Original Article

Gender differences in takeoff techniques of non-elite russian long jumpers

OLEG NEMTSEV[1] ✉, NATALIA NEMTSEVA[1], AYDAMIR BGUASHEV[1], SALMAN ELIPKHANOV[1], IRINA GREKALOVA[2]

[1] Physical Education and Judo Institute, Adyghe State University, Adyghe Republic, Russia
[2] Department of Physical Education, Krasnodar State University of Culture and Art, Krasnodar, Russia

ABSTRACT

The objective of this study was to determine gender differences in takeoff techniques of Russian male and female long jumpers. The competitive performances of twenty-six male and twenty-one female athletes were videotaped with a high-speed digital camcorder for further two-dimensional analysis. It has been found that male jumpers had significantly larger takeoff velocity including its horizontal (7.96 ± 0.44 and 7.06 ± 0.32 m · s^{-1}) and vertical (3.35 ± 0.44 and 2.75 ± 0.37 m · s^{-1}) components, takeoff angle (22.8 ± 2.5 and 21.3 ± 2.4°), the centre of gravity (CG) height at touchdown (0.92 ± 0.04 and 0.88 ± 0.04 m) and takeoff (1.18 ± 0.06 and 1.09 ± 0.04 m), and CG to heel distance at touchdown (0.44 ± 0.06 and 0.39 ± 0.05 m). Female long jumpers demonstrated significantly larger leg angles at touchdown (59.6 ± 2.8 and 57.7 ± 3.0° for female and male athletes respectively). The study has revealed that effective jump distance has a strong correlation with takeoff velocity and ground contact time, and a medium correlation with horizontal and vertical takeoff velocity, leg angle and CG height at takeoff for female jumpers and only one medium correlation with vertical takeoff velocity for male jumpers. **Key words:** TAKEOFF VELOCITY, TAKEOFF ANGLE, GROUND CONTACT TIME, LEG ANGLE, LONG JUMP DISTANCE

✉ **Corresponding author.** Physical Education and Judo Institute, Adyghe State University, 208 Pervomayskaya St., Adyghe Republic, 385000, Russia
E-mail: oleg.nemtsev@mail.ru
Submitted for publication November 2015
Accepted for publication September 2016
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2016.114.05

INTRODUCTION

It is known from mechanics that the ballistic flight range of an object affected by gravity is completely described by the acceleration of gravity, launch velocity, launch angle and launch height of the object (provided air friction is negligible). However, in human motions these dependences are ambiguous. For example, the optimal takeoff angle in long jump is determined not only by mechanical laws, but also depends on the athlete's ability to coordinate movements in horizontal and vertical directions when moving at high speed, as well as on their physical and other abilities. These abilities and their correlations may vary in athletes of different qualification, sex, age, and different preliminary technical training. All this determines the need to study the actual characteristics of athlete's movements in critical phases of long jump (primarily, the takeoff phase) and compare them with those of other jumpers, especially of the opposite gender. This data will allow for a more reasonable approach to training.

Many authors researched the characteristics of long jump takeoff techniques either only for men (Lees, Graham-Smith & Fowler, 1994; Muraki, Ae, Yokozawa, & Koyama, 2005; Campos, Gamez & Encarnacion, 2009), or only for women (Lees, Derby, & Fowler, 1993; Hay, Thorson, & Kippenhan, 1999). The data of these investigations can be used as benchmarks to assess the follow-up studies, but they cannot explain the differences between male and female takeoff techniques in long jump. At the same time, the data of various studies were obtained with the help of various videotaping systems (with different speed of videotaping), and different methods of data smoothing were applied. Therefore, it is difficult to reliably compare the data on male and female jumpers taken from different studies. Also, many investigators present the kinematic characteristics of male and female long jump takeoff techniques at the IAAF World Championships in Athletics and other major competitions without comparing them (Fukashiro et. al., 1994; Arampatzis, Brüggemann, & Walsch, 1999; Koyama, Ae, Muraki, Yoshihara, & Shibayama, 2009 et al.).

According to Linthorne (2008), elite male jumpers have a larger takeoff velocity and its horizontal and vertical components than women; while their takeoff angle and ground contact time do not differ. However, the author makes no statistical comparison of differences in takeoff characteristics between men and women (presenting only a compilation of data provided by other authors), so it is difficult to evaluate some of these differences. Campos, Gámez, Encarnación, Gutiérrez-Dávila, & Rojas (2008) registered significantly larger takeoff velocity and its horizontal component of male jumpers at 2008 IAAF World Indoor Championship in Athletics. However, the study revealed no significant differences in vertical takeoff velocity, takeoff angle and knee angle at touchdown between males and females. Moreover, if the values of vertical velocity were somewhat larger (not significantly) for male jumpers (3,20 ± 0,26 and 3,08 ± 0,22 $m \cdot s^{-1}$ respectively), the takeoff angle values were not significantly larger for female jumpers (20.7 ± 1.62 and 21.1 ± 1.81° respectively). Comparing male and female groups of jumpers with large differences in long jump distance (6.97 ± 0.37 and 4.92 ± 0.48 respectively) Akl (2014) observed significantly larger values of resultant and horizontal takeoff velocities, total takeoff time and body center of mass height at takeoff in male athletes' performances. Vertical takeoff velocity (3.44 ± 0.43 and 2.77 ± 0.59 $m \cdot s^{-1}$) and flight angle (23.00 ± 2.92 and 21.30 ± 3.27°) were considerably larger in the male group, yet, all differences were not significant. Lees, Derby, & Fowler (1992) compared the performances of the finalists in men's long jump at the 1991 UK National Championship and the participants of women's long jump at the 1991 World Student Games. One meter difference in jump distance was recorded when comparing the results of male and female groups (mean 7.5 and 6.5 m respectively). The authors concluded that men usually attack the board faster than women (horizontal touchdown velocity 9.8 and 8.8 $m \cdot s^{-1}$), hence they are not able to generate higher vertical velocities (3.0 $m \cdot s^{-1}$ for males and 3.1 $m \cdot s^{-1}$ for females), which leads to a lower angle of takeoff (17.7 and 22.0° for male and female groups respectively). At the same time, Panoutsakopoulos, Papaiakovou, & Kollias

(2009) found out that junior male jumpers (average jump distance 6.70 ± 0.27 m) had significantly larger horizontal and vertical takeoff velocity, takeoff angle and height of the body center of mass at takeoff than junior female long jumpers (average jump distance 5.51 ± 0.25 m). This ratio of the kinematic characteristics of long jump was confirmed in the study of Panoutsakopoulos & A. Kollias (2009). The authors found out that top male Greek long jumpers (average jump distance 7.51 ± 0.43 m) had significantly larger horizontal and vertical takeoff velocities, angle of projection and body center of mass height at takeoff than top female Greek long jumpers (average jump distance 6.11 ± 0.27 m). Thus, the experimental data on gender differences in long jump techniques are very various and sometimes contradictory. This suggests that for athletes from different countries, having different technical and physical preparedness, gender differences in long jump techniques may have their own specifics. The study of this specificity may serve as a basis for organizing technical training of male and female athletes and will help to better understand the mechanisms of achieving better results in long jump. So, the aim of this study was to compare characteristics of takeoff techniques and features of their interrelationships between male and female Russian long jumpers.

MATERIALS AND METHODS

This research project has been approved by the Ethics Committee of the Adyghe State University in accordance with the Declaration of Helsinki. Twenty-six male (twelve long jumpers and fourteen combined events athletes, aged 21.4 ± 3.8) and twenty-one female (nine long jumpers and twelve combined events athletes, aged 19.6 ± 3.6) athletes were videotaped during their long jump competitive performances at 2014 Winter Championship of the Southern Federal District of Russia. The officially recorded distances in long jumps were specified by measuring the distance from the toes of the takeoff foot to the takeoff line (effective distance). The kinematic characteristics of their best trials were taken into consideration. No data for the standard anthropometric measurements of body height and body mass were available. Videotaping was done with a high-speed digital camcorder Casio EX-ZR700 operating at 240 Hz. The camera was placed perpendicular to the runway, about 4 m away from the takeoff board. The optical axis of the camera was aligned with the takeoff line. Two-dimensional video analysis was carried out with the help of SkillSpector (Version 1.3.2) software. Twenty-point Full Body model was used to evaluate CG position and the kinematic characteristics of the athletes' movements. The following measurements were taken: takeoff CG velocity; horizontal and vertical CG takeoff velocities; CG height at touchdown and at takeoff; CG takeoff angle (angle between resultant takeoff velocity and horizontal line); ground contact time (GCT); knee angle at touchdown and minimal knee angle during support time; leg angle at touchdown (angle between the half-line from the ankle through the hip joint of takeoff leg and the horizontal half-line from the ankle in the opposite to run-up direction); CG to heel distance at touchdown in horizontal plane. Measurement accuracy was 0.022 m for displacement and 0.054 $m \cdot s^{-1}$ for velocity.

Data smoothing was done with the help of quintic spline filter. One-way analysis of variance (ANOVA) was used to evaluate the significance of kinematic data on long jump differences between male and female athletes. Pearson's correlation coefficient was used to evaluate the interdependence between the characteristics of takeoff technique in long jump. Pearson's correlation coefficient was interpreted in accordance with Suslakov's categorization (± 1.00 – functional relationship; ± 0.99-0.70 – strong statistical relationship; ± 0.69-0.50 – medium statistical relationship; ± 0.49-0.20 – weak statistical relationship; ± 0.19-0.09 – very weak statistical relationship; modulus of the correlation coefficient is less than 0.09 – no correlation) (Suslakov, 1982). Multiple regression was used to measure the influence of each individual variable on the effective distance of the long jump (method: stepwise; criteria: probability of F-to-enter ≤ 0.050, probability of F-to-remove ≥ 0.100).

RESULTS

As had been expected, male athletes had significantly larger effective distances, takeoff velocities of CG and their horizontal and vertical components ($P < 0.001$, Table 1). Also, male and female long jumpers demonstrated significant differences in many other characteristics.

Table 1. Characteristics (Mean ± S.D.) of takeoff technique of male and female long jumpers.

Characteristics	Male jumpers	Female jumpers	*F* (*p* value)
Effective distance (m)	6.94 ± 0.38	5.50 ± 0.41	156.43 (0,000)
Takeoff velocity ($m \cdot s^{-1}$)	8.64 ± 0.46	7.58 ± 0.36	73.51 (0,000)
Horizontal takeoff velocity ($m \cdot s^{-1}$)	7.96 ± 0.44	7.06 ± 0.32	61.67 (0,000)
Vertical takeoff velocity ($m \cdot s^{-1}$)	3.35 ± 0.44	2.75 ± 0.37	24.57 (0,000)
Takeoff angle (°)	22.8 ± 2.5	21.3 ± 2.4	4.20 (0,046)
GCT (s)	0.130 ± 0.011	0.133 ± 0.011	0.59 (0,446)
Touchdown CG height (m)	0.92 ± 0.04	0.88 ± 0.04	7.08 (0,011)
Takeoff CG height (m)	1.18 ± 0.06	1.09 ± 0.04	33.74 (0,000)
CG to heel distance (m)	0.44 ± 0.06	0.39 ± 0.05	8.71 (0,005)
Knee angle at touchdown (°)	167.2 ± 4.5	165.5 ± 4.6	1.81 (0,186)
Minimum knee angle (°)	136.8 ± 4.9	137.2 ± 5.0	0.07 (0,793)
Leg angle at touchdown (°)	57.7 ± 3.0	59.6 ± 2.8	5.03 (0,030)

So, as can be seen from Table 1, male long jumpers demonstrated significantly larger takeoff angles ($P < 0.05$), CG heights at touchdown and at takeoff ($P < 0.05$ and $P < 0.001$), CG to heel distances ($P < 0.01$). Female jumpers had significantly larger leg angle at touchdown ($P < 0.05$, Table 1). Three characteristics of takeoff technique had only insignificant differences between male and female long jumpers: ground contact time, knee angle at touchdown, and minimum knee angle during support time ($P > 0.05$, Table 1).

The correlation analysis has shown that the effective distance had no strong dependences on takeoff technique characteristics in the male group of jumpers and revealed only one medium dependence on vertical takeoff velocity (Table 2). Strong positive correlations were found in male long jumping between the takeoff velocity and its horizontal component, vertical takeoff velocity and takeoff angle, CG height at touchdown and takeoff, GCT and CG to heel distance (Table 2). Also, a strong dependence was found in the male group between CG to heel distance and leg angle (negative) along with medium dependences between CG to heel distance and CG height at takeoff, CG height at takeoff and ground contact time.

Table 2. Dependences (coefficients of Pearson's correlation without zeros and dots) between characteristics of takeoff technique at male (bottom and left) and female (top and right, bold) long jumpers.

Data	ED	V_{TO}	HV_{TO}	VV_{TO}	A_{TO}	GCT	CGH_{TD}	CGH_{TO}	CGHD	A_K	A_{KMin}	A_L
ED	1	**75**	**64**	**61**	**40**	**-70**	**-40**	**-53**	**20**	**27**	**08**	**-50**
V_{TO}	46	1	**94**	**62**	**29**	**-67**	**-18**	**-38**	**07**	**14**	**07**	**-21**
HV_{TO}	31	94	1	**32**	**-05**	**-59**	**00**	**-28**	**01**	**02**	**05**	**-11**
VV_{TO}	52	47	14	1	**93**	**-52**	**-49**	**-42**	**19**	**35**	**11**	**-35**
A_{TO}	42	13	-21	90	1	**-33**	**-52**	**-33**	**20**	**35**	**10**	**-34**
GCT	-35	-33	-33	-09	02	1	**31**	**64**	**25**	**-14**	**-27**	**04**
CGH_{TD}	-15	-17	-09	-25	-24	22	1	**85**	**-40**	**05**	**01**	**58**
CGH_{TO}	04	-09	-10	00	02	51	85	1	**-20**	**13**	**-22**	**42**
CGHD	18	-08	-21	30	37	74	14	50	1	**-15**	**-16**	**-79**
A_K	-01	13	29	-34	-44	-15	35	18	-12	1	**35**	**10**
A_{KMin}	15	30	33	05	-10	-44	06	-10	-28	24	1	**26**
A_L	-29	03	18	-36	-49	-49	33	-04	-80	33	20	1

Notice: ED – effective distance, V_{TO} – takeoff velocity, HV_{TO} – horizontal takeoff velocity, VV_{TO} – vertical takeoff velocity, A_{TO} – takeoff angle, GCT – ground contact time, CGH_{TD} – CG height at touchdown, CGH_{TO} – CG height at takeoff, CGHD – CG to heel distance, A_K – knee angle at touchdown, A_{KMin} – minimum knee angle during support time, A_L – leg angle at touchdown.

More strong and medium dependencies between effective distance and characteristics of takeoff technique were found in the female group of jumpers. It has been established that the effective distance strongly depends on takeoff velocity (Table 2). Also, female long jumping revealed a strong negative correlation between effective distance and ground contact time. Medium dependences were found between effective distance and horizontal and vertical takeoff velocity, leg angle (negative), CG height at takeoff (negative).

Takeoff velocity proved to have a strong positive dependence on horizontal takeoff velocity and medium positive dependence on vertical takeoff velocity. The takeoff angle in the female group of jumpers strongly depended on vertical takeoff velocity and had a medium negative dependence on CG height at touchdown. The leg angle had a strong negative dependence on CG to heel distance and a medium positive dependence on CG height at touchdown (Table 2). Ground contact time in the female group was found to have a medium positive correlation with CG height at takeoff and medium negative correlation with takeoff velocity and its horizontal and vertical components. The correlations between other characteristics of takeoff techniques were weak, very weak or absent for both male and female jumpers.

The stepwise multiple regression analysis revealed the numerical values for the strongest dependences between the effective distances and takeoff characteristics in both groups of long jumpers, male and female.

The regression equations describing the effective distances are as follows:

$ED = 0.447VV_{TO} + 5.448$ for male jumpers;
$ED = 0.430V_{TO} - 0.057A_L - 16.282GCT + 7.807$ for female jumpers,

where *ED* is effective distance (m), VV_{TO} – vertical takeoff velocity (m · s^{-1}), V_{TO} – takeoff velocity (m · s^{-1}), A_L – leg angle (°), *GCT* – ground contact time (s).

The statistical significance of the multiple regression analysis is shown in Table 3.

Table 3. Summary of multiple regression statistics (coefficient of variation, R^2; standard error, SEE; ANOVA statistic, F; the significance value, p).

Sex	R^2	SEE	F	p
Male	0.269	0.330	8.84	0.007
Female	0.779	0.209	19.97	0.000

DISCUSSION

The analysis of the investigation results has shown that takeoff techniques of male and female Russian long jumpers have a lot of differences. Furthermore, their main characteristics have various interrelationships revealed by these groups of athletes. The values of takeoff velocity and horizontal takeoff velocity of male and female long jumpers are smaller than in many other studies (Fukashiro et al., 1994; Arampatzis et al., 1999; Linthorne, 2008; Koyama et al., 2009). This might be a consequence of differences in performance levels between the participants of this study and those involved in other investigations. For example, in a certain male group of jumpers, mean long jump distance of 8.15 ± 0.17 m was registered the horizontal velocity 8.80 ± 0.12 m · s^{-1} (Fukashiro et al., 1994) or, respectively, 8.11 ± 0.18 m and 8.77 ± 0.22 m · s^{-1} (Arampatzis et al., 1999), while in the present study mean long jump distance was 6.94 ± 0.38 m and the horizontal velocity 7.96 ± 0.44 m · s^{-1}. Moreover, in a female group of jumpers jump distance 6.95 ± 0.43 m was achieved at horizontal takeoff velocity 7.92 ± 0.31 m · s^{-1} (Fukashiro et al., 1994). These values match the data which this study has revealed for men. This tendency confirms the assumption that long jump performance is strongly conditioned by takeoff and horizontal velocities (Linthorne, 2008). From this perspective, it seems odd that this study has found only one strong correlation between effective long jump distance and takeoff velocity in the female group of jumpers (r = 0.75, Table 2), and no strong correlation whatsoever between these variables in the male group. Female jumpers revealed medium correlations between effective long jump distances and both horizontal and vertical takeoff velocities. Only medium interdependence between effective long jump distance and vertical takeoff velocity was found in the male group. Horizontal takeoff velocity and takeoff velocity had only weak correlations with long jump performances in this group. This proves the significance of vertical velocity for long jump distance for men and women, as well as evidences that the part of surveyed men jumpers probably have not an optimal technique of flight and landing, thus distorting the dependence between effective long jump distance and takeoff velocity and its horizontal and vertical components. This has confirmed the opinion that the athletes of ordinary level have greater variability in the investigated parameters, and they can reach their maximum lengths of jumps in many different ways (Luhtanen & Komi, 1979). The present study has also shown that in both male and female long jumps the takeoff velocity has a strong correlation with horizontal takeoff velocity (Table 2), thus proving that at this performance level one of the main tasks is to attain fast horizontal velocity at the end of the run-up and save it at takeoff (Linthorne, 2008). As it follows from this study, male and female jumpers of this performance level successfully coped with their movement coordination in the horizontal and vertical directions at the high speed run-up (the absence of a negative correlation and a weak positive correlation between the horizontal and vertical takeoff velocity in groups of men and women, Table 2). In the previous studies, there is some evidence for a strong negative correlation between these characteristics revealed by male jumpers (r = – 0.736) (Graham-Smith & Lees, 2005).

The values for vertical takeoff velocity of male jumpers in the present study reached the levels of elite athletes (e.g. for the athletes' performance of 8.15 ± 0.17 m, this parameter was equal to 3.44 ± 0.19 m · s^{-1} (Fukashiro et al., 1994), and for 8.11 ± 0.18 m it equaled 3.42 ± 0.26 m · s^{-1} (Arampatzis et al., 1999)). In some studies, one can see lower (long jump distance 8.31 ± 0.10 m, vertical takeoff velocity 3.04 ± 0.27 m · s^{-1} (Seo et al., 2011)) and higher (long jump distance 7.50 ± 0.36 m, vertical takeoff velocity 3.52 ± 0.26 m · s^{-1} (Panoutsakopoulos, Papaiakovou, Katsikas, & Kollias, 2010)) values for vertical velocities demonstrated by elite male jumpers. Vertical takeoff velocities in female long jumps in the present study were lower than those of elite athletes (long jump distance 6.95 ± 0.43 m, vertical takeoff velocity 3.05 ± 0.24 m · s^{-1} (Fukashiro et al., 1994); long jump distance 6.75 ± 0.13 m, vertical takeoff velocity 2.96 ± 0.14 m · s^{-1} (Seo et al., 2011)). Perhaps such high vertical velocity values reached by male jumpers in this study (comparable to those of elite jumpers) have produced only a weak correlation between this parameter and takeoff velocity (Table 2), while there is a medium correlation between vertical and takeoff velocities of female jumpers (Table 2). This indirectly confirms the importance of developing a larger vertical takeoff velocity to increase the jump distance of a female jumper at this level of performance. The takeoff angle is largely determined by vertical takeoff velocity in case of both male and female long jumpers (strong correlation, Table 2). At the same time, the takeoff angle does not depend on horizontal takeoff velocity (weak negative correlation in male group and no correlation in female group, Table 2). The values for takeoff angles in the present study are slightly larger than those in the previous investigations. Thus, various researchers quote the values of 21.4 ± 1.5° (Fukashiro et al., 1994), 21.3 ± 1.5° (Arampatzis et al., 1999), 18.5 ± 2.24° (Seo et al., 2011) for elite male jumpers, and 21.1 ± 2.0° (Fukashiro et al., 1994), 20.9 ± 1.7° (Arampatzis et al., 1999), 20.7 ± 1.03° (Seo et al., 2011) for elite female athletes. While in various studies takeoff angles were slightly larger in male or female or equal in both groups (Linthorne, 2008), in the present investigation the takeoff angle of the males is significantly larger (Table 1). Possible differences or parities in these characteristics of male and female long jumpers are attributable to the interrelation of horizontal and vertical takeoff velocities in the observed groups of men and women. As correlation analysis has shown, vertical takeoff velocities in the present study strongly determined takeoff angles in both male and female groups (strong correlation, Table 2). This confirms the available data on a strong correlation existing between vertical takeoff velocity and takeoff angle of a male jumper (Graham-Smith & Lees, 2005). However, while earlier studies insisted on there being also a strong negative correlation of takeoff angle with horizontal takeoff velocity (r = – 0.869) (Graham-Smith & Lees, 2005), the present study revealed only a weak negative correlation for men and no correlation for women (Table 2). It shows that at various performance levels the adjustment of takeoff angle in long jump can be quite different.

Male and female long jumpers in the present study showed no significant differences in ground contact time, but there are big gender differences in the correlation of this parameter with other characteristics of a long jump technique. Thus, there is a strong correlation between ground contact time and CG to heel distance of male long jumpers (Table 2). As for female long jumpers, their ground contact time has a strong negative correlation with effective jump distance and a medium correlation with takeoff velocity and its horizontal and vertical components (Table 2). Therefore, the decrease of takeoff time should be one of the main objectives when training female jumpers of this performance level. It is worth noting that the values for ground contact times registered in this study for males (0.130 ± 0.011 s) and females (0.133 ± 0.011 s) are larger than those of elite jumpers (for males 0.12 ± 0.02 s (Seo et al., 2011); 0.11 (Linthorne, 2008) and for females 0.12 ± 0.01 s (Seo et al., 2011); 0.11 (Linthorne, 2008)). At the same time, the reduction of ground contact time in long jumps is certainly the problem of physical rather than technical training.

Significantly larger CG to heel distance of male jumpers revealed in this study might be the result of men being generally taller than women (Alexander, 1990). Gender differences in CG height at touchdown and takeoff can also be explained by the differences in the height of male and female jumpers (Table 1). This is indirectly confirmed by a strong positive correlation between CG height at touchdown and takeoff in both male and female groups of jumpers (Table 2).

Another characteristic of long jump technique that showed significant gender differences in this study is leg angle. As seen from Table 1, this value is larger for female long jumpers. Furthermore, in the female group leg angle had a strong negative correlation with CG to heel distance and a medium negative correlation with effective distance. This implies that women should be recommended to change their leg angle so that it would match male parameters, and one of the possible ways to do it is to increase CG to heel distance at touchdown.

The present study has not revealed any significant gender differences in knee angle at touchdown and minimum knee angle during takeoff (Table 1). These values are somewhat smaller than in previous studies (Lees et al., 1994; Linthorne, 2008; Seo et. al., 2011), and there is no one a strong or medium correlation between these and effective distance and other characteristics of long jump technique (Table 2).

The performance levels of the long jumpers participating in the present study most closely match those of the subjects in the research of Panoutsakopoulos, Papaiakovou & Kollias (2009). Thus, the effective distance of female Russian long jumpers was 5.50 ± 0.41 m and that of their junior Greek counterparts was 5.51 ± 0.25 m; for male jumpers it was 6.94 ± 0.38 and 6.70 ± 0.27 m respectively. The values of horizontal takeoff velocity in these two studies are almost identical (7.72 ± 0.57 m · s^{-1} for male and 7.10 ± 0.37 m · s^{-1} for junior female Greeks). The vertical takeoff velocity (3.05 ± 0.26 m · s^{-1} and 2.51 ± 0.32 m · s^{-1}) and takeoff angle (21.6 ± 2.6° and 19.5 ± 2.3°) for junior Greek males and females are slightly lower than those of Russian athletes (Table 1). The values of vertical takeoff velocity and takeoff angle of Russian jumpers (Table 1) reach the values of top Greek long jumpers in Panoutsakopoulos & Kollias (2009) study (vertical takeoff velocity 3.43 ± 0.36 m · s^{-1} and 2.81±0.19 m · s^{-1} and takeoff angle 22.7 ± 1.8° and 20.6 ± 1.2° for male and female athletes respectively). Interestingly, similar gender differences in takeoff characteristics have been singled out for Russian and Greek athletes of the same performance level. Thus, junior male Russian and Greek long jumpers demonstrated significantly larger horizontal and vertical takeoff velocity, takeoff angle, body center of mass height at takeoff than their female counterparts. It is remarkable that the aforesaid differences in takeoff characteristics of men and women have been also confirmed for the top Greek long jumpers (Panoutsakopoulos & Kollias, 2009). However, the present study has revealed a positive correlation between vertical velocity and jump distance for male and female jumpers, as well as the importance of leg angle reduction for females (*r* = – 0.50 between leg angle and effective distance, Table 2). It should be particularly emphasized that the biomechanical pattern (Bridgett & Linthorne, 2006), according to which the increases in the length and speed of run-up entail a considerable reduction of the takeoff angle and takeoff duration, increase in knee angle at touchdown, and just a slight decrease in leg angle (–0.6 ± 0.2 degrees per $m \cdot s^{-1}$), does not apply to both male and female takeoff characteristics. Thus, in the present study male jumpers developed larger takeoff velocity (as a result of a more rapid run-up), while they also had a lager takeoff angle; at the same time, takeoff duration and knee angle at touchdown were similar in male and female groups, whereas leg angle was significantly larger for male jumpers (the difference in horizontal takeoff velocities between male and female jumpers was 0.90 m, while leg angle difference constituted 1.9°).

It should be noted that like the present study, previous studies have reported cases of the absence of strong correlations in the male group between jump effective distance and key characteristics of the takeoff technique. Thus, fourteen long jumpers (effective distance 7.45 ± 0.18 m) were found to have only a weak correlation between effective distance and take-off velocity (*r* = 0.403), horizontal and vertical takeoff velocity (*r* = 0.215 and 0.279 respectively) and no correlation between effective distance and centre of body mass height at takeoff (*r* = – 0.083) (Graham-Smith & Lees, 2005). The authors conclude that this might be due to the variability of range for each of the variables, and one-to-one correlation is not enough to correctly reflect the interdependence between the main characteristics of long jump technique and effective distance. So Graham-Smith and Lees (2005) suggest using multiple regression analysis to address this issue. However, the present study was not able to obtain any new information out of multiple regression analysis to improve the understanding of relationships between key characteristics of long jump technique and effective distances in male long jumps. Vertical takeoff velocity has been the most significant variable used in this study to determine effective distance, yet, this model can explain only 26.9% of variation in the male group of jumpers (Table 3). In the regression model of the effective distance dependence for women, the most significant variables were takeoff velocity, leg angle and ground contact time. These variables explain 77.9% of effective distance variation. Regression equation for women has confirmed the correlation analysis data and suggests that a too large leg angle at touchdown should be considered a technical mistake of a female jumpers at this performance level. From the regression equation for women it is also clear that to improve the performance distance female jumpers have to increase their takeoff velocity and decrease the duration of takeoff phase. However, it is impractical to compare the equations calculated in this investigation to those used in other studies because different researchers use different variables for their regression analyses.

Limitations

All strong and medium correlation coefficients discussed in this study are significant ($P < 0.01$). However, one should bear in mind that the small number of subjects in this study results in significant width of confidence intervals for some calculated correlation coefficients. For example, 95% confidence interval for 0.94 correlation coefficient of the dependence between takeoff velocity and its horizontal component for females, found in this study (Table 2), is from 0.86 to 0.98 (according to Ivanov, 1990). Hence, this dependence in general population is likely to be strong, too. However, confidence interval for 0.52 correlation coefficient of dependence between long jump distance and vertical takeoff velocity of male jumpers (Table 2) is from 0.16 to 0.75 (according to Ivanov, 1990). Hence, this dependence in general population may be either very weak or strong. Therefore, the conclusion of this study which is based on the analysis of medium statistical relationship needs to be further confirmed by other investigations.

CONCLUSIONS

The present study has increased the awareness of male and female long jump takeoff technique features as well as gender specifics of correlations between characteristics of takeoff technique and jump distance. The study has revealed that takeoff techniques of non-elite male and female long jumpers have significant differences in variables which are determined by physical abilities and prior technical training. Out of all the characteristics considered in this study, only vertical takeoff velocity proved to have a medium correlation and was the one that mostly determined the effective distance of male long jumpers at this performance level. It indicates that different male long jumpers can use different ways to improve their performance distances. The effective distance in female long jumps strongly depends on takeoff velocity, leg angle and ground contact time. Therefore, the improvement of effective distances of female long jumpers may be achieved by improving the mechanisms that determine these characteristics.

REFERENCES

1. Akl, A-R. (2014). Biomechanical study to assess the variations between male and female in long jump. *Sport Scientific And Practical Aspects, 11* (1), 33-36.
2. Alexander, R.McN. (1990). Optimum take-off techniques for high and long jumps. *Philosophical Translations of the Royal Society, 329*, 3-10.
3. Arampatzis, A., Brüggemann, G.-P., & Walsch, M. (1999). Long jump. In Biomechanical analysis of the jumping events. In G.-P. Brüggemann, D. Koszewski & H. Müller (Eds.), Biomechanical Research Project Athens 1997: Final Report (pp. 82-102). Oxford: Meyer & Meyer Sport.
4. Bridgett, L. A. & Linthorne, N. P. (2006). Changes in long jump take-off technique with increasing run-up speed. *Journal of Sports Sciences, 24*(8), 889–897.
5. Campos J., Gámez J., Encarnación E., Gutiérrez-Dávila M., & Rojas J. (2008). Análisis de la técnica de la batida entre finalistas, hombres y mujeres, del Campeonato del Mundo de Atletismo en Pista Cubierta 2008. In World Congress on Science in Athletics (pp. 1-9). Publisher: Fundación CIDIDA.
6. Campos, J., Gamez, J., & Encarnacion, E. (2009). Kinematical analysis of the men‘s long jump at the 2008 IAAF‘s World Indoor Championships in Athletics. In A. Hökelmann, W. Kerstin, & P. O'Donoghue (Eds.), *Current trends in Performance Analysis* (pp. 185-188). Aachen: Shaker Verlag.
7. Campos, J., Gámez, J., Encarnación, A., Gutiérrez-Dávila, M., & Rojas J. (2013). Three Dimensional Kinematic Analysis of the Long Jump at the 2008 IAAF World Indoor Championships in Athletics. *New Studies in Athletics*, 28:3/4, 115-131.
8. Fukashiro, S., Wakayama, A., Kojima, T., Ito, N., Arai, T., Iiboshi, A., … Tan, H. P. (1994). Biomechanical analysis of the long jump (in Japanese). In Japan Association of Athletics Federations (Ed.), The techniques of the World top athletes (Research report of the 3rd World Championships, Tokyo) (pp. 135-151). Tokyo: Baseball Magazine Co.
9. Graham-Smith, P. & Lees, A. (2005). A three-dimensional kinematic analysis of the long jump take-off. *Journal of Sports Sciences, 23*, 891-903.
10. Hay, J. G., Thorson, E. M., & Kippenhan, B. C. (1999). Changes in muscle-tendon length during the takeoff of a running long jump. *Journal of Sports Sciences, 17*(2), 159-172.

11. Hussain, I., Khan, A., Mohammad, A., Bari, M.B., Ahmad A. (2011). A comparison of selected kinematical parameters between male and female intervarsity long jumpers. *Journal of Physical Education and Sport, 11* (2), 182-187.
12. Ivanov, V. S. (1990). Fundamentals of Mathematical Statistics (in Russia). Moscow: Physical Culture and Sports.
13. Koyama, H., Ae, M., Muraki, Y., Yoshihara, A., & Shibayama, K. (2009). Biomechanical analysis of the men's and women's long jump at the 11th IAAF World Championships in Athletics, OSAKA 2007: A brief report. *Bulletin of Studies in Athletics of JAAF, 5*, 107-118.
14. Lees, A., Derby, D., & Fowler, N. (1992). Sex differences in the jump touchdown and take-off characteristics of the long jump. *Journal of Sports Science, 10*(6), 558-589.
15. Lees, A., Derby, D., & Fowler, N. (1993). A biomechanical analysis of the last stride, touch-down, and takeoff characteristics of the women's long jump. *Journal of Sports Sciences, 11*, 303-314.
16. Lees, A., Graham-Smith, P., & Fowler, N. (1994). A biomechanical analysis of the last stride, touchdown and takeoff characteristics of the men's long jump. *Journal of Applied Biomechanics, 10*, 61-78.
17. Linthorne, N. P. (2008). Biomechanics of the long jump. In Y. Hong & R. Bartlett (Eds.), Routledge Handbook of biomechanics and human movement science (pp. 340-353). London: Routledge.
18. Luhtanen, P., Komi, P. V. (1979). Mechanical power and segmental contribution to force impulses in long jump takeoff. *European Journal of Applied Physiology, 41*, 267-274.
19. Muraki, Y., Ae, M., Yokozawa, T., & Koyama, H. (2005). Mechanical properties of the takeoff leg as a support mechanism in the long jump. *Sports Biomechanics, 4*(1), 1-15.
20. Panoutsakopoulos, V. & Kollias, I. A. (2009). Biomechanical analysis of the last strides, the touchdown and the takeoff of top Greek male and female long jumpers, *Hellenic Journal Physical Education & Sport Science, 29* (2), 200-218.
21. Panoutsakopoulos, V., Papaiakovou, G., & Kollias, I. A. (2009) A biomechanical analysis and assessment of the technique elements of the last strides, the touchdown and the takeoff of junior male and female long jumpers. *Inquiries in Sport & Physical Education,* 7 (3), 333-343.
22. Panoutsakopoulos, V., Papaiakovou, G. I., Katsikas, F. S., & Kollias, I. A. (2010). 3D Biomechanical Analysis of the Preparation of the Long Jump Take-Off. *New Studies in Athletics, 1*, 55-68.
23. Seo, J-S., Kim, H-M., Woo, S-Y., Kim, Y-W., Nam, K-J., Park, Y.-H., … Kim J-H. (2011). 2011 IAAF World Championships, Daegu KSSB Project Final Report. Men's Long Jump Finals. Women's Long Jump Finals. In Y-S. Bae (Ed.), Biomechanics Research Project in the IAAF World Championships Daegu 2011 (pp. 65-80). Daegu: Korean Society of Sports Biomechanics.
24. Suslakov, B. A. (1982). Statistical methods of processing of measurements (in Russian). In V.M. Zatsiorskiy (Ed.), *Sports metrology* (pp. 18-63). Moscow: Physical culture and sport.