple jump performance is not as significant.

Even so, most of the studies shown that the approach velocity was found highly correlated with the jumping distance (Liu, Mao and Yu, 2015; Niessen et al. 2004; Panoutsakopoulos et al. 2016; Panoutsakopoulos and Kollias, 2008; Perttunen et al. 2000; Yongkui Zhang, 2013). The jump phases of triple jump are affected not only horizontal velocity values, but also loss in the horizontal velocity (Fukashiro et al. 1981; Liu, Mao and Yu, 2015).

It seems that biomechanical analyses are crucial applications in developing and understanding technical level of athlete by serious quantitative information to evaluate the performance of athletes (Eissa, 2014) in according to individually (Yu, 1999). Therefore the researches should be apply to on target athletes. The purpose of this study was to determine relationships between horizontal velocity variables and jumping distance variables in Turkish male triple jumpers.

Methods

The research group was composed of 38 Turkish male triple jumpers who were 19,4±2,8 years old. The findings were obtained during the official competitions which were in the calendar of Turkish Athletic Federation, and with the permission of the federation.

All trials of the athletes in the research group were recorded by two camcorders at 100 fps (Panasonic HC-w850). The first camera was placed perpendicular to the take-off board and covered the last step of approach and the hop. The second camera also was placed perpendicular to the runway, and covered from the step to landing area in the sand. The photocells which are used to determine running times of athletes have been established 1m, 6m and 11m distance from the take-off board (SmartSpeed, FusionSport, Australia). Velocities for 11m-6m section (V1), 6m-1m section (V2), total 10m (V10) and difference between V2 and V1 (V2-V1) were calculated for each jump. The official jump distances were recorded. Best performances of the athletes were analysed by the two dimensional analysis software (Tracker, v4.90-95). The official distance, actual distance, distance lost at take-off, hop distance, step distance, jump distance, hop percentage, jump percentage and step percentage, step length and velocity variables, contact time variables were measured and calculated according to the method of Hay (1999) and Hay & Miller (1985).

General characteristics of the participants were presented as means and standard deviations (±SD). Pearson correlation coefficients (r) were used to express the relationships between parameters. Interpretation of correlation coefficients was as follows: $r \leq 0.49$ weak relationship; $0.50 \leq r \leq 0.74$ moderate relationship; and $r \geq 0.75$ strong relationship (Portney and Watkins 2015). Linearregression analysis was used to find coefficients of determination (r^2) for the relationships. For the statistical procedure IBM-SPSS 20.0 pocket program was applied and statistical significance was set at $p<0.05$.

Shapiro-Wilk test was applied in order to test of normality for the variables, therefore it was observed that the research group has shown normal distribution ($p>0.05$).

Results

The triple jump kinematic variables of the athletes are presented in Table 1. The research group has 14.78 m mean value of actual distance for triple jump. The distance lost mean value of the athletes is 0.08 m. Their last step (LS) length is 2.24±0.18 m and velocity of the last step is 10.39 m/s. The athletes have demonstrated mostly the hop dominated technique (66%). Few athletes' technique is jump dominated (%5) and the rest on have balanced technique (11 athletes). As for the change velocity percentage, it was observed that horizontal velocity have decreased up to 26%

except last step velocity.The durations of support phases are progressively increase from hop to jump phase (0.140, 0.170 and 0.190 s; hop, step and jump, respectively).

Table 2. The triple jump kinematic variables (mean ± SD) of the research group (n=38)

Variables		Mean	SD
Distance (m)	Official Distance	14,70	0,83
	Actual Distance	14,78	0,82
	Distance lost	0,08	0,06
Velocity Values (m/s)	V1	9,14	0,44
	V2	9,10	0,47
	V10	9,14	0,40
	VLS	10,39	0,66
	Vhop	8,51	0,50
	Vstep	7,78	0,59
	Vjump	5,56	0,52
Jump Phases Distance (m)	Hop	5,49	0,36
	Step	4,37	0,34
	Jump	4,92	0,49
Jump Phases Ratio (%)	Hop	37,2	1,9
	Step	29,6	1,7
	Jump	33,2	2,4
Change Velocity Percentage (%)	V2-V1	-0,4	5,2
	VlossLS	13,5	8,2
	VlossHop	-17,2	6,6
	VlossStep	-8,5	6,2
	VlossJump	-26,8	6,0
Support Phases (s)	Hop CT	0,140	,010
	Step CT	0,170	,020
	Jump CT	0,190	,020

Table 3. The relationships between velocity variables with jump distances

		Approach Run Velocities				Jump Phases Velocities			Vloss
		V1 (m/s)	V2 (m/s)	V10 (m/s)	VLS (m/s)	Vhop (m/s)	Vstep (m/s)	Vjump (m/s)	V2-V1 (%)
Official D.	r	.76**	.79**	.88**	.45**	.63**	.48**	.03	.08
(m)	p	.00	.00	.00	.01	.00	.00	.90	.64
Actual D.	r	.77**	.77**	.88**	.45**	.62**	.47**	.06	.06
(m)	p	.00	.00	.00	.01	.00	.00	.81	.72
LostD.	r	-.04	-.27	-.17	-.06	-.13	-.07	.29	-.25
(m)	p	.83	.11	.31	.72	.45	.66	.24	.14

The relationships between horizontal velocity variables with jump distances were given in Table 3. It was found that there are strong relationships among the variables of approach run velocities (V1, V6 and V10) and official distance, also with actual distance (from r=0.76, to r=0.88; p<0.05). The moderate relations were observed between hop phase velocity with official distance (r=0.63) and actual distance (r=0.63). It was not found any relationship the lost distance with horizontal velocity variables. Triple jump phases which are hop, step and jump distance have positive moderate and weak correlations with horizontal velocity values (Table 4). There is a statistically significant strong relation between jump phase's ratios and the velocity of jump phase (r=0.80, p<0.05).

Table 4. The relationships between velocity variables with variables of the jump phase's ratios

		Approach Run Velocities				Jump Phases Velocities			Vloss
		V1 (m/s)	V2 (m/s)	V10 (m/s)	VLS (m/s)	Vhop (m/s)	Vstep (m/s)	Vjump (m/s)	V2-V1 (%)
Hop	r	.53**	.42**	.55**	.36*	.51**	.13	-.09	-.07
(m)	p	.00	.01	.00	.03	.00	.43	.72	.66
Step	r	.54**	.45**	.54**	.33	.41*	.16	-.42	-.06
(m)	p	.00	.00	.00	.05	.01	.34	.08	.72
Jump	r	.52**	.67**	.68**	.23	.38*	.58**	.69**	.20
(m)	p	.00	.00	.00	.18	.02	.00	.00	.23
Hop	r	-.15	-.31	-.24	-.03	-.02	-.34*	-.28	-.17
(%)	p	.37	.06	.14	.85	.90	.03	.25	.32
Step	r	.02	-.12	-.08	.05	-.03	-.23	-.62**	-.16
(%)	p	.90	.48	.61	.76	.84	.16	.01	.35
Jump	r	.11	.33*	.26	-.01	.04	.45**	.80**	.24
(%)	p	.53	.04	.12	.94	.79	.00	.00	.14

Table 5. The relationships between velocity variables with contact time (CT) of the jump phase ratios

		Approach Run Velocities				Jump Phases Velocities			Vloss
		V1 (m/s)	V2 (m/s)	V10 (m/s)	VLS (m/s)	Vhop (m/s)	Vstep (m/s)	Vjump (m/s)	V2-V1 (%)
Hop CT	r	-.08	-.28	-.19	-.12	-.17	-.32*	-.24	-.21
(s)	p	.65	.09	.27	.49	.31	.05	.33	.20
Step CT	r	.02	-.20	-.06	-.06	-.17	-.56**	-.37	-.22
(s)	p	.91	.23	.70	.75	.32	.00	.13	.18
Jump CT	r	.01	-.16	-.03	-.05	-.10	-.33*	-.03	-.18
(s)	p	.96	.33	.85	.79	.57	.04	.91	.29

The relationships between horizontal velocity variables and contact time of jump phases were demonstrated in Table 5. According to these values that there are negative and moderate relation between the velocity of step phase and step contact time ($r=-0.56$, $p<0.05$). It means that the velocity of step phase decreased when jump contact time increased. Similar direction, but weak relationships were observed between step phase velocity with hop contact time and jump contact time ($r=0.32$, 0.33, hop and jump, respectively). The jump contact time has a weak and positive relation ($r=0.33$) with step phase ratio, too (Table 6).

Table 6. The relationships between support phases variables with jump distances

		Official Distance (m)	Actual Distance (m)	Lost Distance (m)	Hop (m)	Step (m)	Jump (m)	Hop (%)	Step (%)	Jump (%)
Hop CT	r	-.22	-.21	.18	-.15	.01	-.25	.04	.21	-.18
(s)	p	.18	.21	.29	.36	.96	.14	.83	.20	.27
Step CT	r	-.06	-.05	.18	.06	.09	-.19	.14	.18	-.24
(s)	p	.71	.76	.29	.74	.59	.25	.41	.28	.14
Jump CT	r	-.07	-.08	-.09	.00	.18	-.26	.10	.33*	-.31
(s)	p	.66	.63	.57	1.00	.28	.11	.57	.04	.06

Linear regression model of run-up velocity and the jump distance

With the last 10 meters of approach velocity (V10) as the independent variables, and distance of triple jump performance (official distance) as the dependent variables, establish the regression model (Table 7).

Table 7. Fitting results of regression model

R	R^2	Adjusted R^2	Std. Error of the Estimate
0,88	0,78	0,77	0,40

Table 8. Significance test results of regression model

	Sum of Squares	df	Mean Square	F	p
Regression	19,702	1	19,702	125,774	,000
Residual	5,639	36	,157		
Total	25,341	37			

Table 9. Significant test results of regression coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	p
	B	Std. Error	Beta		
(Constant)	-1,952	1,486	-	-1,314	,019
V10	1,822	,162	,882	11,215	,000

At the end of the simple linear regression analyse to predict the effect of the triple jumpers approach run velocity on the jump distance, it was found out that there is an important correlation (r=0.88, r^2=0.78) and it was found out that the velocity of the approach run is a predictor for the jumping distance ($F_{(1-36)}$=125,774, p<0.05)(Table 8.). The approach run velocity is explaining 78% of the jumping distance. The regression equation main predictive variable coefficient (B=1,822) significant test shows that the approach velocity is a significant predictor (p<0.01) (Table9.). According to the regression analyse finding the equation for the triple jump distance prediction is as:

Predictive Jump Distance= Y

Velocity of last 10 meters (V10) = X

Y = (1.822X) - 1,952

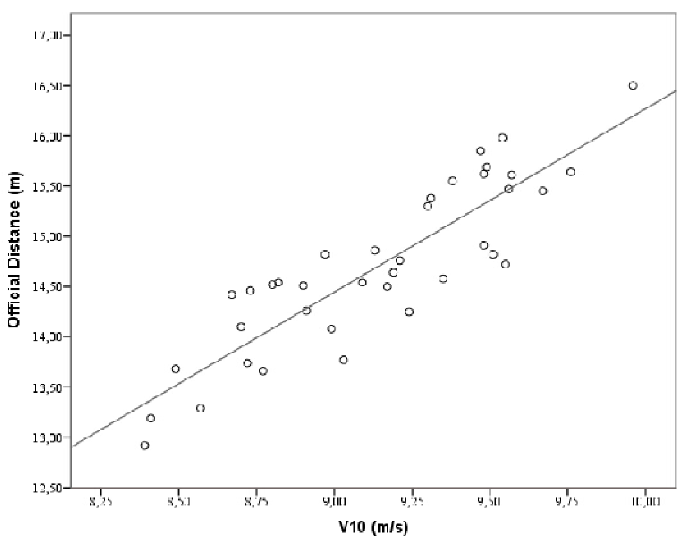

Figure 1. The relationship between the approach run-up velocity which is V10 (11-1 m) and official triple jump distance (r=0.88, p<0.05; r^2=0.78)

Discussion

The horizontal velocity is a crucial component in the triple jump performance. The finding was reported most of the studies which were examined on relationship between approach velocity triple jump performance(Fukashiro et al. 1981; Liu, Mao and Yu, 2015; Niessen et al. 2004; Panoutsakopoulos et al. 2016; Panoutsakopoulos and Kollias, 2008; Perttunen et al. 2000; Yongkui Zhang, 2013). The present study has found a similar relation between official jump distance and last ten meters of run-up velocity (r=0.88, p<0.05). The approach velocity mean values are over 10 m/s for elite triple jumpers who has jumped over 17 meters(Donley, 1991; Hommel, 2009; Miller and Hay, 1986; Woo and Kim, 2011), more than 1m/s faster from Turkish triple jumpers (V10=9.14±0.4 m/s).

It is known that the horizontal velocity decreased during the jump phases, because of the consecutive three take-off. The changes velocity are 6% for the hop phase, and more than twice that much during each of succeeding phases(Hay and Miller 1985). It means that the changes velocityare range from -6.0% to -13.6%. Miller and Hay (1986) have reported the values from -6.8% to -17.8% in order to the relative changes in horizontal velocity during the jump phases. The current study has found the relative change velocity values between -8.5% and -26.8%. The increasing in the changes of horizontal velocity would affect all jump phases which named hop, step and jump as the study of Liu et al. (2015). Whereas it was not found any relationship between the changes velocity and other variables in the current study.

As for the contact time of the phases are 0.140, 0.170 and 0.190 s for hop, step and jump, respectively according to the findings of this study. Hay & Miller (1985) has noticed that the contact time of the hop-step-jump phases are 0.132, 0.169 and 0.188 s, respectively.Fukashiro et al.,(1981) reported that the contact time values are 0.120 s for hop, 0.150 s for step and 0.160s for jump phase. In another study it was found 0.135, 0.168 and 0.185 s for hop, step and jump contact time, respectively (Miller and Hay 1986). The contact time values of jump phases was identified 0.134 s (hop), 0.161 s (step) and 0.190 s (jump) byPanoutsakopoulos et al.(2016). They have also found negatively relationships between actual distance and contact time values for hop and step ($r=-0.64/-0.62$, $p<0.05$, respectively). Whereas to this findings, it was not observed any relationship between jump distance and contact time values in the present study. However, it was found that there is a weak positive relation between step distance ratio and jump contact time ($r=0.33$, $p<0.05$). Additionally, the velocity of step phase has weak and moderate negative correlations with contact time of hop-step-jump phases in this study. This findings have emphasized that the contact time of the jump phases are a significant component of triple jump in according to the previous studies (Panoutsakopoulos et al. 2016; Panoutsakopoulos and Kollias, 2008). Because there are an advantage of the shorter contact times to achieve better jumping distance for athlete.

The one of the prominent finding of this research is a relationship between the last 10 m velocity of approach run and official distance ($r=0.88$, $p<0.05$). Previous studies have shown a similar relation between this variables. For instance, Zhang (2013) has observed strong correlation ($r=0.84$, $p<0.05$) among the performance and run-up speed in triple jump. Fukashiro and Miyashita (1983) has found a similar relation between the horizontal velocity and the jumping distance ($r=0.91$, $p<0.001$).Further Fukashiro et al. (1981) reported that there is a moderate correlation about this issue ($r=0.68$, $p<0.01$).

According to the regression model of this study that the determination coefficient (r^2) is 0.78. It may be stated that 78% of the jumping performance variation can be explained by horizontal velocity of approach (V10). For the other 12 % it needs other variables to clarify the variation of jump performance for male triple jumpers.Many studieshave found a similar determination coefficient in their regression model. Liu et al. (2015) noticed that the horizontal velocity of approach explained 94% of the actual distance in triple jump. Zhang (2013) was found 0.707 for determination coefficient.

Practical Application:The run-up velocity of last 10 m (V10) is calculated during the competition or technical training. According to the equation below, the predictive jump distance is found for a male triple jumper.

Predictive Jump Distance = (1.822*V10) - 1,952

Then, the measured jump distance value is divided by the predictive jump distance value. Thus, a technical effectiveness score is obtained from this dividing for an athlete.

Technical effectiveness score = Measured Distance / Predictive Distance

If the score is less than 1, it means that the technical effectiveness of athlete is low level. If the score is more than 1, the athlete's technical effectiveness is high level.

Conclusions

This study has demonstrated that the approach velocity is highly related to jumping performance in triple jump. It was observed that this correlation is more important than other performance component in Turkish male triple jumpers. Even if the literature has explained the many component of the jumping performance. It can be suggested that the speed ability should be priority testing in talent identification in triple jump. In addition, the effectiveness score which is explained in this study can use by the athletic coaches to assess of their athletes' technical level.

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