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Differences in Kinematic Parameters of the Long Jump between Male and Female Finalists of World Championships – Berlin 2009

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Abstract

In order to have successful technical analysis athletics uses modern biomechanical methods, and the obtained results are subjected to numerous analyzes. On the basis of the results of biomechanical parameters the most successful motor structure techniques of a competitor can be planned, programmed and analyzed, and based on this information projections for the top model in a given discipline can be made. Also based on these data possible gender differences between the jumpers can be analyzed, in order to possibly establish model and numerical values for both male and female population of jumpers. The survey was conducted on a sample of male and female finalists of the World Athletics Championships in Berlin in 2009 with the aim of determining the difference in the kinematic parameters that are important in achieving the score success. The sample included 16 athletes (8 female and 8 male), who participated in the finals World Championship.

Using T-test module were obtained the results which established statistically significant differences between male and female athletes in eight (72%) of the analyzed kinematic parameters in favor of male jumpers. The differences were identified in the following kinematic parameters: running speed on the section run (11-6m; T=8,347) and (6-1m, T=8,031), the speed of the second step (VLCT2SB, T=8,678), the first step (VLCT1SB, T=11,463) and the horizontal speed of the rebound (HoVLCT, T=4,627) to the level of significance (p<0,001).Also were identified differences in the parameters of the length of the third step (LNGT3SB, T=2,840), the first step (LNGT1SB, T=2,270) and vertical speed of the rebound (VoVLCT, T=2,246) to the level of significance (p<0,05). Kinematic parameters (28%) of the second step length (LNGT2SB), the duration of phase contact (CONTACT) and the angle of reflection (ANGLE) have not recorded statistically significant differences between male and female finalists, which amounts to 28%.

Keywords: kinematic parameters, differences, long jump, top athletes

Introduction

Athletic jumps are specific cyclically-acyclic movements that despite the good performance of the techniques require from competitors a high level of motor, specific-motor and functional abilities. Also all the jumping disciplines contain appropriate morphological profile of athletes (height, weight, BMI, age) that is characteristic for it. It is usually said that the jumpers are of high growth and relatively low weight, with long legs, long and thin muscles, and the muscle structure is dominated by white muscle fibers (Pavlović, 2016). According to the constitution the leading is a leptosome type with the participation of athletics. Both male and female jumpers are dominated by muscle mass (50-53%), on the second place are bones (16-19%), and the last are fats (5-9%). Based on these parameters, it can be concluded that the jumpers of both sexes are dominates by mesomorphic with a share of ectomorphic component (Ugarković, 1996).

The long jump is an athletic discipline of speed-strong character and with triple jump it belongs to a group of remote jumps, in relation to the trajectory of the body center it belongs to the horizontal jumps (Smajlović, 2010; Pavlović, 2016). The speed of running start is as important as the strength of the lower extremities which give the final impetus bounce (Jaitner, Mendoza, & Schöllhorn, 2001), so the result depends on the speed, jumping ability and technique of movement (Idrizović, 2010). Long jump technique is based on a natural and quite easy movement, where the jumper strives for greater speed (horizontal component-horizontal shot) which will convert the reflection to the greater distance jump (ballistic curve-pitched shot). The ratio of the horizontal component (speed of running start) and vertical component (speed of reflection, flash) is in relation 2:1. The effect of the horizontal and vertical components directs the body so that an elevation angle can be from 18º-26º. This means that the decreasing of the angle (β) increases a result of movements (R) reducing the elevation angle (α). Bearing all this in mind, a reflection with the long jump should be executed at top speed and to the limit only after the moment of verticals. Research of some authors have confirmed the inverse relationship of horizontal and vertical body centre ascent, ie. with increasing horizontal speed decreases the vertical and vice versa (Lees, Fowler, & Derby, 1993, Pavlović, 2012).

In all jumps there is an unwritten rule that every next stage in the technique of execution is conditioned by the previously performed step (accuracy of movement). Any mistake made has a significant impact on the accuracy of movement in the coming stages and the final result of competitors. Character of jump and parabola of trajectory of the body center is conditioned by the nature of the obstacles, so that in the long jump this parabola has a horizontal path and can use the formula for the length of the body flight projected at an angle relative to the horizontal level:

$$S = \frac{(VO \times \sin 2\alpha)}{2g}$$

However, this formula can be taken with caution, because it does not take into account differences in the levels of the body center (TT) of the jumpers at the beginning and at the end of the flight, as well as the movement of a TT forward during rebound and landing. It follows that the distance to which a body is thrown (S) is proportional to the square of the initial velocity (Vo^2) and sinuses angle (2α). In practice, this is something different. Gravity is a constant value and it is not under our influence, and to jump as far as possible, it is necessary to develop the highest starting rate of ascent at an angle and at a certain moment. Theoretically, the longest flight with the same speed, is achieved when the angle of ascent is

45º, and sinus 2α (or sin 90º) is equal to 1, which is the maximum value that a sinus can have. In practice, the angle of ascent of TT from 45º is only possible in the long jump from place, but with the long jump with a running start the angle has a value of 18-26º (Smajlović, 2010; Pavlović, 2016). The total length of the long jump has three partial lengths marked by the trajectory of the body center (*length of reflection* makes 5.1% of the total length of the jump, *flight length* - makes about 90% of the total length of the jump, *landing length* - the distance from the vertical projection of the body center and heel footprint in the sand at the time of their first contact with the ground (Idrizović, 2010). Top jumpers are characterized by greater height, developed muscles, limb length and speed and dynamics of sprinters, which means that each jumper can be a good sprinter. This is due to the fact that the jumper, before coming to the reflex board, must develop a maximum running speed (over 10m/s), which will be transformed into a high quality rebound.

The study Bridgett, &, Linthorne, 2006 was to determine the influence of run-up speed on take-off technique in the long jump. Seventy-one jumps by an elite male long jumper were recorded in the sagittal plane by a high-speed video camera. A wide range of run-up speeds was obtained using direct intervention to set the length of the athlete's run-up. As the athlete's run-up speed increased, the jump distance and take-off speed increased, the leg angle at touchdown remained almost unchanged, and the take-off angle and take-off duration steadily decreased. More detailed biomechanical analysis shows that in the long jump are performed elements (a running start, reflection, flight, landing), which is very difficult to master, and which represent synchronization techniques and motor-functional potential of jumpers within the framework of spatial-temporal parameters (Lees, et all., 1993). Each of these phases has its cinematic specificity in terms of performance, which requires full attention and concentration from the competitor. Running start is the first phase in the structure of jumps, which should provide a good starting speed of body flight (Vo), respectively, to achieve the best transition of the maximum speed in the best reflection of jumpers (Jaitner, et al., 2001; Janković, 2009). Precisely in this combination and transition of maximum speed in the final steps and reflection there is a part of the biggest secrets of the success of top jumpers.

The purpose Chow & Hay, 2005. was to examine the interacting roles played by the approach velocity, the explosive strength (represented by vertical ground reaction force [VGRF]), and the change in angular momentum about a transverse axis through the jumper's center of mass (delta Hz) during the last support phase of the long jump, using a computer simulation technique. A two-dimensional inverted-pendulum-plus-foot segment model was developed to simulate the last support phase. Using a reference jump derived from a jump performance reported in the literature, the effects of varying individual parameters were studied using sensitivity analyses. In each sensitivity analysis, the kinematic characteristics of the longest jumps with the deltaHzz considered and not considered when the parameter of interest was altered were noted. A sensitivity analysis examining the influence of altering both approach velocity and VGRF at the same time was also conducted. The major findings were that 1) the jump distance was more sensitive to changes in approach velocity (e.g., a 10% increase yielded a 10.0% increase in jump distance) than to changes in the VGRF (e.g., a 10% increase yielded a 7.2% increase in jump distance); 2) the relatively large change in jump distance when both the approach velocity and VGRF were altered (e.g., a 10% increase in both parameters yielded a 20.4% increase in jump distance), suggesting that these two parameters are not independent factors in determining the jump distance; and 3) the jump distance was overestimated if the deltaHzz was not considered in the analysis.

Graham-Smith, & Lees, 2005 were to conduct a three-dimensional analysis of the touch-down to take-off phase in the long jump and to explore the interrelationships between key variables. Fourteen male long jumpers were filmed using three-dimensional methods during the finals of the 1994 (n=8) and 1995 (n=6) UK National Championships. Various key variables for the long jump were used in a series of correlational and multiple regression analyses. The relationships between key variables when correlated directly one-to-one were generally poor. However, when analysed using a multiple regression approach, a series of variables was identified which supported the general principles outlined in the two models. These variables could be interpreted in terms of speed, technique and strength. Bounce (reflection) takes 0,12-0,15s, from the moment of contact of the leg with a board in the front stage of support and lasts till the loss of contact in the last stage of resistance with the vital task of transforming the horizontal speed to the vertical acceleration of the jumper's body in order to provide the most favorable angle of ascent TT (21-30º).

Linthorne, Guzman, & Bridgett, 2005, found that the optimum take-off angle for a long jumper may be predicted by combining the equation for the range of a projectile in free flight with the measured relations between take-off speed, take-off height and take-off angle for the athlete. The prediction method was evaluated using video measurements of three experienced male long jumpers who performed maximum-effort jumps over a wide range of take-off angles. To produce low take-off angles the athletes used a long and fast run-up, whereas higher take-off angles were produced using a progressively shorter and slower run-up. For all three athletes, the take-off speed decreased and the take-off height increased as the athlete jumped with a higher take-off angle. The calculated optimum take-off angles were in good agreement with the athletes' competition take-off angles.

This study (Lees, et al. 1993) was concerned with the measurement of a selection of performance variables from competitors in the women's long jump final of the World Student Games held in Sheffield, UK in July 1991. Several performances of each of six finalists were ecorded on cine-film at 100Hz. Resulting planar kinematic data were obtained for the last stride, touch-down and take-off. For the analysis, the point of maximum knee flexion was established and this was used to represent the point at which the compression phase had ended. A variety of variables describing the position, velocity and angular changes are presented as descriptive data. The data were interpreted on the basis of a technique model of long jumping established from the literature. It was confirmed that take-off velocity was a function of touch-down velocity, and that there was an increase in vertical velocity at the expense of a reduction of horizontal velocity. An attempt was made to identify the mechanism acting during the touchdown to take-off phase which were responsible for generating vertical velocity. It was concluded that there was evidence for mechanical, biomechanical and muscular mechanisms. The former relates to the generation of vertical velocity by the body riding over the base of support; the second is the elastic re-utilization of energy; and the third is the contribution by concntric muscular contraction.

According to biomechanical characteristics, long jump belongs to a group of complex spatial movement and according to motor activity character belongs to a group of natural locomotion without usage of technical accessories. Long jump as athletic discipline consists of four different phases i.e. approach (runup) phase, phase of bounce off, phase of leap and the last is landing phase. (Hay, Miller, & Canterna, 1986). Many jumpers use their maximal speed of approach combined with technique (optimal technique is used to achieve as bigger speed while sprinting as possible and to bounce off as much as possible) hoping to achieve the longest possible distance (Bridgett, Galloway & Linthorne, 2002). The long jumping performance is determined primarily by the athlete's ability to attain a fast horizontal speed at the end of the approach run (Lees, et. al.,1993). While approaching, the jumpers regulate acceleration using their visual regulation in the last three steps (Glizen & Laurent, 1997).To make best use of the run-up speed the athlete must use an appropriate take-off technique to launch the body into the air (Bridgett and Linthorne, 2006).

The purpose of study Akl, Abdel-Rahman (2014) is assessment the variations between male and female in long jump and determine the causes that led to the differences between male and female in long jump for improve the performance. Ten long jump players are high level athletes participated in this study (Five male and five female). They were the elite athletes in Egypt. The long jumps were performed on a two-dimensional analysis, marker position data were obtained by a high-speed camera (JVC GR – DVL 9800) at a frequency of 240Hz, video point v 2.5 2D motion analysis for Biomechanical parameters, and statistically T-test for independent samples and Change Ratio were used to compare results for male and female. The results of iomechanical parameters between male and female ranged between (0.89% - 34.57%) in favor of male or female, male surpassed in velocity of free leg swing during takeoff phase, Selected a biomechanical parameters group influential in the long jump performance (pre- last stride resultant velocity, last stride resultant velocity, horizontal velocity at touch down, resultant velocity at touch down, resultant velocity of the free leg at touch down, horizontal velocity at takeoff, resultant velocity at takeoff, resultant velocity of the free leg at takeoff, total takeoff time, linear momentum at touch down, kinetic energy at touch down, linear momentum at takeoff, and kinetic energy at takeoff), and confirmed by the strong correlation between these parameters and long jump distance.

The study Haridi, Tantawy, & Akl, (2012) aims to analyze the performance of long jump contestants (under 16, under 18, under 20years and the high level) during national championships, The study attempted to determine the values of some kinematic variables of the final approaching phase (last two steps) and takeoff for long jump contestants (under 16, under 18,under 20 and high level) and comparing kinematic variables for different age groups to determine the dynamics of enhancement for some variables affecting performance in the long jump. The sample consisted of twenty three contestants from the national champions, Data was collected by means of measurement, video recording and movement analysis. As a results, 1-Rate of horizontal acceleration and resultant velocity directly before takeoff, increase as the age group gets higher but there is no significant difference between ages 18 and 20 years; 2- Rate of horizontal and vertical velocity at the moment of takeoff increases as age group gets higher for the sample individuals but there is no significant difference between ages 18 and 20 years and high level in vertical velocity but it is present between 16 years old group and others; 3- A great rate of loss in horizontal and vertical velocity for all contestants at take-off more that at the last step before take-off ranging between 0,40-0,67m/s.

Precisely previous kinematic parameters (running speed, altitude and speed of bounce, bounce angle, length of contact, muscular contractions...) next to the motor-functional parameters are important in achieving successful results in the long jump. Depending on the performance of techniques and physical preparation of jumpers, sex, age, motivation and other exogenous and endogenous factors depends their expression and possible differences. Based on the specific findings of the previous research of biomechanical parameters and their relationships in the jumps structure there has been produced the idea of current research. The main objective of this research was to determine the differences kinematic parameters of long jump between male and female finalists in WC in Berlin 2009.

There will be determined differences in the parameters the velocity on a section, the lenght of steps before take-off, the velocity steps before take-off, the horizontal and vertical velocity take-off, contact and angle take-off.

Methodology

The population defined in the research has included top male and female athletes in the Long Jump World Championship-Berlin, 2009. The sample included a total of 16 finalists (8 male and 8 female competitors), who participated in the Long Jump finals.

The variables of kinematics parameters:

1. the velocity on a section of 11-6 m - VLCT 11-6m (m/s)
2. the velocity on a section of 6-1m - VLCT 6-1m (m/s)
3. the lenght of 3 steps before take-off - LNGT 3 SB (m)
4. the lenght of 2 steps before take-off (m) – LNGT 2 SB (m)
5. the lenght of 1 steps before take-off (m) – LNGT 1 SB (m)
6. the velocity 2 steps before take-off (m/s) –VLCT 2 SB (m/s)
7. the velocity 1 steps before take-off (m/s) –VLCT 1 SB (m/s)
8. the horizontal velocity take-off (m/s) – HoVLCT (m/s)
9. the vertical velocity take-off (m/s) – VeVLCT (m/s)
10. time of contact –CONTACT (s)
11. Angle take-off –ANGLE (º)

Data obtained in the survey were analyzed by standard descriptive methods, and the differences between groups of respondents-finalists were tested using Student's t-test for independent samples. Statistical analysis was done using the statistical program Statistica 6.0.

Table 1. Parameters of kinematics male and female finalist WCh Berlin, 2009.*

	Men / Women	***Velocity of 11-6 m (m / s)***	***Velocity of 6-1 m (m / s)***	***Length of 3 steps (m)***	***Length of 2 steps (m) PP***	***Length of 1 steps (m) PO***	***Velocity of 2 steps (m/s)***	***Velocity of 1 steps (m/s)***	***Horizontal velocity take-of (m/s)***	***Vertical velocity take-of (m/s)***	***Contact (s)***	***Angle take-of (°)***	***Result (m)***
1	**D. Phillips**	11,06	10,93	2,30	2,62	2,00	11,12	10,78	9,23	3,35	0,11	27	8,54
2	**G. Mokoena**	10,37	10,33	2,27	2,32	2,19	10,44	10,34	8,67	3,79	0,11	26	8,47
3	**M. Watt**	10,55	10,46	2,45	2,63	2,42	10,59	10,43	8,83	3,71	0,11	22	8,37
4	**F. Lapierre**	10,25	9,91	2,24	2,36	2,28	10,33	10,28	7,99	4,23	0,12	28	8,21
5	**G. Rutheford**	10,24	10,41	2,23	2,19	2,24	10,39	10,44	9,16	3,14	0,12	23	8,15
6	**S. Sdiri**	10,23	10,29	2,24	2,59	2,16	10,31	10,17	8,69	3,15	0,12	23	8,07
7	**G. Garenamotse**	10,41	10,49	2,30	2,38	2,22	10,61	10,41	9,17	3,17	0,12	26	8,06
8	**C. Tomlinson**	10,23	10,32	2,40	2,49	2,14	10,40	10,31	8,53	3,72	0,13	30	8,06
1	**B. Reese**	9,78	9,76	1,91	2,45	1,97	9,89	9,59	8,31	3,14	0,13	29	7,10
2	**T. Lebedewa**	9,26	9,40	2,04	2,21	2,17	9,53	9,34	7,62	3,40	0,11	25	6,97
3	**K. Mey Melis**	9,19	9,09	2,06	2,16	1,95	9,23	9,13	7,87	3,42	0,11	27	6,80
4	**N. Gomes**	8,99	9,36	2,41	2,61	2,08	9,47	9,43	8,10	3,22	0,12	28	6,77
5	**O. Kucherenko**	9,11	9,21	2,17	2,32	2,09	9,29	9,14	7,39	3,37	0,12	27	6,77
6	**S. Proctor**	9,25	9,15	2,07	2,16	2,09	9,34	9,07	7,64	3,10	0,13	27	6,71
7	**M. Maggi**	9,46	9,49	2,30	2,44	2,28	9,60	9,52	8,30	2,64	0,11	21	6,64
8	**K. Balta**	9,44	9,53	1,91	2,15	1,94	9,55	9,39	8,04	2,96	0,11	27	6,62

*Mendoza, L., Nixdorf, E., Isele, R., Gűnther, C. (2009). Biomechanical Analysis of the Long Jump Men and Women Final. Scientific Research Project Biomechanical Analyses at the 12 IAAF World Championship, Berlin, 2009 Final Report Long Jump.

Results

Table 2. Descriptive Statistics –Berlin, 2009.

Parameters	Gender	Mean	Min	Max	Range	Std.Dev	Skew	Kurt
Velocity of 11-6 m (m / s)	M	10,42	10,23	11,06	,83	,28	2,04	3,39
	F	9,31	8,99	9,78	,79	,25	,85	,91
Velocity of 6-1 m (m / s)	M	10,39	9,91	10,93	1,02	,28	,36	2,60
	F	9,37	9,09	9,76	,67	,22	,43	-,29
Length of 3 steps (m)	M	2,30	2,23	2,45	,22	,08	1,12	,05
	F	2,11	1,91	2,41	,50	,18	,63	-,43
Length of 2 steps (m)	M	2,45	2,19	2,63	,44	,16	-,27	-1,19
	F	2,31	2,15	2,61	,46	,17	,69	-,85
Length of 1 steps (m)	M	2,21	2,00	2,42	,42	,12	,11	1,51
	F	2,07	1,94	2,28	,34	,12	,59	-,17
Velocity of 2 steps (m/s)	M	10,52	10,31	11,12	,81	,26	1,96	3,21
	F	9,49	9,23	9,89	,66	,21	,81	,92
Velocity of 1 steps (m/s)	M	10,40	10,17	10,78	,61	,18	1,43	3,26
	F	9,33	9,07	9,59	,52	,19	-,10	-1,60
Horizontal velocity take-of (m/s)	M	8,78	7,99	9,23	1,24	,42	-,85	,66
	F	7,91	7,39	8,31	,92	,34	-,25	-1,29
Vertical velocity take-of (m/s)	M	3,53	3,14	4,23	1,09	,39	,62	-,52
	F	3,16	2,64	3,42	,78	,26	-1,06	,97
Contact (s)	M	,12	,11	,13	,02	,01	,40	-,23
	F	,12	,11	,13	,02	,01	,62	-,48
Angle take-of (°)	M	25,63	22,00	30,00	8,00	2,77	,14	-1,03
	F	26,38	21,00	29,00	8,00	2,45	-1,75	3,66
Result	M	8,24	8,06	8,54	,48	,19	,60	-1,47
	F	6,80	6,62	7,10	,48	,16	,99	,36

Legend: *Mean (average value), standard deviation (St.Dev), Min-Max (minimal and maximal result), Skew (skewness), Kurt (kurtosis*

Table 2 presents the basic central and dispersion parameters of male and female finalists of the World Championship in Berlin, 2009. What is evident is the fact that all the numerical parameters are within the normal Gaussian distribution. Given that this is a top-notch sample it is logical that the discrepancies in terms of the dispersion of results are minimal. The smallest deviation in terms of distribution of results is in the speed parameters (acceleration) in the specified sections of 11-6m and from 6-1m. However, the heterogeneity of results distribution characterizes the stride length and bounce angle as a determinant of technical quality of jumpers. In these kinematic parameters are very much present discrepancies both within the same population and within the same sub-samples. The difference in the length of the last 3 steps ranges from 34 to 50cm (women) and 22-44cm (men), while the rebound angle reaches the value of 21-29º (women) and 22-30º (men), which is in the range of 8º. In the range of these results, the speed, the length of the last steps, rebound angle, normally with the correct execution of the technique, lies the secret of mastery and success of jumpers. It can also be inferred from the values of the horizontal and vertical speed of the rebound that is mainly found in inverse relation to the female and male finalists. In order to further discuss and analyze within the allowed limits and correct statistical inference a T-test was applied for small independent samples (Table 3). The analysis included only kinematic parameters of differences between male and female finalists, i.e. parameters having a significant impact on the score success.

Table 3. Differences of kinematic parameters finalists (T-test independent samples)

Parameters	Gender	Mean±Std.Dev.	T-value	p-level
Velocity of 11-6 m (m/s)	M	10,42±0,28	8,347	**,000****
	F	9,31±0,25		
Velocity of 6-1 m (m/s)	M	10,39±0,28	8,031	**,000****
	F	9,37±0,22		
Length of 3 steps (m)	M	2,30±0,08	2,840	**,013***
	F	2,11±0,18		
Length of 2 steps (m)	M	2,45±0,16	1,624	**,127**
	F	2,31±0,17		
Length of 1 steps (m)	M	2,21±0,12	2,270	**,040**
	F	2,07±0,12		
Velocity of 2 steps (m/s)	M	10,52±0,26	8,678	**,000****
	F	9,49±0,21		
Velocity of 1 steps (m/s)	M	10,40±0,18	11,463	**,000****
	F	9,33±0,19		
Horizontal velocity take-of (m/s)	M	8,78±0,42	4,627	**,000****
	F	7,91±0,34		
Vertical velocity take-of (m/s)	M	3,53±0,39	2,246	**,041***
	F	3,16±0,26		
Contact (s)	M	,12±0,01	-,000	**1,00**
	F	,12±0,01		
Angle take-of (°)	M	25,63±2,77	-,574	**,575**
	F	26,38±2,45		

Legend: *Mean (average value), standard deviation (St.Dev), coefficient of t-test value (T-value), significance level p (Sig.* p<0,05; Sig. **p<0,001)*

By inspecting the Table 3 it can be concluded that from the total number of the analyzed kinematic parameters, in 8 parameters (72%) were recorded statistically significant differences. Differences were found in the speed of running on running jump shares (VLCT11-6m, T= 8,347**, VLCT 6-1m, T=8,031**), the speed of the last steps (VLCT 2SB, T= 8,678**; VLCT1SB, T=11,463**) and HoVLCT, T= 4,627** for the significance level of p <0,001. Differences in the level of significance of p<0,05 were reported in variable stride length (LNGT 3SB, T=2,840* and LNGT1SB, T=2,270*) and vertical speed rebound (VeVLCT, T= 2,246*). The remaining three variables (LNGT 2SB, CONTACT and ANGLE) did not record statistically significant differences between male and female finalists, although numerical differences were observed. An interesting fact is that only the average duration of contact phase (0,12s) was the same for both male and female finalists (0,12s). Based on the value of T-test it can be concluded that men had better values of kinematic parameters, except for the duration of the contact phase (same value) and corner reflectors, where women had a greater angle of reflection on average by about one degree. This can be explained by the fact that the larger the angle of reflection is result of less vertical speed of reflection (VeVLCT=3,16m/s). Given that this is a top sample of respondents, a consequence of this relationship of results can be explained by differences in gender, technique, mental and physical abilities, and mostly by cognitive and conative characteristics of participants.

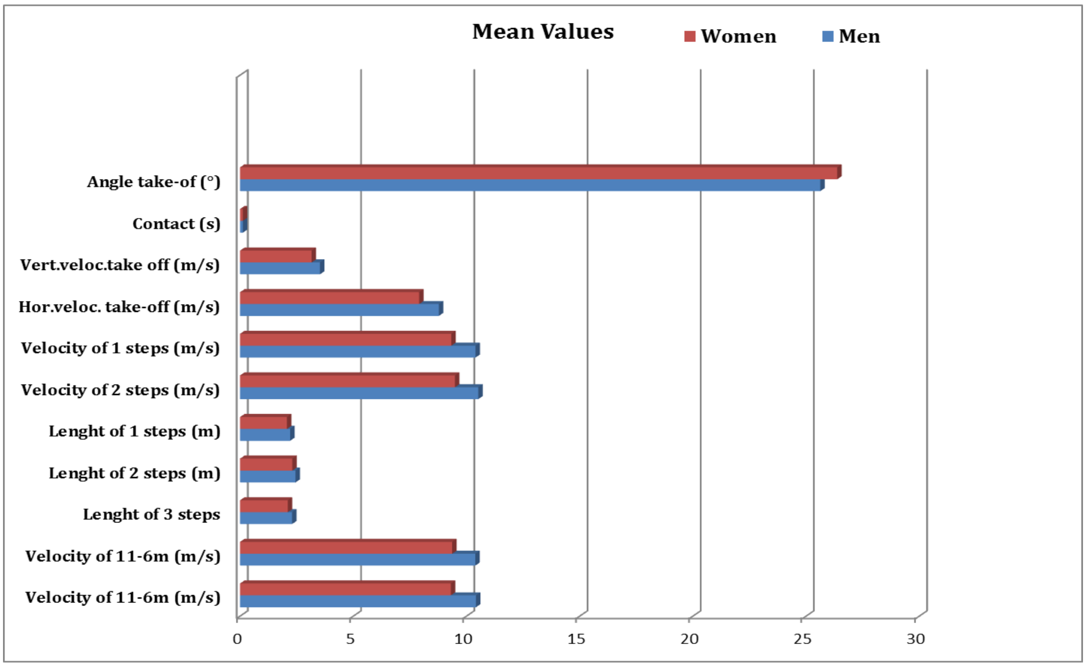

Figure.1 The mean for male and female jumpers

Discussion

The aim of this study is to determine the differences in the kinematic parameters between male and female finalists in the discipline - jump at the World Champioship in Berlin in 2009. Although it covers only 16 male and female athletes the obtained results are significant because they were competitors who qualified for the finals of the WCh. These results confirmed that significant differences exist in eight (72%) of the analyzed kinematic parameters in favor of male jumpers. The differences were not identified only in the parameters of the duration of the contact phase in the rebound, corner reflectors and the length of the second (penultimate) step before the rebound.

The long jump an athletic event (track and field) in which athlete combines approach speed, last stride, foot planting, take-off, air bone and landing. The performance is obtained by measuring the length of an imaginary perpendicular line from the front edge of the take-off board to the nearest mark that the athlete makes in the sand (Hay, & Miller, 1985). There were researches (Galloway, & Connor, 1999) and on wide range the variables that serve to influence the long jump performance. The long jumping performance is determined primarily by the athlete's ability to attain a fast horizontal speed at the end of the approach run (Lees et. al., 1993). To make best use of the run-up speed the athlete must use an appropriate take-off technique to launch the body into the air (Bridgett and Linthorne, 2006). The approach speed (Berg, & Greer, 1995) found to be lower than the optimal speed.

Speed running start, intensity of take-off, momentum free extremities are the basic components of which depends on the length of the jump without distinction on which the technique talking (Pavlovic, 2016). The long jumping performance is determined primarily by the athlete's ability to attain a fast horizontal velocity at the end of the approach run (Lees et al., 1993). So the last two strides of the approach are crucial. More than 67% of the total adjustment to correct for prior errors in striding is made during the last two strides of the approach (Hay, 1988). Furthermore, elite long jumpers adjust their body position in order to prepare for take-off during the pre-last stride by increasing their stride length and thus lowering their BCM (body's center of mass) height (Hay, & Nohara, 1990). Therefore the approach velocity and the take-off technique are the most important for the long jump length (Luhtanen, & Komi, 1979**;** Chow, & Hay, 2005; Bridgett, & Linthorne, 2006; Muraki, Koyama, & Yokozava, 2008). The takeoff phase is critical to the success of the entire performance.

The rate at which top jumpers come to the board of reflection ranges from 9,50m/s to 11,50m/s. However, some jumpers approaching the rebound place reduce the speed of running, trying to catch the pace for the last three steps before take-off, unlike others that increase the running speed approaching the rebound place (Pavlović, 2016). It is important to note that the speed achieved by a jumper on the run is not identical to the maximum sprint speed, due to the inability of quality of reflection. Top jumpers more exploit their sprint speed (about 90%) than the jumpers of middle and lower level (85%). According to the authors (Idrizović, 2010; Pavlović, 2016), Carl Lewis in Tokyo in 1991, during a jump of 8,91m, crossed the last ten meters (11m-1m) before the glare for 0,89s, which represents speed of 11,26m/s, which is 95.3% of his maximum speed. Giovanni Evangelisti during a jump of 8,08m, crossed the same ten meters for 0,93s, which is the speed of 10,75m/s, which is 97,5% of his maximal running speed. The record holder Mike Powell when setting record of 8,95m crossed the same share for 0,92s, running at a speed of 10,87m/s. This data indicates that the speed is significant, but more important is the ability of speed transition in the jump length, which was confirmed in this study. The average speed of male finalist in Berlin, 2009, on the section of 11-6m amounted to 10,42m/s (max.11,06m/s-D.Phillips) and 10.39m from 6-1m/s (max.10,93m /s-D. Phillips) where was evident a drop in speed. Among women, the speed increased from 9.31m/s (11-6m, max. 9.78m/s-B.Reese) up to 9,37m s (from 6-1m, max.9,76m/s-B.Reese). These results support the results reached by Panoutsakopoulos & Kollias, 2007, that is, by approaching the rebound place the speed decreases, on account of the increase of the stride length (Hussain, Khan, Mohhamad, Bars, & Ahmad, 2011b; Haridi, Tantawy, & Akl, 2012) which also have an important role, allowing high-quality horizontal transition in the vertical component, i.e. quality rebound.

Concerning the structure of the last three steps of men (2,30m-2,45m-2,21m), the dominance is at the second step. At female finalists there is also the domination of the second (2,31m) compared to the last step (2,07m)(Table 2). This changing rhythm of steps is followed by the linear decline rate in the second and first step before the rebound. At male jumpers it amounts an average of 0,12s and 0,13s at females. D. Phillips scored the highest speed in the second step (11,12m/s), and the first step before the rebound (10,78m/s). From female finalists the top speed was achieved by the first-ranked B. Reese in the second (9,89m/s) i.e. (9,59m/s) in the last step. Compared with the first-ranked D. Phillips this difference in the second step is 1,23m/s, in the last 1,19m/s, which confirms the fact that good jumpers are also good sprinters. This decrease of speed follows the increase of the length of the second, and a reduction of the first step. This is largely common with most jumpers, and it is concluded due to the neutralization of reactions between the mats and safer arrival at the rebound place. In this way the jumpers are able to make a successful transition of horizontal component (running start speed) in the vertical component (reflection speed). The most important phase of the long jump is the realization of the movement that causes a reflection when the jumper imposes to his/her body an initial speed and direction that will start the phase of flight (bounce impulse). Consequently, the initial speed of flight of the best jumpers is 9,3-9,6m/s, and it is achieved at the running start speed of 10,4-10,7m/s. The average horizontal velocity of reflection (HoVLCT) in the men's final of the World Cup in Berlin in 2009 amounted to 8.78m/s, and the vertical (VeVLCT) 3,53m/s. At women was recorded slightly lower speed, HoVLCT 7,91m/s., and VeVLCT 3,16m/s. This standard relationship between the two components 2:1, both at male and female finalists in Berlin was 2,5:1

From this stems the conclusion that the jumpers accomplish much more horizontal than vertical ascent speed of the body centre. An inverse relationship of the value of these components can also be observed, that is, with the increase of one, reduces the second component. For example, HoVLCT of the first-ranked D. Phillips first placed was 9.23m/s, and VeVLCT 3,35m/s. Second ranked Mokoena had a slightly lower HoVLCT 8,67m/s, but he increased the value of VeVLCT to 3,79m/s. At women B. Reese also made HoVLCT of 8,31m/s, and VeVLCT of 3,14m/s. (Table 1). The obtained results of inverse relationship between horizontal and vertical components are consistent with the results of earlier studies (Lees, et al., 1993; Chow, & Hay, 2005; Bridgett, Linthorne, 2006; Matić, Mrdaković, Janković, lić, Stefanović, & Kostić, 2012; Haridi, Tantawy, & Akl, 2012).

In order to achieve a high speed of TT movement in the vertical direction and thereby increase the elevation angle, the jumper acts on the surface with the great powers at the stage of front resistance, while the ground reaction force (Rp) is directed dorsally and acts in the opposite direction to the direction of the running start. In the long jump, the impulse of front support is much greater than the moment of the last support which is negligible. Therefore, the speed of the body center of the runner is much smaller after than before the reflection, so the speed of TT's top jumpers in the running start reaches 11 m/s, (Phillips 11,06m/s) and the initial flight speed is below 10 m/s (Phillips, 9,23m/s), which is confirmed by this study. The efficiency of technique depends on the skill of jumper to exercise great pressure on the track in the small protrude of leg, especially in the last step, which provides the necessary height of the jump and the horizontal movement of the body. Thus excellent jumpers, depending on gender, develop great pressure force (from 300-400kg) on the board, where the stepping leg slightly bents at the knee β = 175º-178º or 165-172º (Lees, et al., 1993), slightly less at the hip joint (γ = 165º-170º), and there is also a partially bending at the joints of the spine. It all causes eccentric character of the work. Intentional loosening of the knee joint is done in order to utilize the forces of mm. quadriceps femoris to the extent where leg can withstand the pressure, because it is not possible to avoid the torque of the pressure component in relation to the knee joint. In order to offset the effect of this moment, and to achieve the rebound it is necessary that the product of muscle force (Q) and its prong (r is constant) is equal to or greater than the product of the pressure force (R) and its prong (k). The current top jumpers at the time of the rebound have less flexion of the knee joint but a stronger force of quadriceps.

As the last phase preceding the good flight good is the running start, which lasts on average 0,12-0,15s, i.e from the moment of contact of the leg with a board in the front stage of support and lasts till the loss of contact in the stage of last counteraction. This parameter is precisely the thing which balanced male and female finalists in Berlin. The average time of contact between the two phases of support amounted 0,12s for both subsamples. The rebound begins by setting the foot (outer part) of the leg to the reflection board with the main task of transforming the horizontal speed into the vertical acceleration of the jumper in order to secure the most favourable angle of ascent TT (21-30º). The angle of reflection in male finalists at WC in Berlin, 2009, was 25,63º (ranging from 22º-30º), and in women 26,37º (21º-29º). The biggest bounce angle was achieved by C. Tomlinson (30º) of the male and of the female it was achieved by B. Reese (29º). In the regard of bounce angle this research is in accordance with the results given by Alexander, 1990**,** Bridgett, & Linthorne, 2006, Hussain, Khan, Mohammad, 2011a, and contrary to the results of research Linthorne, Guzman, & Bridgett, 2005.

Conclusion

The aim of this study was to determine differences in the kinematic parameters between male and female finalists in discipline-jump at the World Championships in Berlin in 2009. Although it covers only 16 male and female athletes obtained results are significant because they are top athletes who qualified for the finals of the World Championship. These results confirm that significant differences exist in 8 (72%) of the analyzed kinematic parameters in favor of male jumpers. The differences were established in the running speed on energy shares (VLCT 11-6m, VLCT 6-1m) in the speed of the last steps (VLCT 2SB, VLCT 1SB) and HoVLCT, the significance level of $p<0,001$. The differences in the level of significance of $p<0,05$ were reported in variable stride length (LNGT 3SB and LNGT 1SB) and vertical speed rebound (VeVLCT). The remaining three variables (LNGT 2SB, CONTACT and ANGLE) did not record statistically significant differences between male and female finalists. Completed research, although on a small sample, is a good indicator of the significance of certain kinematic parameters and their values that determine the differences in terms of gender. Also the obtained numerical values of kinematic parameters of male and female athletes and their relationship can be a significant model in the projection of a long jump result performance.

Conflict of Interest

The authors have not declared any conflicts of interest.

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