New aspects in perfecting the long jump technique

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ABSTRACT

The aim of this study was to provide directions for the perfection of the last two steps of the approach and take-off in the long jump. Using tenso-metric platforms, video recordings and photo-cells, 62 jumps by a mixed ability subject group were analysed and compared to videos of some of the world's best long jumpers to identify key factors for improving take-off technique. The author and his colleagues then developed a series of training exercises and attempted to train 8 subjects to alter their technique in line with the findings. They found the short-term results impressive but concluded that a longer period was required to stabilise the desired changes in adult jumpers. They also studied 110 jumpers aged 13-14 and found that many possessed a natural tendency towards the desired technique.

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Introduction

The long jump is an exceptionally beautiful discipline in which competition results depend on a variety of factors. Speed and strength are of primary importance[5,7] but a rational technique is necessary for an athlete to realise his/her maximum potential.

A great variety of research related to long jump technique exists in the methodological literature. The projects are most often related to the execution of the take-off[1, 4, 8, 10, 12, 13, 14], the preparation for take-off during the last 5-6 steps of the approach[2, 3, 6, 9] and the distribution of effort along the complete length of approach[5,11,15]. The literature gives instructions on how to avoid technical faults but there is not enough data on the reasons for making them or how they are best corrected.

Analysis of the literature shows that the main faults of long jumpers preparing to take off include:

- leaning the torso backwards;
- excessive lowering of the centre of mass (CM);
- artificially lengthening the last steps;
- a touch by the free leg heel in the last step of the approach;
- placing the take-off foot too far ahead of the projection of the CM.

When faults are made, it is, of course, very important to quickly find the reasons and undertake appropriate measures to eliminate them. Problems in one phase of the jump are often related to mistakes in an earlier phase. For example, if equilibrium is lost during the flight phase and the landing in the sand is poor, the reason is nearly always a weakness in the execution of the take-off. An ineffective take-off is most often related to faults in the preparation for take-off, which in turn is related to faults in the approach run.

Our analysis of the literature data, long experience in coaching and observations of many athletes of various performance levels have shown us that the issue of a rational preparation for the take-off has not yet been completely solved. There is a considerable way to go in perfecting the last steps of the approach and thus maximising the potential of each long jumper's speed and strength qualities.

This situation has given us the direction for the work described below.

Objectives, tasks and methods

The main objective of our research is to define the particularities of the kinematics and dynamics of take-off preparation and provide directions for the perfection of the last two steps of the approach and the take-off in the long jump.

In our effort to realise this objective we have set ourselves the following tasks:

- Analysis of long jump execution by current world class performers;
- Measurement and analysis of the kinematics characteristics of the motions of the last two steps of the approach;
- Measurement and analysis of the dynamic characteristics of the motions of the last two steps of the approach;
- Defining the methodological directions and developing a complex of means for perfecting the execution technique of the last two steps of the approach and the take-off;
- Conducting a sport-pedagogical experiment to determine the effectiveness of these means.

We have applied the following methods:

1. Literature Analysis

An analysis was made of the methodological literature data on issues related to technique and the means and methods for perfecting technique in the long jump.

2. Sport-pedagogical measurements

Long jumpers of various levels of performance took three or four jumps with approaches of 25-35m. During the execution of the jumps, we recorded the dynamic indexes of the support phases and some kinematical characteristics of the execution of the last two steps prior to the take-off. Twenty-one long jumpers (11 women and 10 men) took part. They ranged in age from 16 to 25 years and included the 2000 European Indoor Champion Petar Dachev. Seventy-four jumps were recorded, and 62 of these were analysed. Table 1 presents the indexes measured and the units of measurement.

Figure 1

Table 1

_	INDEX	Measurement units
T_1	Result	metres
T_2	Length of the next to last step of the approach	metres
T_3	Length of the last step of the approach	metres
T_4	Velocity of the next to last step of the approach	m/s
T_5	Velocity of the last step of the approach	
T_6	Duration of the next to last support (NLS) of the approach	seconds
T_7	Duration of the last support (LS) of the approach	seconds
T_8	Knee joint angle of the support leg (take off leg) at the moment of touch-down the next to last support (NLS) of the approach	degrees
T_9	Knee joint angle of the support leg (take-off leg) at the moment of maximum bend of the next to last support (NLS) of the approach	degrees
T_{10}	Fold magnitude (amortization) within the knee joint of the support leg (take off leg) during the next to last support (NLS) of the approach	degrees
T_{11}	Amortisation duration of the next to last support (NLS) of the approach	seconds
T_{12}	Knee joint angle of the support leg (swing leg) at the moment of touching the last support (LS) of the approach	degrees
T_{13}	Knee joint angle of the support leg (swing leg) at the moment of maximum bend of the last support (LS) of the approach	degrees
T_{14}	Bend magnitude (amortisation) within the knee joint of the support leg (swing leg) during the time of the last support (LS) of the approach	degrees
T_{15}	Amortisation duration of the last support (LS) of the approach	
T_{16}	Angle between the thighs at the moment of touching the next to last support" (NLS) of the approach	degrees
T_{17}	Angle of the shin-horizontal of the non-supportleg (swing leg) at the moment of touching the next to last support (NLS) of the approach	degrees
T_{18}	Angle between the thighs at the moment of touching the last support (LS) of the approach	degrees
T_{19}	Angle of the shank-horizontal of the non-support leg (take-off leg) at the moment of touching the last support (LS) of the approach	degrees

For better clarity of the data analysis, we have made the following conditional designations (Figure 1):

- The support phase of the swing leg prior to the take-off has been called "Last Support of the Approach" (LS);
- The support phase of the take-off leg prior the take-off has been called "Next to Last Support of the Approach" (NLS).

The angle parameters measured are shown in Figure 2.

Figure 2

3. Mathematical and statistical methods for analysing the test data

a) Variation analysis

The following indexes were calculated:

$\bar{X}$ average value,
$\pm M_x$ standard error,
S standard deviation,
E_x excess coefficient,
A_s asymmetry coefficient,
R range,
X_{min} minimal value,
X_{max} maximum value,
V% variation coefficient.

b) Correlation analysis

The coefficients of the linear correlation dependence between the indexes studied and the results have been calculated as well as the inter-correlation relations between the indexes.

c) Student's t-test

We made use of the Student's t-test related to dependent samples in order to compare some of the indexes studied

4. Instrumental methodologies

The following instrumental methodologies have been applied to the research:

a) Tensometry

Two tenso-metric platforms (dimensions: length: 100cm, width: 80cm, height: 12cm, vibration frequency: 200Hz) were used. They were built into a specially designed wooden runway (overall dimensions: length: 35m, width: 115cm, height: 12cm). The platforms were placed at such a distance from each other that the last two support phases of the approach could be recorded on them (Figure 3). The data from the two platforms were collected by a special tape reader and then processed by appropriate computer programs. In total, 248 tenso-grams of the 62 jumps were processed and analysed to provide the horizontal and vertical components of the support reaction. The support duration is calculated to 0.001 sec and the modification of the support reaction force during the support periods is given in kg.

b) Videometry

All jumps were recorded by a "Panasonic" digital video camera, providing the possibility for computer processing of the recordings to a frequency of 50 frames/sec. The camera was positioned 8m from the runway, midway between the tenso-metric platforms. The video camera signal was connected to a computer and the jumps were recorded directly on the computer. The video materials were processed by appropriate computer programs, resulting in cinegrams of the last two steps of the approach and the jump itself. Sixty-two cinegrams (50 frames/sec) were produced.

c) Photo diode chronometry:

Three pairs of photocells were placed at intervals of 2m in order to measure the velocity during the two last steps of the approach. Forty-three other cinegrams of world-class long jumpers were produced so that comparisons with the experimental group could be made.

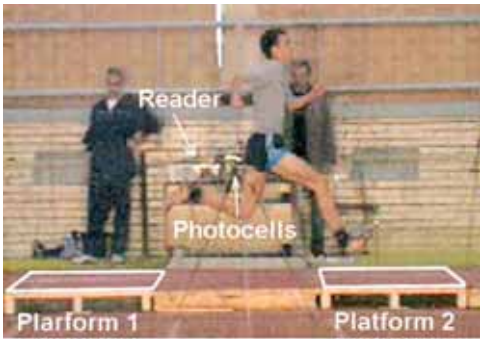

Figure 3

Analysis of the results

World-class long jumpers

Analysis shows that the world's best long jumpers execute the last two steps of the approach in various ways. To support our observations we use the examples of two of the most titled athletes in the world – Carl Lewis (USA) and Ivan Pedroso (CUB).

In a careful analysis of a jump by Lewis (Figure 4), we have established that at the

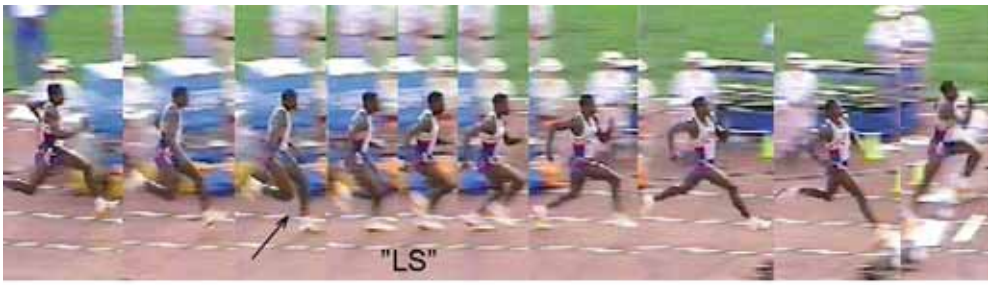

Figure 4

Figure 5

Figure 6

moment of touchdown of the last contact before the take-off (the left leg in this case), the LS, the take-off leg (the right) is located behind the support leg while the angle between the thighs is more than 20º and the foot contact is mainly on the heel. As a result, a prolonged and considerable bending of the left leg knee joint is seen during the support period. In other words, the amortization phase is very clearly exposed.

Something completely different has been established for Pedroso's jump (Figure 5). At the moment of contact of the support leg (the left in this case), the knee of the take-off leg (the right) is located in front of the support leg knee while the front part of the foot makes the support contact. As a result, hardly any bending of the support leg knee joint is observed during the support period.

Figure 6 shows the moments of LS touchdown by three other famous long jumpers. It can be seen that for Mike Powell (USA) the take-off leg knee (the left) gets ahead of the swing leg while for Tatiana Lebedeva (RUS) and Carolina Klüft (SWE) the take-off legs stay behind the swing legs.

Variation analysis of the sport-pedagogical measurement results

Table 2 presents the variation analysis data of the sport-pedagogical measurements we made. We purposely selected athletes of various performance levels and ages in order to look for reliable inter-relationships between the indexes and the distance jumped. We also processed the data separately for the men and women. We have established that with

Table 2: Variation analysis of the research data

	$\bar{X}$	$\pm M_x$	S	E_x	As	R	X_{min}	X_{max}	V %
T_1	5.56	0.10	0.78	-1.24	0.42	2.51	4.47	6.98	14.12
T_2	2.09	0.02	0.18	0.86	-0.70	1.12	1.25	2.37	8.56
T_3	2.09	0.02	0.19	0.20	-0.22	0.90	1.56	2.46	8.95
T_4	7.45	0.08	0.60	0.17	0.64	2.64	6.45	9.09	8.10
T_5	7.93	0.10	0.75	-0.84	0.28	3.07	6.45	9.52	9.45
T_6	0.128	0.002	0.014	-0.57	-0.51	0.052	0.098	0.150	10.60
T_7	0.131	0.001	0.011	0.85	-0.68	0.049	0.103	0.152	8.05
T_8	140.93	0.92	7.21	2.39	0.69	44.00	124.00	168.00	5.11
T_9	131.64	1.00	7.84	-0.47	-0.31	33.00	115.00	148.00	5.96
T_{10}	9.30	0.75	5.89	-0.02	0.53	25.00	0.00	25.00	63.32
T_{11}	0.049	0.003	0.021	1.24	0.95	0.12	0.000	0.120	42.98
T_{12}	138.51	0.73	5.67	1.41	0.36	33.00	125.00	158.00	4.09
T_{13}	120.62	1.24	9.71	-0.24	-0.33	44.00	99.00	143.00	8.05
T_{14}	17.89	0.99	7.75	0.64	0.62	39.00	3.00	42.00	43.35
T_{15}	0.061	0.002	0.012	-0.14	-0.02	0.040	0.040	0.080	19.63
T_{16}	17.51	1.45	11.32	-0.81	-0.21	46.00	-7.00	39.00	64.67
T_{17}	27.21	1.31	10.26	-0.28	-0.61	42.00	3.00	45.00	37.70
T_{18}	17.36	1.51	11.78	-0.64	-0.40	47.00	-9.00	38.00	67.88
T_{19}	22.95	2.00	15.61	1.03	-1.02	74.00	-23.00	51.00	68.02

the exception of the distance jumped and the speed of the last two steps (T_1, T_4, T_5), there are no substantial differences between the sexes with regard to the indexes studied. The best result for the women studied is 5.50m and the velocity of their last steps is about 1.0m/sec less than that recorded by the men.

The results of the jumps were within the range of 4.47 – 6.98m and the average distance resulting from the measurements is $\bar{X}$=5.56m with margin for error of 0.10m.

The excess coefficient (E_x) and the asymmetry coefficient (A_s) have values approximately 1.00 or less, which means a normal distribution of the data.

The greater part of the indexes indicate non-significant differences between the athletes researched from a statistical point of view as their variation coefficients (V%) are less than 10. These include the length of the last two steps of the approach (T_2, T_3), the velocity of the last two steps of the approach

(T_4, T_5), the support duration of the LS (T_7), as well as the knee joint angle at the moment of contact of the LS (T_{13}). On other side, some of the indexes show significant differences as the variation coefficients here are higher than 30. These include the magnitude of the knee joint bending in the NLS (T_{10}) and the LS (T_{14}), the amortization duration of NLS (T_{11}), as well as the four indexes (T_{16}, T_{17}, T_{18}, T_{19}) – the angle between the thighs and the angle between the lower leg and the horizontal at the moment of contact of the last two support phases.

Taking into account the non-significant differences in the speed indexes and small differences in the distances jumped (T_1), where the variation coefficient (V%) is 14.12, it is mainly the significant differences in the T_{16}, to T_{19} indexes that have shown that the subjects are executing the last two steps of the approach in completely different ways.

The duration of the NLS (T_6) does not considerably differ from the last support duration - LS (T_7), as the average values are correspondingly 0.128 and 0.131sec. The calculated value of the Student's t-test is 1.01 while its critical value is 2.00 within the sample. The review of all the research data shows that for some athletes the support duration of the NLS is greater than the LS, while for other athletes it is vice versa. On the other hand, the range (R), i.e. the difference between the minimum and maximum values of an index, is correspondingly 0.052 sec. and 0.049 sec, which shows definite duration differences in the take-off of the various athletes.

Correlation analysis of the sport-pedagogical measurement results

All the above has suggested looking for fixed inter-relations between the indexes studied and the distance jumped, as well as between the indexes themselves, with the hope of finding directions for improving the take-off preparation in the last two steps of the approach.

Analysis of the inter-correlation matrix values is shown in Table 3.

The critical value of the linear correlation coefficient (r) for the analysed cases (n=62) is 0.33, with a guaranteed probability of 99%. This means that all values in Table 3 that are greater than 0.33 show a considerable linear correlation dependency.

Running velocity is one of the mechanical determining factors in the distance jumped. The results (T_1) logically show a high correlation dependence on the velocity of the last two steps of the approach (T_4 and T_5), r = 0.75 and 0.84. On the other hand, the correlation between the duration of the NLS (T_6) and the distance jumped is considerable (r = -0.68), while the duration LS (T_7) does not significantly correlate with the distance jumped (r =-0.29). This suggests that the long jumper should not only pass quickly through the LS, but that he/she should perform certain moves in order to favourably position parts of the body to execute an effective take-off.

The fact that the distance jumped does not correlate with the angle indexes of the NLS (T_8, T_9, T_{10}) measured as well as to the amortisation duration of the NLS (T_{11}) are of interest to us. On the other side, the distance jumped shows a high negative correlation with the indexes T_{12} and T_{13} – the angle of the support leg knee joint at the moment of contact in the LS and that of maximum bend. This means that setting the support leg (the swing leg) in a more bent position leads to better execution of the jump. To a certain degree this contradicts the generally accepted view in the methodological literature that there should not be excessive bending of the support leg knee in the LS.

For this reason we made a detailed review of that moment for all the jumps in our study. The results showed that athletes setting their free leg in a more bent position at the LS bring the point of contact closer to the projection of the general centre of mass (the pelvis), while the position of the leg itself is either over the front part of the foot or

Table 3

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
T_1	1.00											
T_2	0.35	1.00										
T_3	-0.02	0.00	1.00									
T_4	0.75	0.33	-0.26	1.00								
T_5	0.84	0.22	-0.13	0.79	1.00							
T_6	-0.68	-0.41	0.26	-0.43	-0.72	1.00						
T_7	-0.29	-0.22	0.11	-0.38	-0.34	0.32	1.00					
T_8	-0.12	0.01	-0.09	-0.17	-0.24	0.04	0.00	1.00				
T_9	-0.14	0.15	0.11	-0.41	-0.32	-0.13	0.12	0.70	1.00			
T_{10}	0.03	-0.18	-0.26	0.33	0.12	0.21	-0.14	0.30	-0.48	1.00		
T_{11}	-0.20	-0.25	-0.19	-0.07	-0.17	0.20	0.09	0.56	0.30	0.33	1.00	
T_{12}	-0.46	-0.12	0.02	-0.34	-0.52	0.41	0.09	0.41	0.31	0.09	0.29	1.00
T_{13}	-0.62	0.00	0.28	-0.60	-0.73	0.55	-0.01	0.43	0.49	-0.13	0.16	0.60
T_{14}	0.44	-0.10	-0.34	0.50	0.54	-0.45	0.09	-0.23	-0.39	0.24	0.01	-0.02
T_{15}	-0.26	-0.17	-0.14	-0.21	-0.16	0.22	0.24	-0.25	-0.16	-0.09	-0.07	0.04
T_{16}	-0.36	-0.06	-0.06	-0.03	-0.28	0.60	-0.05	-0.16	-0.30	0.20	0.06	0.18
T_{17}	-0.50	-0.01	0.24	-0.29	-0.35	0.58	-0.07	-0.15	-0.10	-0.06	-0.17	0.15
T_{18}	0.05	-0.01	0.03	0.06	0.04	0.14	0.16	-0.33	-0.25	-0.08	-0.25	-0.27
T_{19}	-0.36	0.04	0.31	-0.41	-0.35	0.47	0.12	-0.38	-0.09	-0.35	-0.43	0.02

directly above the foot. Athletes who position the free leg in a more straight position, or whose point of contact is far in front of the projection of the overall centre of mass with contact on the heel, or whose last step is executed – as all others do – directly from the approach (without any take-off preparation), tend to have less successful (shorter) jumps. Of course, we have established that dependency within a range of 33º within the frames of 158º and 125º of the knee joint angle when setting LS. However, the correlation dependency established does not mean that an endless decrease of the angle placement will necessarily lead to a rational execution of the take-off preparation.

The angle between the hips (T_{16}) and the angle between the lower leg and the horizontal (T_{17}) at the moment of contact in the NLS

	T_{13}	T_{14}	T_{15}	T_{16}	T_{17}	T_{18}	T_{19}
	1.00						
	-0.81	1.00					
	-0.20	0.28	1.00				
	0.15	-0.05	0.27	1.00			
	0.43	-0.42	0.17	0.56	1.00		
	-0.38	0.28	0.49	0.29	0.06	1.00	
	0.23	-0.28	0.39	0.40	0.61	0.45	1.00

appear to be indexes of the activity of the approach run, as the support that is closest to the ordinary running step. These indexes show a high negative correlation to the distance jumped (r = -0.36 and r = -0.50). This means that the smaller the angle between the hips and the less raised the position of the lower leg upward and backward at the moment of contact during the run, the more active the swinging motion and the quicker the non-support leg is positioned forward, which in the end favourably effects the distance jumped.

The indexes we measured enter into compound correlation inter-relationships between themselves. We decided to select those that have a direct relation to the issue under investigation and could bring directions towards perfection of the long jump technique.

It is known that a jump during which the take-off duration is shorter is more effective and that the increase in the take-off effectiveness is related to a decrease in the duration of the amortisation phase. It has been proved both in practice and numerous studies that lowering the overall centre of gravity in the take-off preparation is largely done in the last step of the approach. Consequently, efforts to perfect long jump technique should be directed towards creating conditions where the amortisation phase of the LS is minimal. Our practical activity shows that directing athletes not to lower their centre of mass (pelvis) in the last step do not give a positive effect in most cases.

From our point of view, the analysis of the correlation inter-relationships in Table 3 shows a very important dependence. The angle between the thighs at the moment of contact in the LS (T_{18}) has a high correlation with the duration of the amortisation phase of the LS (T_{15}), r being = 0.49. Also considerable is the correlation dependence between the angle lower leg and horizontal at contact of the LS (T_{19}) and the amortisation duration of the same support (T_{15}), r = 0.39. This means that the greater the angle between the thighs at the moment of contact in the LS and the more the non-support leg (the take-off) is moved backwards-upwards, the longer the duration of bending (amortisation) of the knee joint of the support leg of the LS.

A similar dependence does not exist in the NLS. The correlation dependences of T_{11} with T_{16} and T_{17} are respectively r = 0.06 and-0.17.

In order to check the reason for such a difference in the two support phases, we analysed all the jumps studied. From this we established a very interesting regularity:

1. The amortisation duration of the NLS is on average 0.049 sec. For 11 out of the 62 jumps (17.74%), the bending of the knee joint lasts till the moment in which the foot of the non-support leg passes in front of the support leg. For the rest of the cases (82.26%), the amortisation phase does not depend on the foot position of the non-support leg (Figure 7) while at the moment of the greatest bend of the support leg knee (the left in this case), the foot of the non-support leg (the right) is located behind the support leg. The moment of the greatest bend of the support leg knee coincides or is very close to the moment of the vertical, in which the projection of the general centre of gravity (the pelvis) coincides with the support point. This is a characteristic of ordinary sprinting.

2. This dependency is completely different in the LS. The amortisation phase duration is on average 0.061sec. For 55 out of the 62 jumps (88.71%) the amortisation phase lasts

Figure 7

Figure 8

Figure 9

until the moment in which the non-support leg's foot (the left in this case) passes in front of the support leg (Figure 8).

Only in 7 of the jumps studied is the amortisation phase completed prior to the non-support leg foot (the left leg in that case) passing in front of the support (right) leg (Figure 9).

Reviewing these jumps very carefully, we established that they were executed by only two of the studied athletes where no take off preparation was observed. For these athletes the last step of the approach does not differ in any way from their ordinary running steps.

Analysis of the jumpers' interaction character with the support

In order to establish regularities of the dynamics execution of the take-off preparation, we analysed the character of interaction of the jumpers with the last two support periods of the approach. The analysis of the tensogram data we processed shows the following:

1. No essential differences are observed between the various athletes in the execution of NLS. The horizontal and vertical curve component type of the support reaction is presented in Figure 10.

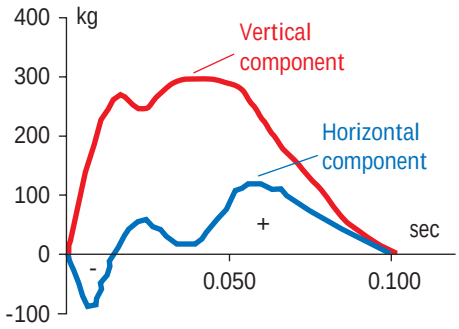

Figure 10: Next to last support (NLS) of the approach

Fixed differences have been established in the correlation between the positive and negative part of the support reaction horizontal component. For some athletes the duration of the negative part is considerably longer than the one shown in Figure 10, which points to weak acceleration. For the greater part of the jumps, the vertical component of the support reaction increases quickly during the first 0.020sec then decreases to a certain degree before increasing again. For fewer athletes, the increase of the support reaction of the vertical component is gradual and the curve has just one peak (Figure 11). Such a curve is characteristic of ordinary sprinting, and indicates that no take-off preparation took place.

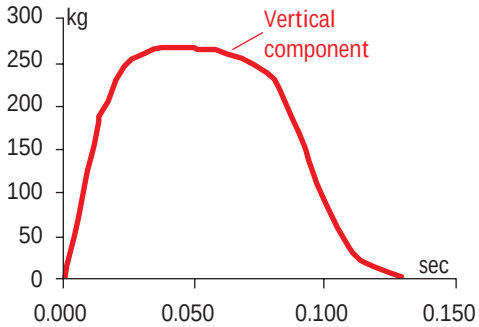

Figure 11: Next to last support (NLS) of the approach

2. Great differences in the support reaction have been established for the LS. Particularly substantial are the differences in the type of the curve of the support reaction horizontal component. Because of the great differences in the execution of this support, it proved impossible to make a statistical processing of the data and present the average values. On one side, we have established

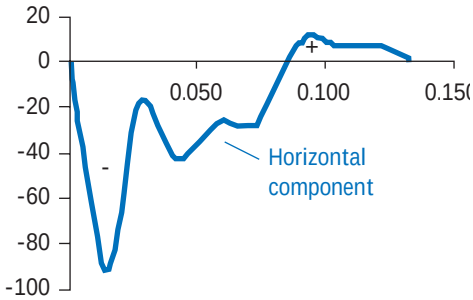

Figure 12: Last support (LS) of the approach

that for some of the athletes studied the support reaction has negative and positive parts, both clearly exposed. The correlation between the duration of both the positive and negative parts varies and for some of the jumps the negative one is predominating while the positive one is predominating for the others (Figure 12).

For the second variant of executing the same support period, the support reaction's horizontal component is completely positive (Figure 13).

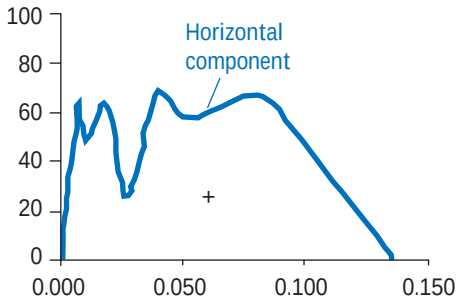

Figure 13: Last support (LS) of the approach

This means that during the overall duration the take-off force is directed forwards without an opposite stopping movement. The support reaction increases very quickly during the first 0.010-0.020sec, which shows a striking position of the leg at the point of support. For the third variant of LS execution, considerable fluctuations are observed in both directions – positive and negative part (Figure14).

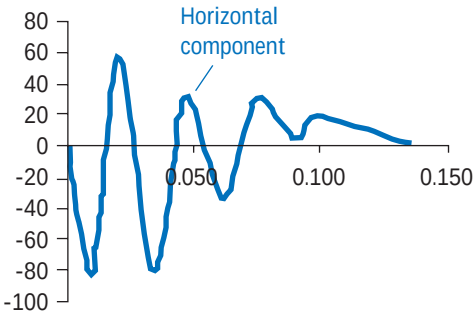

Figure 14: Last support (LS) of the approach

After carefully analysing the movements of the jumpers, we have established that those where such a curve of the horizontal component of the support reaction is registered are executing the LS with their swing leg very passive and without an apparent active push forward towards the take-off. The latter provides for, to a certain extent, free platform vibrations. Therefore, the curve of the interaction of the jumpers with the support does not have a characteristic form.

The tensogram analysis shows that the differences described are observed both between the various athletes and between the different jumps of each athlete.

All this goes to show that in relation to the interaction of the jumpers with the support, the execution of the LS) is characterised by essential differences and great instability. This, once again, confirms our point that there is great scope for perfecting that part of the long jump approach.

General conclusions from the sport-pedagogical measurements

The research results analysis of the sport-pedagogical measurements have provided us reason to make the following general conclusions:

1. The jumpers studied execute the last two steps of the approach in various ways related to the differences in positioning the various parts of the body and the differences in the character of interaction with the support, particularly in the LS. This defines the effectiveness of the take-off preparation and the successful execution of the jump as a whole.

2. There exists great scope for perfecting the execution of the take-off preparation in the last two steps of the approach. Efforts should be directed to looking for methodological instructions and the application of means to provide for favourable positioning of the

parts of the body at the moments of contact in the last two support periods of the approach and an effective push from these support periods. This will result in:

- decreasing the amortisation phase of the LS,
- a very quick motion of the take-off leg towards the take-off point during the LS.

Thus, the following should be observed when working to perfect long jump technique:

1. During the approach run, the non-support leg should outpace the support leg at the moment of contact with the ground in each running step, particularly in the last steps prior to the take-off. This will be affected much easier by striving for a more jerky (more explosive) push-off and quicker movement of the non-support leg forward following the push-off without providing a possibility for the lower leg to move backward-upward.

2. In the NLS, where the support is on the eventual take-off leg, it is necessary to make an explosive push-off with the aim of maximising the forward motion of the take-off leg. Thus, at the moment when the swing leg is in contact for the LS, the angle between the thighs will be as small as possible. In other words, the athlete should strive to have the take-off leg outpace the swing leg and the position of the take-off leg should be near horizontal and (not positioned backwards-upwards).

3. Ground contact for the last LS should be made by the front part of the foot of the swing leg. This will provide for a contact point nearer to the centre of mass projection, decrease the loss of velocity, decrease the amortisation duration and lead to an active start of the take-off. This last step will be executed very quickly and without possibility of its artificial prolongation.

In this way, we have implied a new definition for long jump terminology, i.e. the take-off really starts two steps prior to the take-off board.

Sport-pedagogical experiment

In order to put our conclusions into practice, we organised a sport-pedagogical experiment aimed at perfecting the technique of the last two steps of the approach. Eight athletes – 5 men and 3 women – participated in the experiment. Two of the men were pole vaulters, whose programme very often includes long jumping.

A control mark was placed at a two-step distance from the take-off board. We asked the participants to not think at all about placing the foot of the take-off leg on the take-off board. Corrections to the take-off were made only if there were serious faults. The instructions to the participants were directed to the following tasks:

1. A jerky (explosive) push forward by the take-off leg at the NLS and the quick motion of the same leg forward during the duration of the coming flight;

2. Obligatory contact of the swing leg in the LS with the front part of the foot;

3. Maintaining the forward bending of the torso in the last two steps of the approach.

During the execution of jumps from varying length approaches, we found that the required change to the rhythm of the execution of the two last steps of the approach is very difficult for the athletes to accept. This was essentially a completely new motor habit for them. Very often, they could not feel the exact moment when they had to execute the explosive push forward by the take-off leg two steps prior to the take-off. Sometimes the push forward resulted in too long of a flight phase and prolonged the next to last step of the approach. It was difficult to combine the strong push forward by the take-off leg and the following active unbending of the swing leg knee towards the execution of the LS.

This resulted in our thought to prepare special exercises or modify the way of executing some existing exercises in order to create an

Figure 15

Figure 16

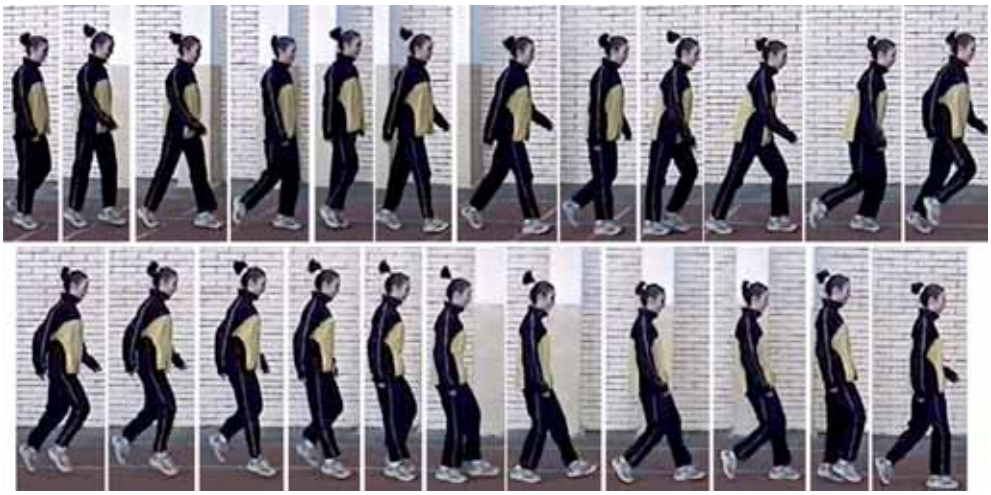

Figure 17

Figure 18

appropriate motor habit. We developed the following exercises and have applied them to our training sessions every day:

Exercise 1: *Setting the take-off leg for take-off from two running steps without moving the hands* (see Figure 15)

Exercise 2: *Setting the take-off leg for take-off from two running steps moving the hands* (see Figure 16)

Exercise 3: *Setting the take-off leg for take-off from four steps – two steps walking and two steps running* (see Figure 17)

Exercise 4: *Setting the take-off leg for take off from an unlimited number of walking steps or a slow run* (A sound signal is used in this exercise. Following the signal, the athlete should put the take-off leg for a take-off as per the conditions mentioned above, i.e. following the execution of two steps and by explosive push forward of the take-off leg at the first of the two steps.)

Exercise 5: *Setting the take-off leg for take-off following the execution of a short run or running with high knees* (see Figure 18)

Exercise 6: *Setting the take-off leg for take-off from two running steps with weights on the shoulders* (see Figure 19)

Weights were put on the athlete's shoulders to increase the loading of the take-off leg at the explosive push forward.

For the execution of exercises 1-6 the athletes are directed not in the way of setting the take-off leg for a take-off but to:

- make an explosive push forward with the take-off leg prior the take-off;
- make a quick motion to the point of contact of the swing leg;
- ensure the swing leg contact is with the front part of the foot.

Exercise 7: *Take off from two running steps* (see Figure 20)

Figure 19

Figure 20

Figure 21

Figure 22

Figure 23

Exercise 8: *Take off from two running steps with weights on the shoulders* (see Figure 21)

Exercise 9: *Take off from four steps with weights on the shoulders – two steps walking and two steps running* (see Figure 22)

Exercise 10: *Complete long jump setting the take-off leg lower two steps prior the take-off* (see Figure 23)

In this exercise, the athletes approach along a platform 12cm high and the last two

steps are executed at the landing sand level. In this way the NLS is executed at a lower point of the support, which hinders the push forward, so the athletes try to apply greater efforts for successfully finish the jump.

Exercise 11: *Complete jumps from different length approaches*

Analysis of the sport-pedagogical experiment results

The results of the experiment were impressive. The repeated execution of the exercises described herein resulted in the creation of a habit of an explosive push forward two steps before the point of the take-off itself; to the quicker motion of the take-off leg forward to the take-off point. This resulted in a much quicker setting of the take-off leg for the take-off and to the execution of a very powerful take-off during the exercises requiring a take-off (Exercises 7, 8 and 9). This habit was very quickly transferred to the execution of the jumps from a short approach (4, 6 and 8 running steps). The take-off was executed with great ease without big efforts.

The athletes reported feeling as if something has been throwing them from the take-off point and feeling much freedom in their motions during the flying phase. This in turn led to very effective landings with the legs stretching far forward.

After carefully analysing the video taped jumps by athletes following our directions, we established that when the jump has been successfully executed, the thigh of the take-off leg is very closely positioned to the swing leg at the moment of contact for the LS and in vary rare cases is even outpacing it. The setting of the take-off leg for take-off is made very quickly and the take-off is very explosive. That has given us the possibility to work on other, very essential details of the long jump technique.

Figure 24 is a cinegram of one of the tested female athlete's last step of the approach and the take-off prior to the start

Figure 24

Figure 25

of the experiment and Figure 25 shows the same part of the jump after the experiment. It is clearly seen in the second case (Figure 25) that at the moment of contact for the LS, the angle between the hips is considerably smaller while the contact is apparently made by the front part of the foot.

However, the execution of complete jumps from a longer approach (12–18 steps) or from a full approach, proved to be much more difficult, as we expected it would be. It shows that one year is not enough time to create a stable habit for executing the last two steps of the approach at high velocity but there were very successful performances of that part of the take-off preparation.

Conclusions and recommendations for practice

The analysis of our research results provides us with reason to make the following conclusions:

1. There exists great scope for perfecting the long jump technique. This is related to the take-off preparation in the last two steps of the approach. We propose the following:

a) explosive push by the take-off leg in the NLS;

b) quick motion of the take-off leg forward during the flight phase following the explosive push accompanied by very rapid fall of the swing leg downwards in the LS of the approach;

c) obligatory contact by the front part of the foot of the swing leg in the LS of the approach.

2. The exercises described by us for perfecting the execution of the last two steps of the approach have shown high effectiveness for execution of jumps from a short approach. Considerable practice is required for executing a rational preparation of the take-off at high velocity. Such practice in all cases brings a qualitatively new, higher level of the technical execution and better realisation of the potential of the jumpers. All partcipants improved their personal long jump results without showing higher results in control exercises reflecting the level of the speed and strength qualities. For example one of the men has improved his result from 7.47m to 7.81m and one of the women has gone from 5.45m to 5.85m.

3. The execution of the long jump with an explosive push by the take-off leg two steps prior to the take-off may serve as a criteria when selecting young long jumpers as that feeling towards the take-off is to a certain degree an inborn quality.

Recommendations

1. Our research has proved that the execution of the take-off preparation with an explosive push of the take-off leg two steps prior the take-off is effective but while proceeding with work to perfect the technique, the following requirements and possible execution faults should be kept in mind:

- the explosive push should be performed low and forward without jumping, keeping the torso leaning forward will help;
- delaying the move of the take-off leg forward following the explosive push results in an excessive prolongation of the next to last step of the approach;
- an incomplete push by the take-off leg two steps prior to the take-off while striving to quickly set the swing leg on the front section of the foot for the LS results in a considerable lowering of the centre of mass (the pelvic section);
- contact on the heel in the LS results in setting the swing leg far in front of the centre of mass projection, a prolonged amortisation phase (which considerably delays the setting of the take-off leg at the take-off point) and prolongs the last step of the approach.

2. The teaching and perfecting of long jump technique by the directions given

above should start at a young age as it is known to be easier to establish a completely new motor habit than to substitute one motor habit for another.

3. The sport-pedagogical experiment was implemented using students from the National Sports Academy in Sofia. They have tested various means on themselves and rationalised the new ideas for long jump technique. As future coaches, we hope they will apply their knowledge and make their own contributions to the development of this beautiful discipline.

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