DIFFERENCES IN LONG JUMP TAKEOFF TECHNIQUES AMONG COMBINED EVENTS ATHLETES OF VARIOUS QUALIFICATIONS

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The aim of this study was to compare the kinematic characteristics of the movements made by combined events athletes of different qualifications at support phase in long jump. The long-jump performances of twenty-five combine events athletes had been videotaped at the Southern Federal District of Russia Championship for further 2D video analysis. Was used 240 Hz video camcorder. The kinematic data of the best twelve and the weakest thirteen athletes in long jumps were ccompared. It has been found that more qualified athletes have significantly smaller contact time and significantly larger knee angle at touchdown, and higher center of gravity (CG) at takeoff. The height of CG at touchdown, takeoff and calf angles, the distance from CG to heel, and maximal knee flexion during contact time among the athletes of various qualifications differ insignificant.

KEYWORDS: center of gravity, ground contact time, takeoff velocity, takeoff angle.

INTRODUCTION: The trajectory of a long jumper's center of gravity depends on takeoff velocity, takeoff angle, and the height of the athlete's CG at takeoff. Long jump distance increases with the increase of takeoff velocity and the height of the athlete's CG at takeoff. According to the equation of free flight, the optimal takeoff angle, which depends on the takeoff velocity and CG position, is about 40° (Hay, 1993). However, in real life performances of long jumpers, their takeoff angle proves to be significantly smaller, and it is not easy to determine what the optimal takeoff angle for long jumpers and combined events athletes of different qualification and sex should be. Many authors have investigated the kinematic characteristics of running long jump and their interaction. At the same time, the majority of research papers discuss the characteristics of long jump technique of identically qualified athletes. Thus, Linthorne et al. (2002) calculated the optimal takeoff angle to be about 23° for three experienced long jumpers. Lees et al. (1992) measured the performance variables from the finalists in men's long jump of the UK National Championships. The takeoff had the following values: vector velocity 9.90 ± 0.43 m/s, horizontal velocity 9.44 ± 0.49 m/s, vertical velocity 2.96 ± 0.50 m/s, CG height 1.31 ± 0.04, projection angle 17.30 ± 3.60°. Barros et al. (2007) presented their data on high-level male long jumpers (official distances from 7.38 to 8.53 m) at takeoff: takeoff angle from 19.9 to 25.6°, height of center of mass from 1.13 to 1.41 m, horizontal velocity from 7.99 to 8.77 m/s, vertical velocity from 2.94 to 4.02 m/s. As one can see, the theoretical and experimental data of various authors strongly vary, and the assessment of these data is rather complicated. For better understanding of what the optimal takeoff technique in long jumps is, some additional information should be derived from the comparison of kinematic characteristics of movements at support phase of differently qualified athletes. So, the aim of the present study was to compare the kinematic characteristics of movements of differently qualified combined events athletes at support phase in long jump.

METHOD: Twenty five male combined events athletes were filmed during their competitive performances in long jumps in 2014 Winter Championship of the Southern Federal District of Russia. The kinematic characteristics of their best trials were taken into consideration. The officially recorded distances in long jumps were specified by measuring the distance from the toes of the takeoff foot to the takeoff line. The corrected distances were ranged, and the athletes were divided into the following two groups: Group A (twelve athletes having the best results: age 20.2 ± 3.1, corrected distances 6.87 ± 0.30 m) and Group B (thirteen athletes with the results ranking from the thirteenth to the twenty-fifth: age 16.6 ± 2.1 years, corrected

distances 5.96 ± 0.43 m). No data were available for the standard anthropometric measurements of body height and mass. Videotaping was done with 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. 2D video analysis was carried out with the help of SkillSpector (Version 1.3.2) software. Twenty-point Full Body model was used to evaluate the kinematic characteristics of each athlete's movements. The following measurements were taken: center of gravity height at touchdown and at takeoff; takeoff velocity (vector); horizontal and vertical takeoff velocities; CG takeoff angle; knee angle at touchdown and knee flexion during takeoff (difference between knee angle at touchdown and minimal knee angle during support time); calf angle at touchdown (angle between half-line from an ankle of takeoff leg through a knee and run-up direction); CG to heel distance at touchdown in horizontal plane; ground contact time (GCT).
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 the two groups of combined events athletes. Pearson's correlation coefficient was used to evaluate the interdependence between takeoff velocity and its components and takeoff angle.

RESULTS: As one would expect, the combined events athletes who were more qualified demonstrated significantly larger takeoff velocities in long jumps (Table 1, $p < 0.001$). Also, horizontal and vertical takeoff velocities were significantly larger in Group A. As seen from the analysis data of Table 1, combined events athletes of higher qualification had significantly smaller contact time ($p < 0.001$) along with significantly larger takeoff CG height ($p < 0.05$) and knee angle at touchdown ($p < 0.01$) in long jumps.

Table 1
Characteristics (Mean ± S.D.) of long jump takeoff parameters of combined events athletes of various qualifications.

Kinematic data	Group A	Group B	F (p value)
Takeoff velocity (m/s)	8.78 ± 0.30	8.11 ± 0.46	18.23 (< 0.001)
Horizontal takeoff velocity (m/s)	8.10 ± 0.24	7.57 ± 0.43	14.16 (< 0.01)
Vertical takeoff velocity (m/s)	3.34 ± 0.54	2.87 ± 0.41	6.08 (< 0.05)
Takeoff angle (°)	22.3 ± 2.8	20.3 ± 2.6	3.71 (> 0.05)
GCT (s)	0.130 ± 0.009	0.146 ± 0.012	14.51 (< 0.001)
Knee angle at touchdown (°)	168.9 ± 3.3	163.2 ± 4.8	11.64 (< 0.01)
Knee flexion (°)	30.9 ± 5.8	30.5 ± 5.7	0.03 (> 0.05)
Calf angle at touchdown (°)	64.7 ± 2.9	65.6 ± 3.6	0.47 (> 0.05)
Touchdown CG height (m)	0.939 ± 0.039	0.911 ± 0.032	3.69 (> 0.05)
CG to heel distance (m)	0.425 ± 0.049	0.447 ± 0.065	0.93 (> 0.05)
Takeoff CG height (m)	1.196 ± 0.042	1.150 ± 0.044	6.87 (< 0.05)

Only insignificant differences were revealed among the athletes of Groups A and B on the following measurements: CG to heel distance at touchdown; touchdown CG height; maximal knee flexion during support phase; calf angle at touchdown and takeoff angle.
A strong positive correlation was found between vertical takeoff velocity and takeoff angle in both groups of combined events athletes (Figure 1). At the same time, only weak negative correlation was revealed between takeoff angle and horizontal takeoff velocity in Group A ($r = -0.002$) and Group B ($r = -0.206$). Also, medium dependence was found between takeoff velocity and takeoff angle for combined events athletes of higher rank ($r = 0.616$) and weak dependence for athletes of lower qualification ($r = 0.099$).

DISCUSSION: The data on significant gains in takeoff velocity and its horizontal and vertical components in long jumps demonstrated by more qualified combined events athletes, presented in this study, coordinate with the results of other researchers and might be explained by the increased level of athletes' physical abilities. Thus, for example, Kilani and

Abu (1998) quote the following values for takeoff velocity and its vertical and horizontal components for the best fifteen high-school long jumpers in Amman: 7.8 ± 0.74 m/s, 2.00 ± 0.53 m/s and 7.6 ± 0.72 m/s. Takeoff horizontal and vertical velocities of CG of male long jumpers who participated in the final of the 11th WC in Osaka varied from 8.27 to 9.26 m/s and from 3.01 to 3.78 m/s, respectively (Koyama et al., 2008). At the same time, the present study has revealed that significant increase of vertical takeoff velocity of CG (strongly correlated with takeoff angle – Figure 1) in the more qualified group of athletes did not lead to any significant gain in takeoff angle (Table 1).

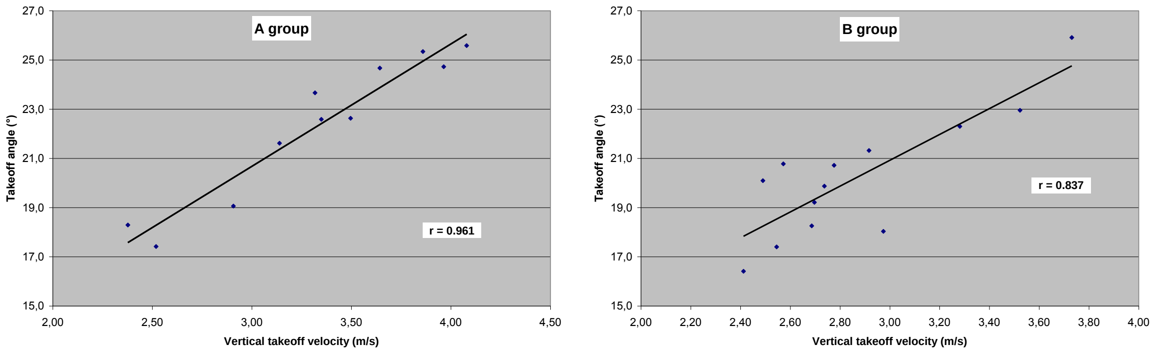

Figure 1: Pearson's correlation between vertical takeoff velocity and takeoff angle in Groups A and B of combined events athletes.

It can be explained by a big variation of takeoff angle values in both higher and lower qualification groups of combined events athletes. It is possible that some members of the more qualified group might have the long jump takeoff techniques typical of less qualified athletes. As seen from Figure 2, the CG trajectory of the athlete from higher qualification group (long jump distance 6.86 m) does not differ from the CG trajectory of the less qualified athlete (long jump distance 5.87 m) in the second half of the support phase. At the same time, the leader of Group A (long jump distance 7.54 m) is seen to increase CG height at the end of the support phase. Positive medium correlation between takeoff velocity and takeoff angle in Group A gives grounds to consider that most of the athletes of this qualification are able to effectively coordinate their efforts in both vertical and horizontal directions.

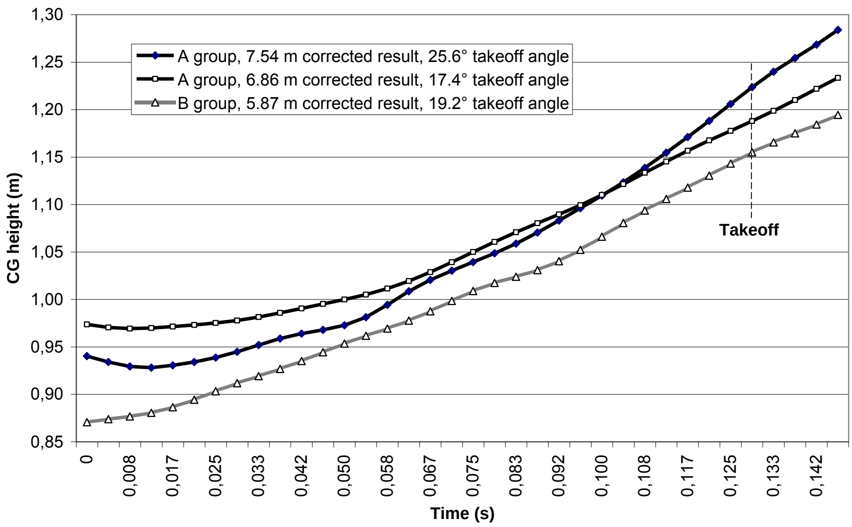

Figure 2: CG height of athletes from Groups A and B during support phase.

Linthorne et al. (2002) showed that run-ups which are shorter and slower than the competition ones allow for experienced long jumpers to increase their takeoff angle. However, the present study has revealed that lower horizontal velocity does not allow the athletes of lower qualification to create a large takeoff angle (Table 1). Only weak negative correlation between takeoff angle and horizontal takeoff velocity in both groups of athletes, found in the present study, confirms to the fact that higher horizontal velocity is not an obstacle for takeoff at a larger angle. Moreover, medium positive correlation between takeoff velocity (vector) and takeoff angle has been established for the group of more qualified combined events athletes.

Significantly larger knee angle at touchdown of the athletes of higher qualification, and insignificant differences in calf angle among the athletes of two groups (Table 1) gave grounds to expect significant differences in the distance between CG horizontal projection and heel. However, this was not observed in the research. It might have been the result of differences in the athletes' height (no data were available). The value of knee angle at touchdown in the group of higher rank athletes in the present study corresponds to the available data on qualified long jumpers (Lees et al., 1992; Papadopoulos et al., 1995), while knee angles of less qualified athletes are significantly smaller (Table 1). At the same time, the values of maximal knee flexion for both groups of athletes involved in the present investigation (insignificant differences, Table 1) are larger than in previous studies: knee angle at touchdown 165.20 ± 7.50° and at maximal knee flexion 141.10 ± 9.70 (Lees et al., 1992); or 8° difference of this variable for one long jumper (Papadopoulos et al., 1995). This might be the consequence of the lower level of power abilities of participants Group A and athletes of lower rank (Group B) in present study. It might also be the reason for GCT significant differences among combined events athletes of various qualifications revealed by the present research.

CONCLUSION: Thus, the present study has revealed the following significant differences in long jump takeoff techniques between the two groups of combined events athletes, with specified competitive results varying from 7.54 m to 6.48 m and from 6.43 m to 4.93 m: more qualified athletes have larger takeoff velocity (vector) and its vertical and horizontal components, larger knee angle at touchdown, larger takeoff CG height, and smaller GCT. There are only insignificant differences in takeoff angle among the athletes of higher and lower qualifications; yet, it might be the consequences of high variation of this parameter in both groups of athletes. However, the lack of negative correlation between takeoff velocity and takeoff angle of less qualified athletes, and, especially, the existence of medium positive correlation between these variables for athletes of higher qualification make the work on increasing the takeoff angle to optimal values in order to improve the long jump technique the major training task.

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