DOI: https://doi.org/10.53350/pjmhs211582324

ORIGINAL ARTICLE

Prediction of Jumping Distance Using Run-Up Velocity and Age for Female Long Jumpers

IŞIK BAYRAKTAR[1], MURAT ÇILLI[2], TUNCAY ÖRS[3]
[1]*Faculty of Sport Sciences, Department of Coaching Education, Alanya Alaaddin Keykubat University, Alanya, Turkey, isik.bayraktar@alanya.edu.tr*
https://orcid.org/0000-0003-1001-5348
[2]*Faculty of Sport Sciences, Department of Coaching Education, Sakarya University of Applied Sciences, Sakarya, Turkey, mcilli@subu.edu.tr*
https://orcid.org/0000-0002-9027-363X
[3]*Ministry of National Education, Aydin, Turkey, tuncayors400@gmail.com , https://orcid.org/0000-0002-6341-8354*
Corresponding Author: Tuncay ÖRS, Ministry of National Education, Aydin, Turkey, E-mail: tuncayors400@gmail.com, Mobile: +90 (539) 763 03 30

ABSTRACT
It is the flight distance which is approximately ninety percent of jump distance in long jump. On the other hand, there are many biomechanical factors that determine the flight distance and horizontal velocity is considered to be the most effective factor. The aim of this study was to create a jump distance estimation model based on run-up velocity that can practically be used by trainers. The research data was included 858 valid trials of 156 female Turkish long jumpers (ages: 17.8±3.4 years). According to the correlation results of the current study; a nonlinear regression model was used between the variables found to have the highest correlation (age, last 10 meter run-up velocity, jump distance). According to this model, 79.10% of the jump distance can be estimated with the variables of age and run-up velocity in the last ten meters. Developed to be used for female long jumpers at a broad performance level, this model may make it possible to make technical evaluations about whether the velocity, technique and strength of a female long jumper are stable.
Keywords: long jump, velocity, age, prediction model

INTRODUCTION

Many studies have been performed on the effects of variables that determine the jump distance performance in long jump[1, 2, 3, 4]. In a study on the share of take-off, flight and landing parameters on the performance, which make up the total jump distance, the ratios were found as follows for take-off, flight, and landing respectively; 5.4%, 92.9%, 8.0%[5]. This makes it clear that the flight phase with the highest share on performance is related to the run-up velocity, the jump angle and the height of the center of body mass from the ground. It has been established in many studies that among the other three variables, velocity gained in the run-up phase constitutes the most important determinant of performance[6, 7, 8, 9, 5, 10]. Fastest athletes are not considered to the best long jumpers; however, the best long jumpers are stated to be the fastest ones. This has been observed in the long jump biomechanical analysis report of the 2009 International Amateur Athletics Federation (IAAF) World Athletics Championships. Both male and female athletes who came first had higher run-up velocities than the others[11]. It is known that Beamon, Powel and Lewis, who have the all-time three best records, each had 11 m/s horizontal velocity. In a study conducted by Bridgett and Linthorne[7] a strong correlation of 0.97 between horizontal velocity and jump distance was reported. In other words, it was observed that for each 0.1 m/s raise in the horizontal velocity resulted a raise in the jump distance by 10.7 cm[1]. Similarly, other studies also demonstrated that each 0.1 m/s raise in the horizontal velocity will result a raise by 8-12 cm in jumping distance[8].

Many such studies have put forth that the velocity gained in the run-up phase constitutes the most important performance determinant[6, 7, 9, 5, 10]. A number of researchers who reported a significant correlation between run-up velocity and jump distance created corresponding prediction models. On the other hand, these studies on the relationship between the run-up velocity and performance revealed various correlation coefficients, as well as various models.

The differences in these studies can be explained by some reasons. Among the reasons, the data of the age, gender, and performance level of the research group in the creation of the models are important. It is also known that these studies have been carried out with a limited number of male jumpers at the time of major competition events. Thus, Hay and Miller [3] carried out their study with twelve athletes in the long jump final event of the 1984 Olympic Games (Los Angeles). On the other hand, Fukasiro and Wakavama[12], made use of the data obtained during the 1968 Mexico, 1988 Seoul Olympics, and the 1991 World Championships (Tokyo). Lees et al.[10] had twelve athletes (competed in the 1991 Summer Universiade) in their study. However, there are some contradictions in the literature regarding how the impact of the correlation between the jump distance and run-up velocity varies based on performance level. In his study with 1856 male and 1240 female long jumpers, Lukin (cited, Hay, 1986) observed that run-up velocity was important as expected in low-performance groups, but this importance would gradually decrease with increasing performance. Karas et al.[13] gathered similar results to Lukin's work in their study with 700 long jumpers.

Another factor for the differences observed in the studies can be the mathematical method used in the model. Many studies report that run-up velocity and jump distance has both linear and quite important relationship[14, 15, 10, 16]. Meanwhile, according to Beres et al.[14], there is no reason for a linear relationship between run-up velocity and jump distance in long jump, the evidence that this relationship may not be linear is from various sources. In cross-sectional studies, Mikhailov, Yakunin, and Aleshinsky (1981) and Tiupa, Aleshinsky, Primakov, and Pereverzev (1982) examined a large number of athletes of different ages, genders and skill levels and reported a non-linear relationship between the two variables (cited, Béres, Csende, Lees, & Tihanyi, 2014). However, a non-linear relationship can be expected on the basis that the velocity cannot increase indefinitely in long jump, and the skills and physical abilities of the athlete to convert the run-up velocity to the jump distance will begin to deteriorate at some point.

Based on the aforementioned reasons, it can be seen that the prediction models developed in different studies may particularly reveal erroneous results in the estimation of data outside the measurement range. While Mikhailov, Yakunin, and Aleshinsky created a prediction model in 1981, as well as Tiupa, Aleshinsky, Primakov and Pereverzev in 1982 (cited, Béres, Csende, Lees, & Tihanyi, 2014), it has been understood that especially regression equations that Mihailov et al. presented erroneous prediction results[8]. Dwight Phillips, the world champion in Berlin in 2009, jumped 8.54m at 11.0m/s run-up velocity in the last ten meters, according to the records[11]. According to the prediction model by Mikhaliov et al., a male athlete with 11m/s run-up velocity should reach a 52.01m distance, which is a result that is not admissible considering the world record of 8.95m in long jump. Whereas the prediction equation by Tiupa et al suggests that an athlete with 11m/s run-up velocity should reach an 8.87m jump distance. Meanwhile, according to the regression equation by Bayraktar ve Çilli[1], an athlete with 11m/s run-up velocity should reach an 8.55m jump distance. It is also seen that there were 13 jumps in the study of Mikhaliov et al., 113 jumps in that of Tiupa et al. (cited, Hay, 1986), and 327 jumps in that of Bayraktar and Çilli. The number of jumps and the range of distances to be evaluated in such studies increase the reliability of the models in estimating the jump distances of athletes at different skill levels. It is thought that models that take into account the effects of variables such as age and gender should give more accurate results.

There is hardly any study in the literature regarding the relationship between jumping distance and run-up velocity on female long jumpers. In a study examining the relationship between jump distance and run-up velocity in the 2009 Berlin World Championships long jump final competition, there was a moderate positive relationship (r=0.66) between the run-up velocity of female athletes in the last ten meters and their performances[17]. Linthorne's[16] model values study on long jumpers emphasizes that a female athlete should have a horizontal velocity of 9.50m/s to reach 6.80m jump distance. Especially for a wide performance range, there is no prediction model in the literature that one can make use of for the prediction of jump distance with run-up velocity for women in long jump. Graham-Smith P, Lees A.[18] developed a model to estimate the average expected jump distance for male and female long jumpers. However, the developed model is based solely on run-up velocity and distance data collected from elite athletes competing in juniors and seniors championships and Grand Prix competitions. It is thought that studies with data from more long jumpers will be beneficial in terms of the distribution of run-up velocity and jump distance values. Hence, it can be said that it will be beneficial to develop models that can make better predictions for jump distance by examining the relationship between age, run-up velocity, jump distance, especially in female athletes.

The aim of the current study was to investigate the relationship between the age, run-up velocity, and jumping distance of female long jumpers. Moreover, it was aimed to create a jump distance estimation model that can easily be used. In accordance with this aim the hypothesis was determined as follows: for female long jump, jumping distance may be estimated from the approach run velocities.

METHODS

The research data was included 858 valid trials of 156 female Turkish long jumpers (ages: 17.8±3.4 years). The results were collected during official competitions (23) from the calendar of the Turkish Athletic Federation (TAF).

The photocells were placed at the following distances to determine the running times: (a) 1m, (b) 6m, and (c) 11m behind the takeoff board (SmartSpeed, FusionSport, Australia). Following parameters were calculated: (a) 11m-6m part velocity (V1), (b) 6m-1m part velocity (V2), (c) the total 10m (V10) velocity. Besides, differences between V2 and V1 (Vloss) were calculated for each jump. The official jumping distances of the athletes were recorded.

Ethics: The data were collected after the approval of local Ethics Committee (No: E.9365) and with the permission of the TAF.

Statistical Analysis: General characteristics were presented as means ± standard deviations (SD). To express the relationships Pearson correlation coefficients (r) were used. The interpretation of correlation coefficients was as follows: weak relationships ($r \leq 0.49$); moderate relationships ($0.5 \leq r \leq 0.74$); and strong relationships ($r \geq 0.75$) (Portney and Watkins 2015). To find coefficients of determination for the relationships (r2) regression analysis was used. IBM-SPSS 22 software was applied for the statistical analysis. Statistical significance was set at $p<0.05$. Non-linear correlation analysis between jump distance and age, and V10 was performed using the nlcor function of R programming language. The determination of the suitable curve was made in SPSS 22 software with 'Curve Fitting'. After determining the trend curve between dependent and independent variables, MINITAB 18 software was used to determine the second-order nonlinear regression model.

Figure 1. Near Here

RESULTS

The information about the athletes was given in Table 1.

Table 1. Near Here

Table 2. Near Here

In Table 2, nonlinear correlation coefficients between jump distance and age, V1, V2 and V10 are given. This run-up velocity variable was preferred for examination since V10 was the highest value in the model. Accordingly, there is a moderate positive relationship between the values and age. Whereas, a strong positive nonlinear relationship between the values and V10 (Figure 2).

Figure 2 and 3. Near Here

The aim was to establish a regression model by using V10 variables, which had the highest correlation value between jump distance and age. For this purpose, it was determined that the most suitable curve between dependent and independent variables was cubic and quadratic considering the coefficients of determination (R^2) for the model. The quadratic model was preferred to make the interpretation of the model easier and not to complicate the model (Table 3 and Table 4).

Table 3. Near Here

Table 4. Near Here

Table 5. Near Here

Nonlinear regression model results are given in Table 5. According to Table 5, the effect of age and V10 variables on the jump distance variable is positive and statistically significant ($p<0.001$). The variable of jump distance increases as the values of age and V10 variables increase. 79.10% of the jump distance variable can be explained with the variables of age and V10. The remaining 20.90% takes place with other variables. The regression model according to Table 5 is as follows:

$$\text{Jump Distance (m)}^{1/2} = 0.7833 + 0.008058 * \text{Age} + 0.17031 * \text{V10}$$

This model equals the following equation:

$$\text{Jump Distance (m)} = (0.7833 + 0.008058 * \text{Age} + 0.17031 * \text{V10})^2$$

TABLES

Table 1. Mean and standard deviation values of the age, jumping distance and velocity variables for athletes

	n	Mean (SD)	Min	Max
Age (year)	858	17.8 (3.4)	13.1	30.1
Jump Distance (m)		5.17 (0.58)	4.00	7.05
V1 (m/s)		7.81 (0.66)	5.81	9.80
V2 (m/s)		7.98 (0.55)	6.57	9.40
V10 (m/s)		7.89 (0.56)	6.29	9.54
Vloss (m/s)		0.18 (0.46)	-1.25	1.47

Table 2. Correlation coefficients between jump distance and age, and V10

	Age	V1	V2	V10
Jump distance	0.656*	0.806*	0.818*	0.874*

Table 3. Curve fitting results between age and jump distance variables

Dependent Variable: Jump Distance [m]					
Conversion	Model Summary				
	R^2	F	Sd1	Sd2	p
Linear	.467	749.841	1	856	<0.001
Logarithmic	.493	832.985	1	856	<0.001
Inverse	.507	880.576	1	856	<0.001
Quadratic	.511	447.041	2	855	<0.001
Cubic	.511	447.041	2	855	<0.001
Compound	.450	699.472	1	856	<0.001
Power	.478	783.731	1	856	<0.001
S	.494	837.318	1	856	<0.001
Growth	.450	699.472	1	856	<0.001
Exponential	.450	699.472	1	856	<0.001
Independent variable: Age					

R^2: coefficient of determination, F: F test statistic, Sd: degree of freedom

Table 4. Curve fitting results between V10 and jump distance variables

Dependent variable: Jump distance [m]					
Conversion	Model summary				
	R^2	F	Sd1	Sd2	p
Linear	.762	2736.575	1	856	<0.001
Logarithmic	.756	2649.580	1	856	<0.001
Inverse	.747	2522.414	1	856	<0.001
Quadratic	.765	1389.167	2	855	<0.001
Cubic	.765	1389.167	2	855	<0.001
Compound	.763	2762.034	1	856	<0.001
Power	.761	2726.359	1	856	<0.001
S	.755	2643.066	1	856	<0.001
Growth	.763	2762.034	1	856	<0.001
Exponential	.763	2762.034	1	856	<0.001
Independent variable: V10.					

R^2: coefficient of determination, F: F test statistic, Sd: degree of freedom

Table 5. Results from the regression analysis between jump distance and age, and V10 variables

Model	B	SE_B	t	p	VIF	R^2
Constant	0.7833	0.0300	26.15	<0.001	-	79.10
Age	0.008058	0.000759	10.62	<0.001	1.65	
V10	0.17031	0.00462	36.86	<0.001	1.65	

B: Regression coefficient, SE_B: Standard error of regression coefficient, t: t test statistic, VIF: Variance inflation factor

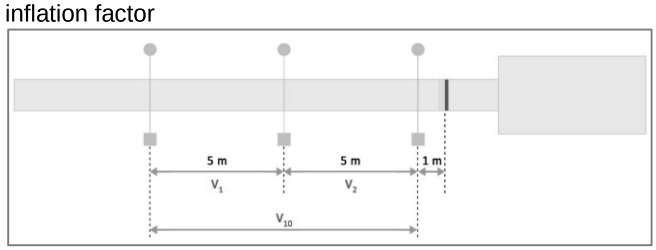

Figure 1. Placement of photocells on the long jump runway

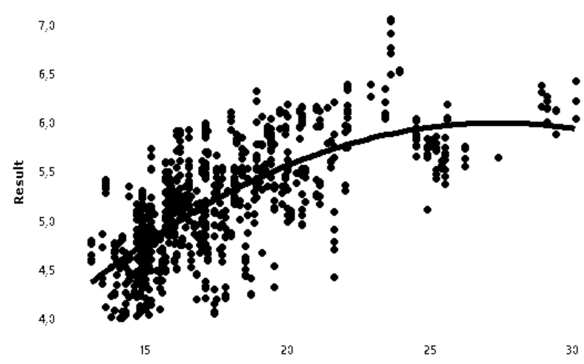

Figure 2. Scatter plot between age and jump distance

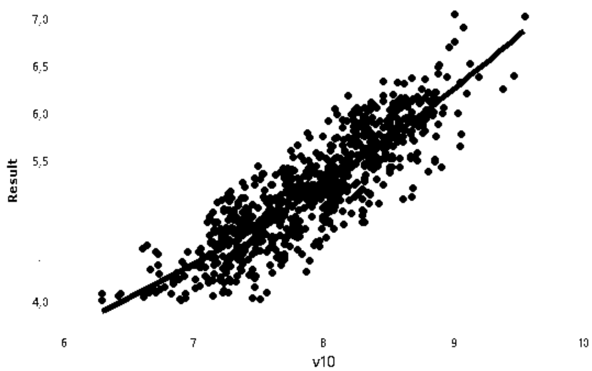

Figure 3. Scatter plot between V10 and jump distance

DISCUSSION

According to the results obtained in the study, there was a strong positive non-linear relationship (r=0.874) between run-up velocity and jump distance. In many studies conducted with male long jumpers, a similar relationship was found[1, 7, 9, 8, 10, 19, 20]. Similarly, in a small number of studies conducted with female athletes, it was observed that there was a strong relationship between run-up velocity and jump distance. Lukin (cited, Hay, 1986)reported that there was a strong positive relationship (r=0.675) between run-up velocity and jump distance in his study with 304 female long jumpers with 3.47m average jump distance. Lukin also stated a lower correlation value (r=0.456) in his study conducted with 546 higher-skill level female athletes with an average jump distance of 5.47m, whereas there was a lower level significant relationship between run-up velocity and jumping distance in 120 elite-level female long jumpers with an average jump distance of 6.16m. Mihailov (cited, Hay, 1986), on the other hand, stated in his study with 5 female long jumpers that there was a significant relationship (r=0.71) between the velocity value in the last 2.5m of the run-up and jump distance.

When the studies are examined, it is seen that the relationship observed between the velocity gained in the run-up and jump distance differs based on the performance levels. This study, similarly, observed that there is a positive moderate non-linear relationship between jump distance and age. In his study with 1856 male and 1240 female long jumpers, Lukin (cited, Hay, 1986) observed that run-up velocity was important as expected in low-performance groups; however, this importance would gradually decrease with increasing performance. Karas et al.[13] observed similar results to those of Lukin's study in their study with 700 long jumpers.

It is observed that a prediction model was created in many studies in which the relationship between the run-up velocity, jump distance and some other variables was examined. However, the number of prediction models developed for female long jumpers is few in the literature. Therefore, this study aims to predict the jump distance in female athletes with the variables of run-up velocity and age. For this purpose, it was determined that the most suitable curve between dependent and independent variables was cubic and quadratic considering the coefficients of determination (R^2) for the model. The quadratic model was preferred to make the interpretation of the model easier and not to complicate the model (Table 3 and Table 4).

In the prediction model, it was observed that 79.10% of the jump distance could be explained with age and V10 variables. It is thought that the remaining 20.90% can be explained by other variables. In other words, it can be said that each 0.1 m/s raise in the horizontal velocity will result in a raise in the jump distance by 9.07 cm. In the model by Lees[21], which is based on the last 10m velocity value of the run-up, it is stated that each 0.1 m/s raise in the horizontal velocity will result in a raise in the jump distance by 9.90cm. In a model developed with male athletes, the jump distance raises by 10.7cm with each 0.1 m/s raise in the horizontal velocity[1]. In different studies conducted with male long jumpers, it is stated that every 0.1 m/s increase in the horizontal velocity will result in an increase by 8-12 cm in the jump distance[8]. When the model by Lees and the model created in this study are compared using the data of female long jumpers that competed in the 2009 Berlin championship, it can be seen that the real performances can be estimated with an average of 5.47% error in Lees' model and 1.82% in this study. It is thought that the age parameter created in this study increases the prediction strength of the model.

CONCLUSION

In conclusion, in the light of the foregoing findings, it was observed that the velocity gained in the run-up in female long jumpers is an important determinant of performance. Henceforth, a model was developed that can be used especially for female long jumpers with a wide performance range. According to this model, it can be assumed that the hypothesis of the study is accepted. It will be possible to make technical evaluations about whether the velocity, technique and strength of a long jumper are in balance with the help of such studies.

Authors Contribution
Idea/Concept: Işık Bayraktar, Murat Çilli, Tuncay Örs**;**
Design: Işık Bayraktar, Murat Çilli, Tuncay Örs**;**
Control/Supervision: Işık Bayraktar, Murat Çilli**;**
Data Collection and/or Processing: Işık Bayraktar, Murat Çilli, Tuncay Örs**;**
Analysis and/or Interpretation: Işık Bayraktar, Murat Çilli**;**
Literature Review: Işık Bayraktar, Murat Çilli, Tuncay Örs**;**
Writing the Article: Işık Bayraktar, Murat Çilli, Tuncay Örs**;**
Critical Review: Işık Bayraktar, Murat Çilli**;**
References: Tuncay Örs**;**
Materials Işık Bayraktar, Murat Çilli, Tuncay Örs.
Acknowledgments: The current study was supported by the Presidency of the Turkish Athletic Federation (TAF). Special thanks to all athletes participated in the current study.
Declaration of Interest Statement: The authors state that there is no conflict of interest.

REFERENCES

1. I. Bayraktar ve M. Çilli, «Estimation of Jumping Distance Using Run-up Velocity for Male Long Jumpers,» Pedagogics, Psychology, Medical-Biological Problems of Physical Training and Sports, cilt 20, no. 3, pp. 124-129, 2018.

2. O. A. Fattah ve A. Bataineh, «Analysis of Kinematic of the Approach Run in Long Jump Event Among Jordanian Male Team,» Rusian Journal of Biomechanics, cilt 24, no. 1, pp. 15-22, 2020.
3. J. Hay ve J. Miller, «Techniques Used in the Transition From Approach to Takeoff in the Long Jump,» International Journal of Sport Biomechanics, cilt 1, no. 2, p. 174, 1985.
4. V. Panoutsakopoulos, A. S. Theodorou, M. C. Kotzamanidou ve I. A. Kollias, «Biomechanical Analysis of the 2017 European Indoor Champion in the Women' s Long Jump: Case Report,» Exercise and Quality of Life, cilt 12, no. 1, pp. 5-13, 2020.
5. J. G. Hay, J. A. Miller ve R. W. Canterna, «The Technique of Elite Male Long Jumpers,» Journal of Biomechanics, cilt 19, no. 10, pp. 855-866, 1986.
6. L. A. Bridgett, M. Galloway ve N. P. Linthorne, «The effect of Run-Up Velocity on Long Jump Performance. In K. E. Gianikellis (Ed.),» In Scientific Proceeding of the XXth International Symposium on Biomechanics in Sports, pp. 80-83, 2002.
7. L. A. Bridgett ve N. P. Linthorne, «Changes in Long Jump Take-Off Technique With Increasing Run-Up Velocity,» Journal of Sports Sciences, cilt 24, no. 8, pp. 889-897, 2006.
8. J. G. Hay, «The Biomechanics of the Long Jump,» Exercise and Sport Sciences Reviews, cilt 14, no. 1, pp. 401-446, 1986.
9. J. Hay, «Citius, Altius, Longius (Faster, Higher, Longer): The Biomechanics of Jumping for Distance,» Journal of Biomechanics, cilt 26, pp. 7-21, 1993.
10. A. Lees, P. Graham-Smith ve N. Fowler, «A Biomechanical Analysis of the Last Stride, Touchdown, and Takeoff Characteristics of the Men' s Long Jump,» Journal of Applied Biomechanics, cilt 10, pp. 61-78, 1994.
11. H. Hommel, «Long Jump (Final Report) - Scientific Research Project Biomechanical Analyses at the IAAF World CH in Athletics - Berlin 2009,» 2009. [Çevrimiçi]. Available: https://www.iaaf.org/development/research.
12. S. Fukasiro ve A. Wakavama, «The Men' s Long Jump,» New Studies in Athletics (NSA), cilt 7, no. 1, pp. 53-56, 1992.
13. V. Karas, P. Susanka, S. Otahal ve E. Moravkova, «Aktuelle Probleme in Der Biomechanischen Forschung Der Sportlokomotion. In W. Baumann (Ed.),» Biomechanik und sportliche leistung, pp. 41-51, 1983.
14. S. Béres, Z. Csende, A. Lees ve J. Tihanyi, «Prediction of Jumping Distance Using a Short Approach Model,» Kinesiology, cilt 46, no. 1, pp. 88-96, 2014.
15. Hussain, A. Khan, A. Muhammad, M. A. Bari ve A. Ahmad, «A Comparison of Selected Kinematical Parameters Between Male and Female Intervarsity Long Jumpers,» Journal of Physical Education and Sport, cilt 11, no. 2, p. 182, 2011.
16. N. P. Linthorne, «Biomechanics of the Long Jump,» %1 içinde Handbook of Biomechanics and Human Movement Science, Routledge, 2008, pp. 340-354.
17. Bayraktar, «The Influences of Run-Up Velocity Variable on Long Jump Performance of Female World Class Athletes and Turkish Athletes,» Bursa, 2017.
18. P. Graham-Smith ve A. Less, «Finding the 'Balance' in the Horizontal Jumps - Part 1 Untilising Speed,» The Coach, cilt May / June, no. 10, pp. 30-33, 2002.
19. M. K. Mishra ve V. S. Rathore, «Speed and Agility as Predictors of Long Jump Performance of Male Athletes,» Turkish Journal of Sport and Exercise, cilt 18, no. 2, pp. 27-33, 2016.
20. N. A. Moura, T. F. de Paula Moura ve J. P. Borin, «Run-up Velocity and Performance in the Horizontal Jumps: What do Brezilian Athletes Do?,» New Studies in Athletics, cilt 20, no. 3, p. 43, 2005.
21. Lees, «Tecnique Analysis in Sports: A Critical Review,» Journal of Sports Science, cilt 20, no. 10, pp. 813-828, 2002.