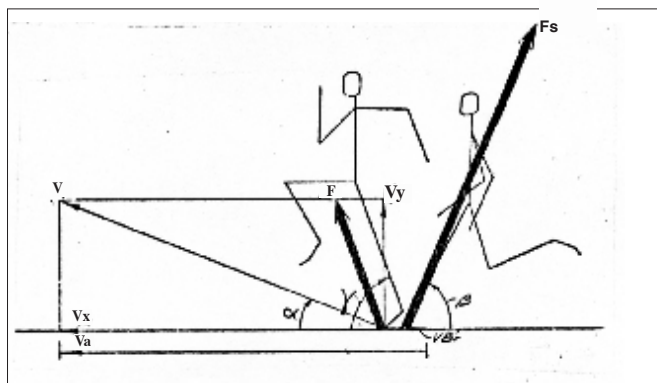


5. SPEED, LONG JUMP



- V_a = Run-up velocity
- V = Take-off velocity
- $V_y(V_x)$ = Vertical (Horizontal) component of take-off velocity
- F_s = Force through the "rod" at touch down (see p.52)
- F = Take off force
- V_{Br} = Braking
- α = Take off angle
- γ = Jump leg's angle against the ground in take off
- β = Jump leg's angle against the ground at touch down.
- $L1$ = Last stride of approach
- $L2$ = Second last stride of approach
- $L3$ = Third last stride of approach

Fig 140 Vector parallelogram with the mechanical magnitudes, which are used to analyze a long jump.

Another typical example where speed is of most importance for performance is long jump. We shall now first analyse different variants of jump techniques. Usually long jump has been considered easy with only two requirements:

- Fastest possible approach speed
- Strong take-off with concentration on height of the jump.

Instead, it is faced with a complex technique with several variants. Of this, the following sections deal specifically two types of jumpers, who after their characteristic style we call:

- High Long Jumper
- Sprinter Long Jumper

High Long Jumper seek primarily large vertical force, with a prominently marked "take-off." Sprinter Long Jumper, however trying more to maintain speed through a flatter "uthopp". This, done right, experienced by the jumper, as running out from the board.

We shall try to describe various ways to perform a long jump with optimal technology. This is possible using stick figures made from movies and data from various studies 1) of jumps which have been performed with lengths from 6.50m to 8.90m.

Long jump Mechanics

A common way to explain längdhoppets mechanics is that use a so-called. vector parallelogram (Fig. 140), which shows the size and direction of take-off velocity, V , and its horizontal (V_x) respectively. vertical (V_y) component. The diagram is an interesting beginning to an analysis of the long jump technique. Take-off velocity V and its direction (Take-off angle) is what primarily determines the long jump. The most important quantities, which are used in a long jump analysis is also shown by the table in Fig 151 page 73.

Jesse Owen, 1935 8.13m

Jesse Owen, the owner of the world record 8.13m between 1935 and 1960 was, judging by the pictures and videos, a typical sprinter long jumper (Author). He succeeded extremely well make use of a high approach speed.

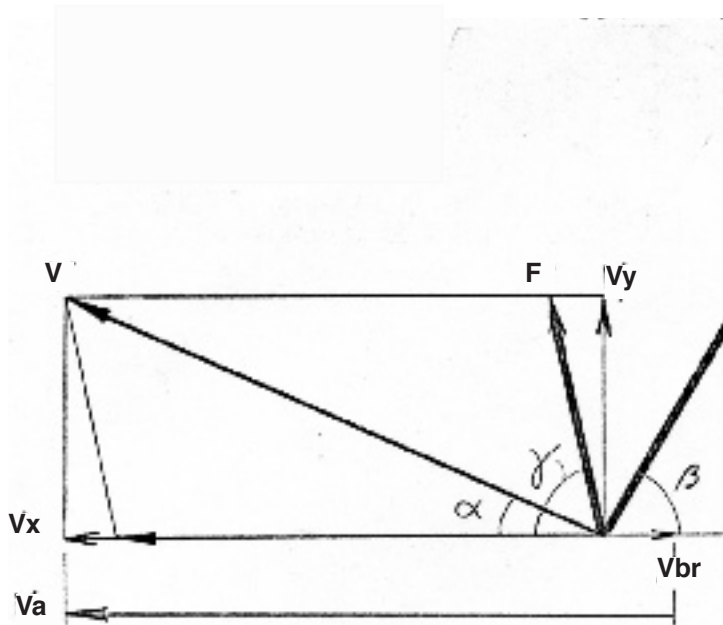


Legendary Jesse Owen, holder of world record 8.13m 1935 to 1960.

5.1 “High Long jump”

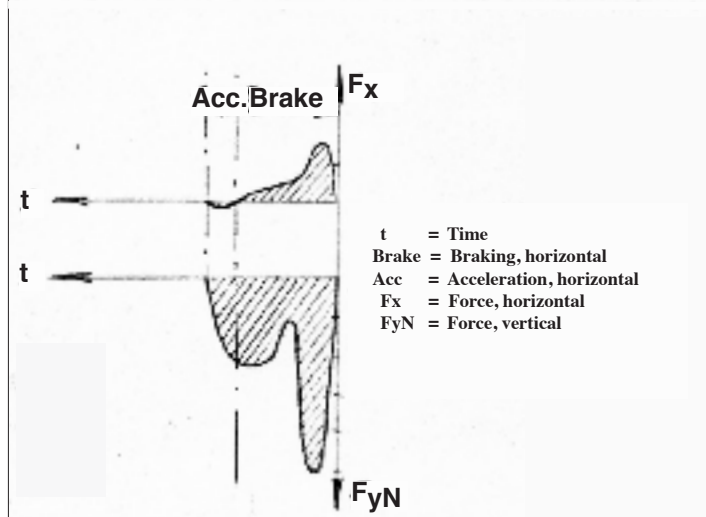
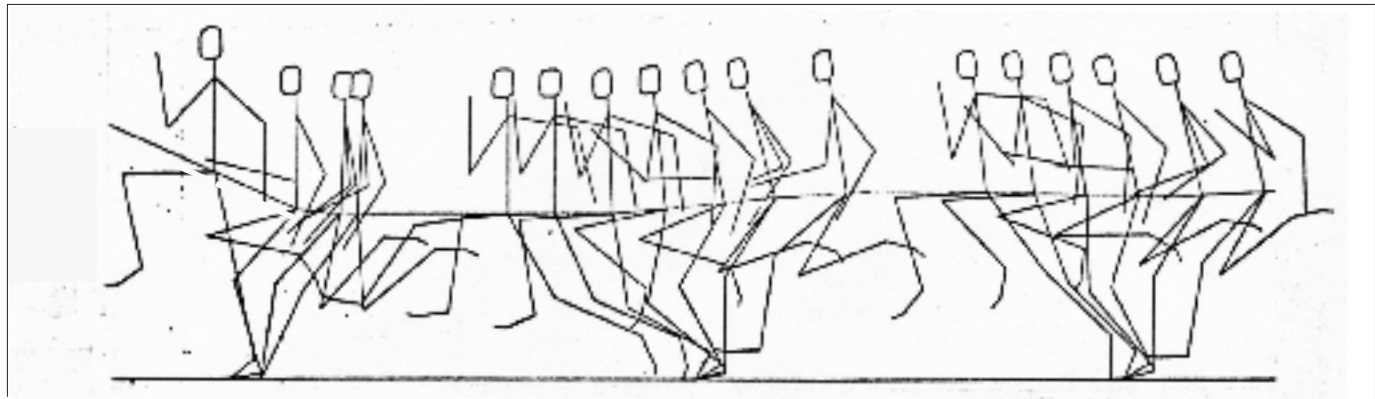
Bob Beamon 1968 8.90m

At the Mexico Olympics in 1968 Bob Beamon USA, took the world with amazement at his amazing world record jump 8.90m. Here we present data from this jump. For several decades into the modern time, many have been inspired by Beamon’s powerful jumping technique.



Beamon’s jump was compared with the elite and it was found:

- Faster approach: 10.7m / s
- Incredibly powerful take off: $V_y = 4.2\text{m / s}$. With braking $V_{br} = 1.2\text{m/s}$ were obtained: $V_x = 9.5\text{m / s}$. The take off angle became $\alpha = 24^\circ$ ($T_g = 4.2 / 9.5$) Thus, steeper than normal for elite jumpers.
- Low center of gravity in touchdown on board, with jump leg’s angle against the ground at touchdown: $\beta = 60^\circ$
- Early toe-off. Jump leg’s angle against the ground in take off: $\gamma = 78^\circ$.



- Beamon's penultimate step measured 2.40m and the last step all over 2.57m. The explanation for this is Beamon's technology with a relatively high knee lift in the last step's push off, followed by a marked out oscillation of the lower leg. Hereby the jump foot had a very long acceleration when it was whipped in the board. The pressure against it must have been very high, but when the jumping leg's motion direction was backwards compared the jump's forward movement the braking was reduced significantly. Elite jumpers otherwise normal have a shorter last step.
- Beamon's pendulum work with the free leg supports the jumping leg's work with a peculiar rhythm and swing.

Fig 141 Bob Beamon's 8.90m jump, as the pressure diagrams probably looks like (The author)

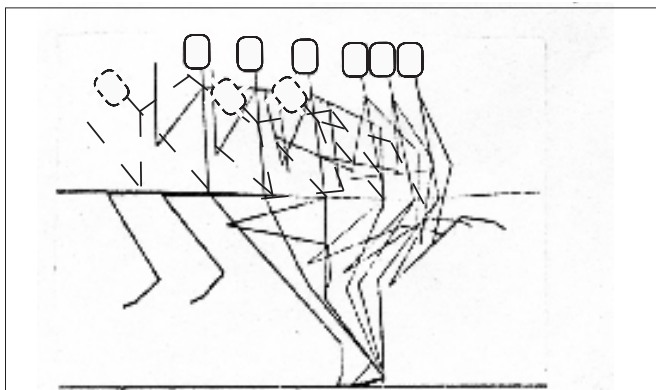


Fig 142 “Drive phase” 4-6 step and “Transition phase” 4-6 steps (according to M. Powel -08). Trunk inclination of the first approach step dashed in the figure

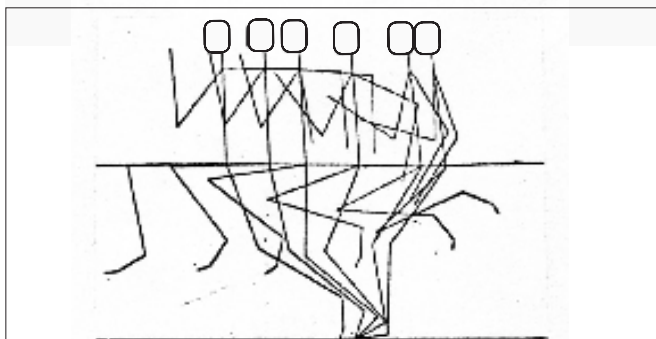


Fig 143 “Attack phase” 4 steps (M.Powel-08).

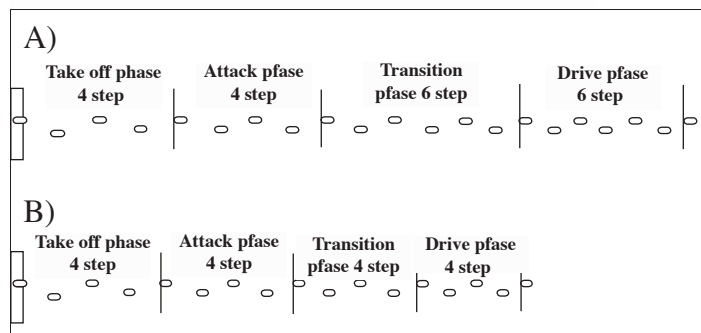


Fig 144 A) Approach: 20-steps with. 10-“cycle rhythm” of elite jumpers.
B) Approach: 16-steps with“. 8 -“cycle rhythm” for youth.
(Mike Powel -08¹⁾)

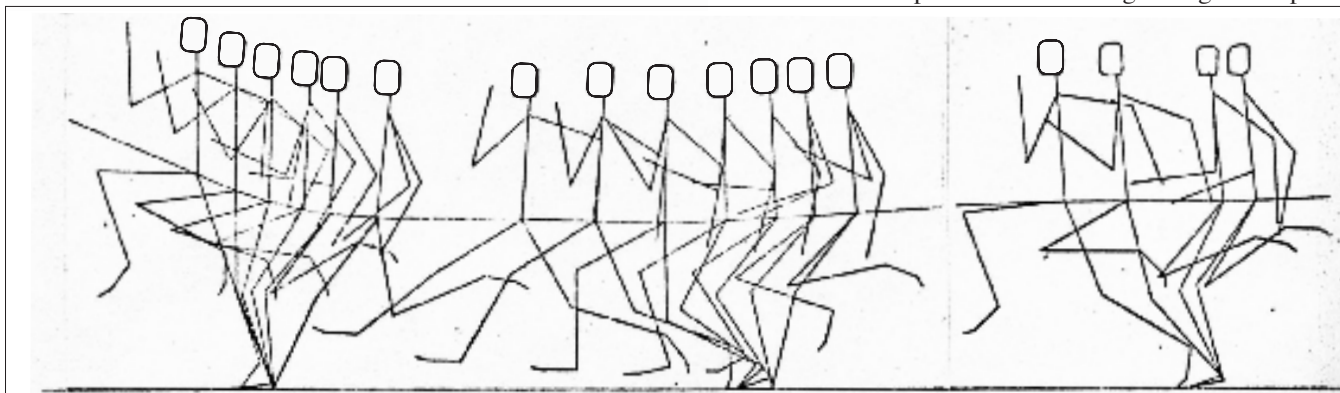


Fig 145 Take off: The last step is usually shorter Penultimate step : Active squats (“pull”). It’s a little longer = CG Lowering

High long jump, approach.

The approach can be likened to a “loose” sprint start, with an slightly slower acceleration than in a 100m race.

A good planning of the approach described Mike Powel -08¹⁾. See Figure 144. For example, at 16 or 20-step approach you count every two step (eg only the jumping leg as in Fig 144). The approach then consists of 8 respectively. 10 “cycles”. Then you divide the approach in four parts: “The drive phase”, “transitional phase”, “attack phase” and “take off phase.”

Drive phase. You push off relatively powerful and about 45 ° trunk inclination in the starting step with head bowed. Now it’s full extensions particularly in the jumping leg with strong supportive arm- and leg-swings.

Transition phase’s tactic is to slowly rise head and trunk during relaxed sprinter running. This is the long jumper’s characteristic easy “sitting” with high knee lift.

During the **Attack phase** the velocity is driven up to near max usually by increasing leg frequency. Hereby focus on pretension (“elastic steel rail”, “stiffness”).²⁾

Take off phase implies a special approach to rhythm and technique (see fig.147) where the first step is a normal sprinter step with concentration on the following important third step ahead of the board. The push off is done with incomplete knee extension, which is making that the jumper “float” forward more horizontally. The second step and last steps before the board is also done with incomplete extensions. The later is pulled out something. It is like waiting for the landing on the runway (Tom Tellez, “Just wait a little:). The last step is usually more shortened.

High long jump, last step and take off.

Ground phase of the last approach step, with special technique. We speak of the “penultimate step”, which suggests the technique of an “active” squats. You “pull” the track. Expressions such as “tearing”, “grab” describes the proper touch-down, which can be done in two ways:

A. A clear heel - toe rolling (Fig. 145)

B. Touch down on the front ball of the foot with easy heel contact (Fig. 141)

B. Gives less braking and admits as A further lowering the center of gravity. This is to meet the board in a deep position with the jumping leg at an acute angle to the runway, which is characteristic of the best high long jumpers such as Beomon 1968 and Salodino, 2007 (see p75). Carl Lewis used A. He compensated the braking with greater speed.

1) Processed. from one Interviews with Mike Powel (<http://trackandfield.about.com/od/longjump/p/powelljumpstips.htm>)

2) Attack phase with the increased step frequency gives a more “ fluid sprint running”, which seems to be great for sprinter long jump (See page 72, Carl Lewis technologies.

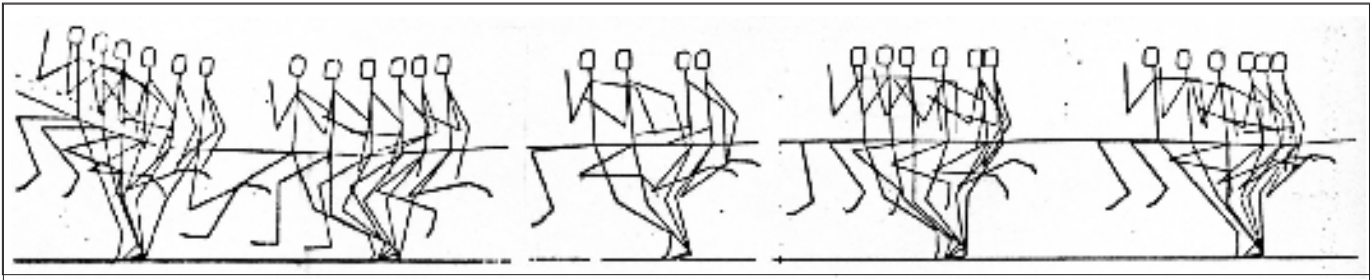


Fig 146 High long jump. Variant with “lifting” in the last step and a higher position at the board (= “bounce” from the board)

High long jump, special variant

High long jump can also be performed with a “lift” in the last step from a deep heel-toe roll in the penultimate step. The take off is then done as a “bounce” in an elevated position with shorter time on the board. The technology can fit explosive jumpers with good jumping capabilities. It reminds of the fast variant of Flop High Jump. See figure 146 and 147.

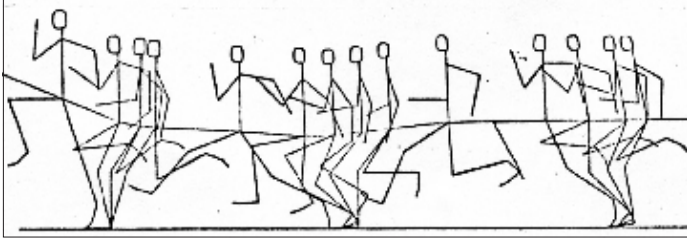


Fig 147 High Long Jump, variant similar above figure 147

High long jump, take off. Analysis.

Upphoppstekniken beskrivs i det följande:

1. The foot is moved mostly in a low motion against the board. (T.Tellez: “Just put it down”). The foot finally meets the board relaxed with a downward - rearward movement, which reduces the braking somewhat. The whole sole of the foot is inserted flat, but the heel meets the ground a “microsecond” before. (So that the gluteus damps the pressure author. reflection)
2. For a brief moment (15-20ms) increases the pressure vertical force (see Figure 141). Then the jumper immediately sag in to knee and ankle. It is during this short time mostly of the vertical velocity increase.
3. The jumper now pivots forwards upwards. The motion first becomes flat rising.
4. Finally the “lift” is performed by quadriceps, gastrocnemius/soleus and the gluteus which are extending completely in all the joints. Great influence comes from the “lead” leg because of its mass. It should perform a short pendulum movement until the thigh is parallel to the ground.

High long jump, discussion

High long jump technique is likely optimal only for the long jumpers of the highest elite (8m-jumpers). It is therefore inappropriate to young people trying to accomplish get height on the jumps by by violently “stomping” the board. Unfortunately, usually the following occur:

- You make technology training with short approach and then tries to jump a long way with the help of a powerful, “springy” stomping take off for height in the jump.
- With a full approach you could possible initially achieve outstanding good performance, but later usually a surprising stagnation occurs.
- Unfortunately, even serious injuries can occur because of too much strain on his leg jumping. (Possible high jump training leads probably to the use of special variant above (author))

In his youth also the 8m-jumper was told från coach:

- “Work long at the board, “ “Push through the hips better “,” strike the board “clawing”.
- Later after many years, coach tell you: “You not seem to increase your approach speed further. Now we must concentrate on a more powerful take off technique.

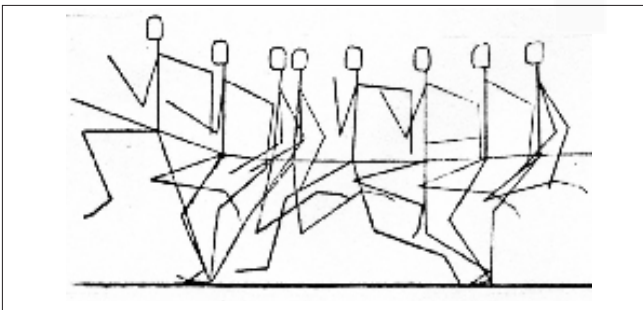


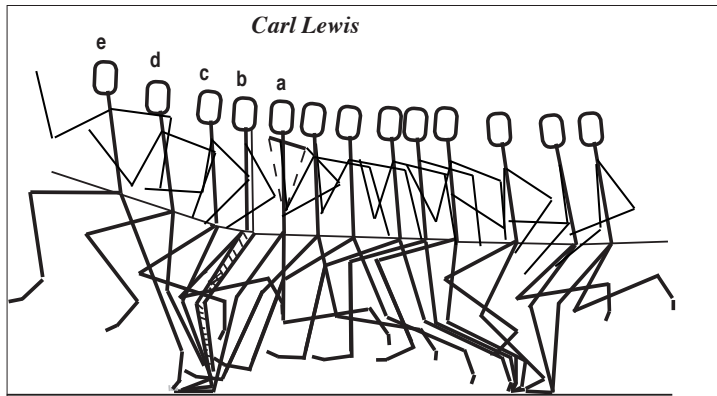
Fig 148 High long jump, touch down and take off

Elite = 8.0m	Bob Beamon 8.90m
Va = 10.5m/s	Va = 10.7m/s
Vx = 9.3m/s	Vx = 9.5m/s
Vy = 3.5m/s	Vy = 4.2m/s
$\alpha = 21^\circ$	$\alpha = 24^\circ$
$\gamma = 70-75^\circ$	$\gamma = 78^\circ$
$\beta = 60-65^\circ$	$\beta = 60^\circ$

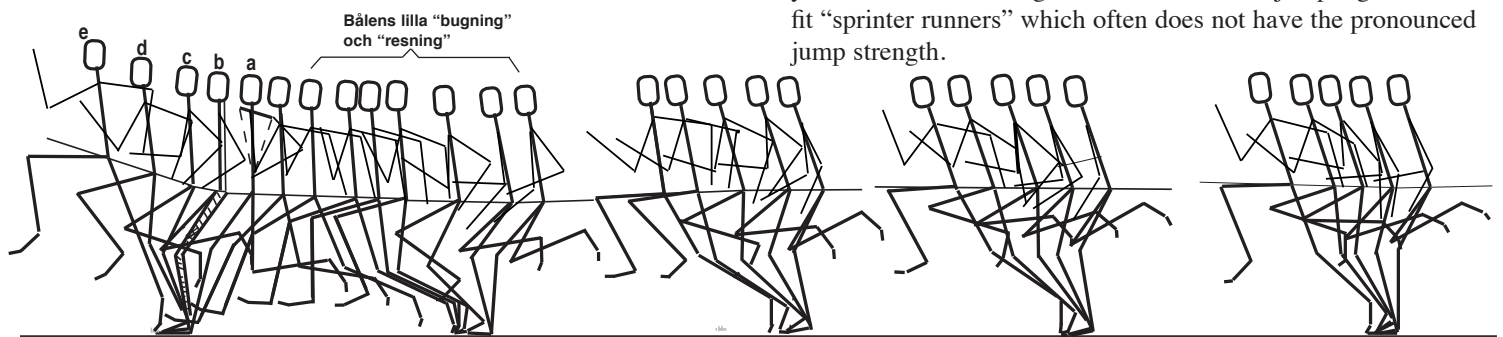
5.2 Sprinter long jump

Carl Lewis

It has always existed in the U.S. Long jumpers, who used their pronounced sprinter speed with technology, which completely differs from the high long jump. Such was Carl Lewis (Fig. 150). It is more talk about a jump in direction outwards than upwards. In take off phase the last approach steps (see Figure 144) is a rhythm changing, which gives a first hint of a “lifting” the last step approach. Then the foot is naturally “whipped” in the plank (as an active “gripping”), with a very short first heel contact. The jump leg is slightly bent with pretension muscularity. The extremely fast last step occurs along with the pendulum leg, as “cutting motion” and end with the feeling of a “volley foot kick” forward-upward. Already during the attack phase (see page 70), with increased cadence, accentuated pretension (elastic “stiffness”, “steel rail”) “amortisationen” was prepared (a-b). From position (b) rod force pivots the whole body quickly forward upwards (b-c) followed by the explosive push off (c-e). This while free leg swings up and is blocked at parallel upper leg. The long deep penultimate step with a “lift” in the last step slows you down, but resulting in a less load on the jump leg. This can fit “sprinter runners” which often does not have the pronounced jump strength.



Carl Lewis last approach step and take off. Notice the free leg movements. The figure shows a unique optimum coordination between the free leg movements and support phases. From touchdown on a plank, then the femur - the knee is vertically below the hip, the feeling being as a “volley kick” of the foot.



Step rhythm: “short” - “long” - “short”
“Feet Runs Underneath the body and then passing” (Auth. talk with Joe Douglas Stihl -83)

Penultimate step: “Just wait a little” (Author's conversation with Tom Tellez -89) in contact with the ground and landing followed by a deeper (“pull”) with

a clear heel roll. Lewis performs here also a small side step. Was recommended author. by Ralph Boston's coach Tom Ecker, Stihl 1962). with outward rotation of the foot, followed by a “sprint screwed pull” (see page 57). The latter implies a “lateral lift” - a “side-nudge” (Author) with feeling of some relief before touchdown on the plank. Here probably it's also obtained a horizontal-vertical speed boost. A contribution to this first vertical center of gravity increase is also a small “bending forward” and “rise” (See fig.) Jump The foot will now also be placed more in line with the center of gravity resulting in a more efficient take off. The foot touch-down occur with a movement forward-downward with unchanged step rhythm in an arcuate motion at lower altitude just below the knee. The lower leg is brought forward out to slightly

as in a sprint stride and “is naturally whipped” in the plank, with a backward gripping motion (with negative velocity). Touchdown is done with the whole ball of the foot, but with an initial brief heel contact. Legs and seat muscles are preloaded for eccentric work during the so called amortisation phase a-b. This pretension is accentuated, as mentioned earlier, already in attack phase. The “springy rod” force is rotating the jumper forward upwards b-c, followed by the explosive push off c-e. An interesting techniques detail is his right arm and shoulder is kept back in a low position at touchdown. It then occurs an elastic stretch of the hip side (which immediately is stretched, “as a rubber strap” (Author's talks with Valeri Bunin at an international training course in the long jump -94, “a secret behind the Russian long- and triple- jumpers”) Another detail is that Lewis performs an “inverted rotated pull”, probably with using adductors extends the pull with higher force in the push off (See also page 75)

Lewis = 8.91m	Powel = 8.95m
Va = 11.06m/s	Va = 11m/s
Vx = 9.72m/s	Vx = 9.09m/s
Vy = 3.22m/s	Vy = 3.70m/s
α = 18.3°	α = 22.1°
γ = 67.5°	γ = 73.9°
β = 77°	β = 71.8°
L1 = 1.88	L1 = 2.28
L2 = 2.70	L2 = 2.74
L3 = 2.23	L3 = 2.40

Fig. 149 Analysis of Carl Lewis sprinter long jump. Data Comparison, Mike Powel - a more typical high long jumper.

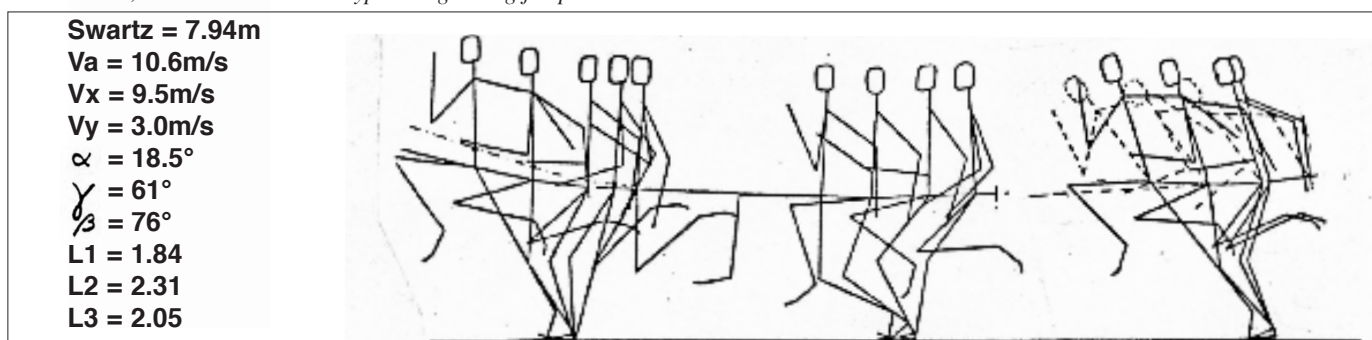


Fig. 150 German 1970's jumper Swartz in a sprint long jump.

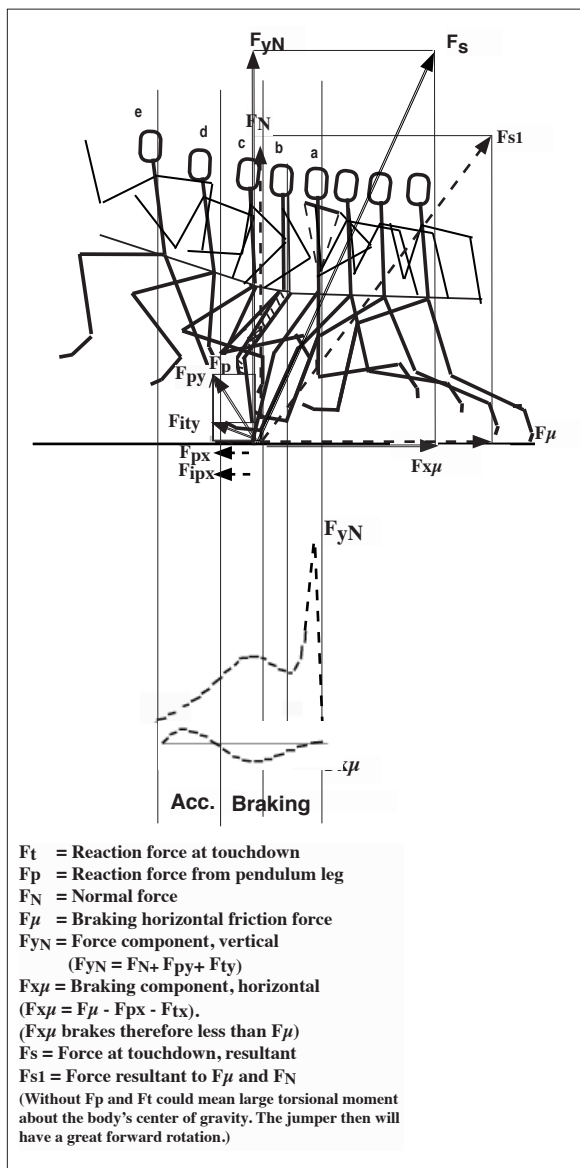


Fig 151 Biomechanical analysis of the sprinter long jump

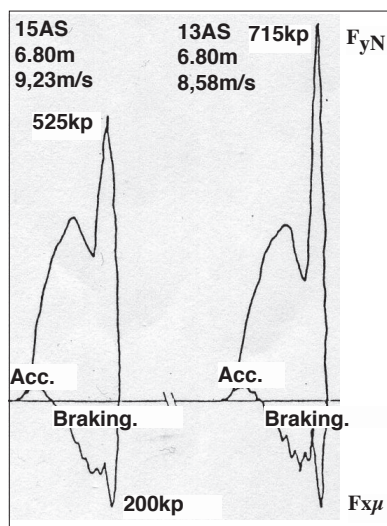


Fig 152 Heiki Drechslers vertical and horizontal reactive forces in the two jumps with the same jump length 6.80m at different number of approach steps (AS) approach speeds 8:58 respectively. 9.23 m / s¹

Sprinter longjump, mechanics, muscle work.

We have also previously in sprinter technology-section used the natural "foot strike" naming the touch down. Put down the foot with a quick sweeping arcuate motion against the board, with slightly bent jump leg, in harmony with the free leg swing movement forward-upward. As in sprinter running the leg's muscles are in pre tension to cope "amortisationen". We shall now describe in more detail what happens:

Take off

The pretensioned leg and buttocks muscles at touchdown means that foot and knee are fixed ("locked"). The pelvis is backward tilted, with isometrically working gluteus and rectus femoris. At touchdown the leg is forming with the upper body, through the pre-tensed muscles a pretty solid unit, which is like a rod. When its lower end (foot) are trapped in the ground, the top (upperbody), gets an increased speed. The rod will thus rotate around its support point in the ground. This is what is meant by the rod-principle. By the rod seems a force. Fig 151 shows the forces during take off using a schematic pressure diagram. Force F_s , consisting of a braking component $F_{x\mu}$ in the horizontal direction and the accelerating component of F_{yN} in the vertical direction, grows rapidly to a high value of up to 10 times the body weight of elite jumpers. The force operate with a high pressure at the board a very short time. Already after about 15ms, the pressure reached its maximum. (b) and then diminishes rapidly.

During touchdown a - c there is also the reaction force $F_p + F_t$ in the jump (running) direction from the ground. The jumper should increase this force, and with an active ("strike") F_t ("gripping") and with a "swung- full" bone pendulum F_p . The braking is then reduced. Another positive effect by F_p and F_t is that force F_s , will be directed more through the body's center of gravity (Fig. 151). The torque around the center of gravity is then zero, so the jumper will be in better balance in the air with little forward rotation. Then one can jump great also with simple techniques in the air as hangstyle. An important fact is that without the sum of F_p and F_{ip} a dangerous force F_{s1} would be produced and partly severely damage the jumper (Note: Serious bone fractures have occurred in long jump) and the jumper would get too strong forward rotation which would frustrate the proper technique in the landing.

In position c the pressure diagram shows that F_{yN} again has risen to about 1/3 of F_s value. From here then the push off is completed c - e, as a powerful sprinter step, but in a more upward direction. Just before d correspond to the point where the vertical line from the body's center of gravity is passing just above the foot. $F_{x\mu}$ then is changed to acceleration in the horizontal direction.

Heiki Drechler was a female representative for sprinter long jump. In Figure 152 displays vertical and horizontal reactive forces in the two training jumps with the same jump length at different approach speeds. Interestingly, at higher speed she needs significantly less vertical force, which incidentally seems extremely short-lived. At World Cup 1991 jumps Heiki 7.29m with only angle 18.3° and compared to the other competitors (see table on page 75), with a significantly lower vertical jump speed.

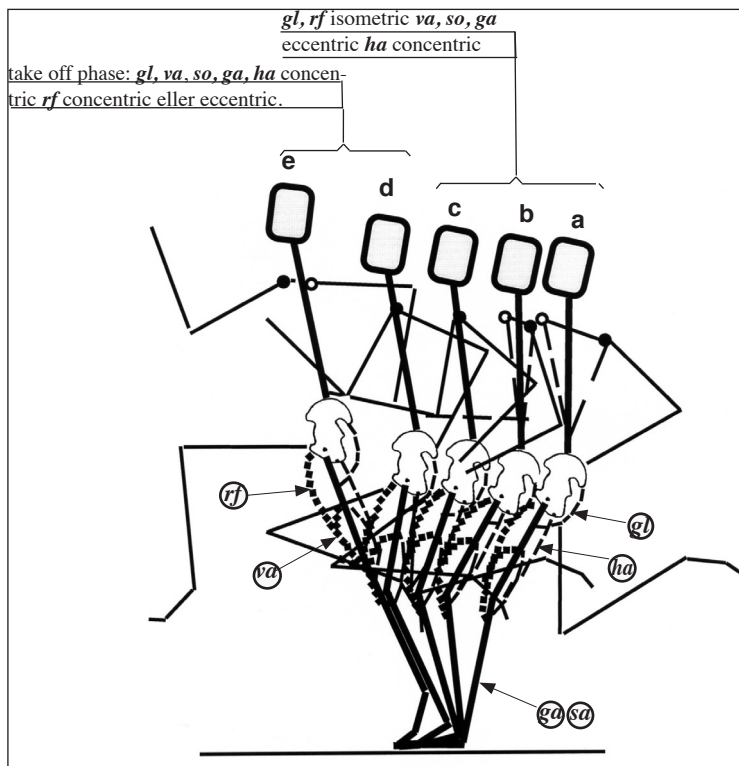


Fig 153 Muscle work at ground phase for a typical sprinter long jump ¹⁾

Muscle work

Study the schematic illustration in fig.153 with *rectus femoris*, *vastus lateralis*, *gluteus*, *gastrocnemius*, *soleus* och *hamstring*. Muscle work happens as follows:

(Nicholas P. Linthorne ¹⁾)

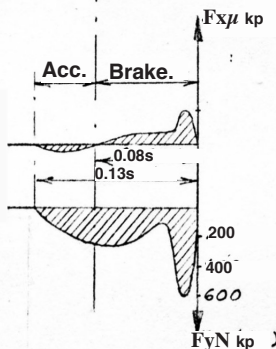
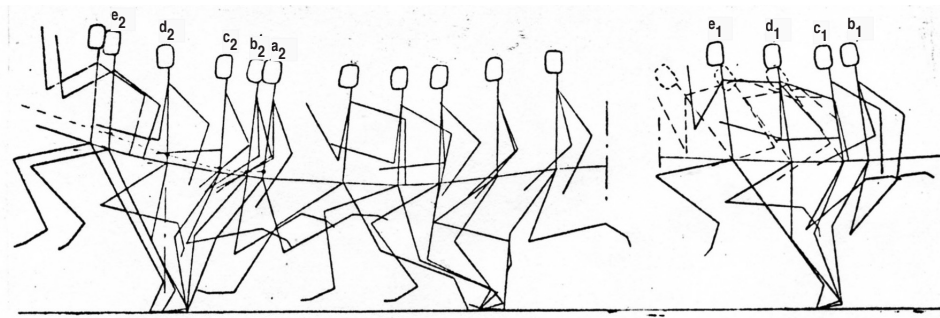
- a - c: *gl, rf* isometric. *va, so, ga* eccentric.
ha concentric.
- c - e: *gl, va, so, ga, ha* concentric.
rf concentric. or eccentric.

Or (according to author's hypothesis):

- a - b: *gl, rf* isometric. *ha* concentric
va, so, ga eccentric.
- b - c: *va, so, ga, rf* isometric.
ha concentric
- c - d: *va, rf* isometric.
ha, so, ga concentric
- d - e: *va, rf, so, ga* concentric.
+ *adductors* concentric

Sprinter Long jump, beginner and intermediate level jumpers (6.50-7.20)

These data with illustrations (author.) is based on an early 1970s study (Ballreich). It was scientifically carefully made and may be well worth to be presented even today. Reason for that this group of jumpers (20 males with jump lengths 6:50 - 7:20m with an average of 6.80m), can be included in the category of sprint long jumpers depends on the relatively flat take off angle 20° with a low braking of horizontal speed. A speed reduction of only 0.9 m / s.-



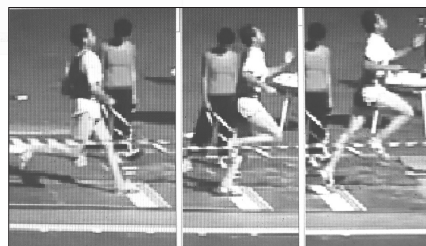
DATA:

Va = 9m/s
Vx = 8,1m/s
Vy = 2,8m/s
 $\alpha = 20^\circ$
 $\gamma = 60^\circ$
 $\beta = 69^\circ$
L1 = 2,10
L2 = 2.28

Properties:

- The "Lift" in the last step relieves the load on the jumpleg. After the active touchdown, jumper can easily "float out" in the jump with a delayed ankle extension.
- The jumper is here totally focused on extension of hip, but less on the knee lift and trunk stability. The trunk "rocks" back slightly (typically for beginners eager to enter the hang-style directly in the jump, the author. refl.). The technology is probably optimal for this long jumpers capacity.

146 Analysis of long jump by an early 1970s study (Ballreich)



Kent Nygren a swedish veteran world champion, here in a 6.50m jump, can be a good representative for this style. He, however, manage just fine with trunk stability

1) Authors study of this article: The EMG activity and mechanics of the running jump as a function of take off angle. W. Kakiyama, S. Suzuki (Journal of Electromyography and Kinesiology 11 (2001, 365-372)
Processed data also from Biomechanics of the long jump, Nicholas P. Linthorne

In conjunction with the World Championships in Osaka in 2007, a biomechanical survey¹⁾ was made in respect of the best long jumper's properties (see table below). It was found three types of jumpers. Depending on velocities in the jumps, one could divide the jumpers into three groups:

1. Large vertical and horizontal velocity
(First Salodino, 2nd Howe, 3rd Phillips)
2. Large vertical and small horizontal velocity:
(4th Lukashevych, 5th Mokoena)
In these two groups we have our "High Long Jumpers" (author)
3. A small vertical and large horizontal velocity
(6th Beckford, 5th Badji 6th Marzouq)
These two jumpers could be considered "sprint jumpers," but far from Carl Lewis capacity (Author.)

	Salodino	Howe	Philips	Lukashevych	Mokoena	Beckford	Badji	Marzouq	Övriga
	8.58m	8.47m	8,50	8,25	8,28	8.20	8.09	8,04	8.15+-0.17
Va	10.52m/s	10.87m/s	10.38m/s	9,97m/s	10,12m/s	10,63m/s	10,16m/s	10.22m/s	10.65+-0.19
Vx	8.90m/s	9.26m/s	8.96m/s	8,27m/s	8,33m/s	9.05m/s	8.83m/s	9,03m/s	8.77+-0.22
Vy	3.75m/s	3.46m/s	3.67m/s	3.78m/s	3.71m/s	3.25m/s	3.17m/s	3.01m/s	3.42+- 0.26
α	22.9°	20.5°	22.3°	24.6°	24.0°	19.8°	19.8°	18.4°	21.3°+- 1.5

From the table below with female Long jumpers from Osaka and Tokyo World Championships we have:

High long jumpers: Lebedeva and J.J Kersee
Sprint long jumpers: H Drechsler and Kotov (Author)

<u>Osaka VM 2007</u>				<u>Tokyo VM 1991</u>		
	<u>Lebedeva</u>	<u>Kolchanova</u>	<u>Kotova</u>	<u>JJ.Kersee</u>	<u>H. Drechsler</u>	<u>Övriga</u>
	7.03m	6.92m	6.90m	7.32	7.29	6.95+-0.43
Va	9,37m/s	9.13m/s	9.08m/s	9.85m/s	9.86m/s	9.53+-0.11
Vx	7.73m/s	7.73m/s	8,14m/s	8.09m/s	8.49m/s	7.92+-0.31
Vy	3.50m/s	3.23m/s	3.18m/s	3.46m/s	2.80m/s	3.05+- 0.24
α	24.4°	22.7°	21.3°	23.2°	18.3°	21.1°+- 2.0

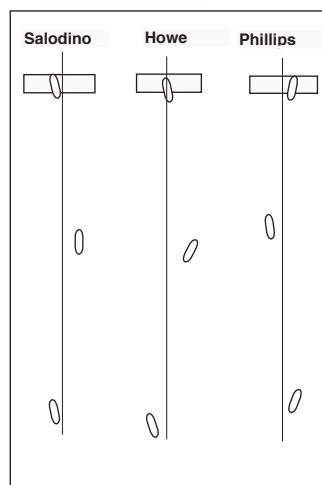
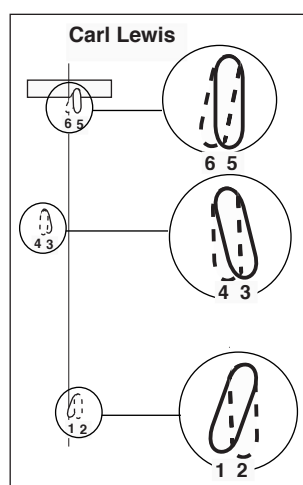


Fig. 155a Touch downs, the last two approach steps and on the board. The three best long jumpers. in Osaka World Championships 2007



155b Carl Lewis footwork, schematically drawn from above with "screwed pull" (see page 57), 1-2, 3-4 and on the board "Inverted pull" 5-6.

They filmed the touch downs and came to what here is described in point 1-3. (see Figure 155a):

1. In the penultimate step the touchdown is slightly from midline, about 10-20cm. This "slide-step" was already used by Jesse Owen but mainly by Carl Lewis (Author).
2. Touchdown on the board is on the center line with the leg slightly tilted inwards. The researchers then concluded that the jumpers effective use abductors (gl.medius, gl.minimus, tensor fasciae lata) and extend the hip side.(Compare page 38 Figure 77 with the text "rubber-strap "(V. Bunin)).
3. Salodini had a large shoulder rotation, which coordinates with the stretching of the hip side in accordance with above point 2. See also p.72, fig 153. Carl Lewis pulls hastily back shoulder before the touch down and this is resulting in a elastic stretching of the hip side. (Author refl.)

In the penultimate stage Carl Lewis has a "slide-step" ¹ after a typical "screwed pull" 1-2 and in the touch down also a well-accnted screwed pull 3-4. The foot is put in a straight line on the board followed by an "Eversion pull", "ie. outward rotation of the sole of the foot over the big toe during simultaneous inward-turning of the heel over middle line.² Muscularly it's likely adductor magnus and vastus medialis, which primarily is engaged for Carl Lewis push off. This will prolong and enhance the accelerating force in the take off.²

1) Modif. ur KINEMATICS OF TAKEOFF MOTION OF THE WORLD ELITE LONGJUMPERS
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