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4. SPEED, SPRINT RUNNING

4.1 Teknik model, sprint 100m.

Acceleration.

As an example of maximum speed performance in sport, we will now process sprinter running. We begin by highlighting sprint technique, with a technique model1) for the track and field’s classic 100m sprint.

Today’s top sprinter, among others characterized by a long acceleration distance of the 100m race, the whole 60m before the maximum speed is reached.

The start - Acceleration Phase
From the start block the pushing force is directed from the foot through leg, hip and the body's center of gravity in a straight line with slope of about 45 against the track (Fig. 96a). The sprinter puts in the foot behind the center of gravity (Fig. 96b) and the extension of ankle, knee and hip joint, occurs with a gradual steeper slope towards the runway.

The pushing from the starting block and into the first steps is usually done with the full extension of the knee. During the first third of the 100m race the sprinting occurs mostly with concentration on high-frequency step2) This is distinctly high for today’s elite sprinters but at the expense of knee extension, which most often in the race will be somewhat incomplete (Fig. 97). The running will become more “luent” in a straight path towards goal. The work is done with higher power output, i.e. great force during short contact time in the track and with better advantage of the stretch-shortening cycle (stretch reflex and elastic energy, see sid.15). This technology allows better use of energy to accelerate further and achieve higher velocity later in the race, and even keep this speed race ut.2)

Pictures of Mike Marsh shows his starting technique during the first four steps. At the push from start block right arm swings back up relatively stretched in the elbow (120°) (5). Left arm however swings more bent up to head height. The power from the arm swing is in harmony wit the pushing action from the start block, in an ideal direction through trunk (cf. Fig 99a). When the right knee moves forwards, the foot is describing a motion (3-6) forwards upwards to knee height. The angle of the knee becomes first quite small when the knee swings up to a relatively high position (5) and the foot is crossing opposite thigh. The foot is put in the track on the ball of the foot (8, 14, 18) ***) and with the first running steps without heel-contact. At the “touchdown” the knee of pendulum leg is hanging in a low position.

Fig 98 Mike Marsh USA Houston Feb.-99 at training. Figure text describing some important technical details.

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1) Many details of this technology model is according to Tom Tellez (coach of C. Lewis, L. Burell, 2) Acc. John Smith, UCLA, Los Angelos-89 (a talk with the author) 3) Ralph Mann -85. (See page47) 4) Mike Marsh, the Olympic gold medalist in the 200m -92 (only one hundredth of the world record in the semifinals).

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Acceleration Phase - max speed.
Gradually the posture becomes more erect. (See fig.99)
The foot put in the track slightly in front of the body’s center of gravity (fig.99a) and when this is crossed the heel easy touch the ground (fig.99b).

In fig100. Mike M. is analyzed with stick figure. Among others is shown here a detail photo of the slightly extended ankle at the touchdown (a) and heel contact with the flexed ankle joint (b).

**IMPORTANT TECHNOLOGY DETAILS**
The figure shows schematically the important pendulum movement of the hip (See also page 38 övn. 14 and 15 and p. 60). At right touchdown left hip and knee are in a low position. From here, the left hip swings (Pelvis side) forward in an oval-shaped moving. It is important to reach far forward with the hip at the knee lift.2) Note that at the touchdown of the right foot, left shoulder is elevated in the high position while the right shoulder instead is clearly lowered. Important that the shoulders are lifted and lowered to create balance and long external levers (see also page 22 and 50). This is a technique detail that you now clearly can see in particular characterizes the Jamaicans Bolt and Powel, but also for former U.S. Green and Others (author) The arms will also provide a significant force additions to the push off the ground by pendulum force1) See in particular the left arm (position a and b, dashed) relative outstretched position, with your hand low along the side. Sprinter drops down the arm relaxed and then “swings” arm high up near the face (see p.48) Even backwards swinging contributes with force.

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1) Tom Tellez told the author at visit Houston february -99
2) This is a very important technology details. “The pelvic side is moving in an oval -shaped moving, and the hip is pressed far forward” (John Smith told the author at visit, UCLA-89.3)
The initial contact with the runway makes the edge of the ball of the foot (Fig. 101C), then during “a micro second” the heel (Fig. 99-101). Elastic energy, stretch reflex and muscle power then extends the ankle, which helps boost the power. This power is also affected by will7), with the exception of the ankle’s extension. Foot arch - lower leg (Fig. 101, a-c) can be likened to a biased elastic steel strip, which at the touchdown is bent and clamped together followed of a “catapult” effect.

The right feeling in sprinting
The right feeling should be that:

- The take off from starting block occurs with perfect extensions directed through the trunk (Fig. 102 a and b)7). Already in the early stages of the race most of the sprinters characterized with a more imperfect extension in the knee joint, providing a more propulsive force. The inclination of trunk becomes progressively more upright (Fig. 102c). The final push off occurs with the feel of so called “rotated (screwed)” where the leg, after the foot’s edge-insertion and heel contact, is pulled backwards and is rotated (“screwed”) over the big toe.

- The touchdown is done with a feeling of “wait for” the ground pliable as frequency and speed increas. Important the sprinter does not force a stamping action from a high position into the ground. At low altitude (Fig. 101C) the explosive take off process is starting with muscle prestressed to add the elastic energy (“steel shank catapult” is loaded). The foot then is rotated” downward-outward which creates edge insertion. The challenge is to find the right location at touchdown ie. just right high center of gravity in which the foot hits the track gradually longer in front of cg. When maximal velocity finally is achieved, the foot optimum lands in front of cg. whereby the maximum power development can be developed during the stretch-shortening phase (sid.15)

- Quadriceps is absorbing the shock at touch-down while hamstring pulls and rotates (at the final stage adductor magnus) leg backwards until the foot leaves the ground over the big toe. The whole pendulum phase, also called recovery phase, with heel kick, knee lift and forward swing occurs, however unconsciously, as a result of total relaxation in the knee, largely with help of mechanical elastic energy. The altitude of the knee lift is then natural affected by the force from the take off work. (See also. p. 53, fig.117, 118 and p. 57 about Powersprint)

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Maximum speed

Figure 104 and 105 shows a sprint stride in maximum speed. The touchdown a little longer in front of tptk. and the trunk is more upright. This change has occurred gradually during acceleration. Max speed is reached after an optimal acceleration at approximately 60m.

A top sprinter can today with relaxed coordination and an extreme endurance implement the entire 100m race with minimal speed reduction.

Fig. 104 Film sequence on Henrik Olausson during maximum speed sprint
Note: Location (a) is just before touchdown (Fig. 108a below)

Fig. 105 Analysis of maximum speed

The challenge is to complete the 100m race at top speed with the concentration of detente. The muscle energy is discharged (page 18) but good speed endurance coupled with mental concentration makes it possible to maintain the speed. The sprinter must concentrate on a long acceleration distance. Often starting speed over- emphasizing at the expense of the very long acceleration.

That during the first third part of the 100m race achieve high step frequency, the second third part obtain maximum speed and during the last third maintain momentum with speed endurance might be a good tactic. 1)

Sprinter running should be very relaxed, among others to be successful exploit elastic energy and stretch reflex (stretch-shortening, see sid.15). Already in the 30′s Jesse Owens showed the way with a unique laid-back running. Being relaxed is probably still the most important advice a sprinter coach can give his adept.

1) According to John Smith, Interview (Author-89)
2) According to John Smith, important technique detail (Author-89)
The rod as a lever and technology model in jumping and running

In some positions in ground phase of the sprinter’s stride and the take off in longjump the legs and the body together is like a springy rod (fig. 114). The rod is a lever with its support point of the ankle. The force from the ground through the rod during the rotation forward-upwards, gives both a braking and by means of elastic energy, an accelerating force.

Upper parts of the rod have higher operating speed (V1) than the lower (V2) at the same rotational speed (so called angle speed). This would mean benefits with a high center of gravity position to make better use of the pole of rotation.

The figure also shows the vertical and horizontal reaction force from the ground. The sprinter / Jumper creates among other things, increase in the external lever (see page 22) and higher CG position by that left shoulder is lifted higher when the right foot is landing in the ground and the opposite relationship right shoulder and left foot (see also fig.100, p. 45). Furthermore the pelvic posture is important for the same reason. This especially true for sprinter model B (see below) with typically tall posture which creates long levers.

Body posture of the maximum speed. The Pelvis, different sprinter models

Previously, the view was that it should creates a body posture in neutral position (Figure 112a). Only with slightly forward tilted Pelvis (“APT” (Anterior Pelvic Tilt)). This couldn’t be the whole truth given the presence of world elite sprinters with significantly APT mode. With respect to Pelvis stance and the push-off leg motion during we can distinguish these two sprinter modes:*:

A. APT mode. “Long rotation in the hip joint”, (mostly incomplete knee extension). (fig 112b, detailed description p 58)

Advantages:
1. Long distance between muscle attachments of the hamstring gives the possibility to high horizontal force during mostly the entire stance phase.
2. Contributes to a more “floating” running - an important basic principle for all sprinting.
3. Ability to extreme improvement of hamstrings horizontally force production.

Disadvantage: Requires, which many lack, extra specific strength in the hip extensors, with a very well developed posterior chain

May be possible by training specific technically with Powersprint®

B. PPT-APT-mode. “Short-long rotation in the hip joint,” Pelvis first backward-tilted, PPT mode (Posterior Pelvic Tilt (Fig.112c) Then individually to APT mode Description p. 59).

Advantage:
1. Tall posture with long levers is created (see above)
2. Energy saving way to develop great horizontal force, both during acceleration and maximum speed, as in the final phase of the race.
Extensive research has been conducted in the United States to determine biomechanical differences between performance level equivalent:

1) World record sprinters (Green, Lewis, Burrell and others (9.8s / 100m),
2) Average international elite (10.3)
3) American College sprinters

We shall now briefly summarize what is characteristic for max speed running of these groups.

In Figure 116a-k, we can study:

- Velocity (fig. a)
- Stride length (fig. b)
- Stride rate (fig. c)
- Touchdown distance in front of the body (fig. d)
- Hip ankle angle (fig. e)
- Knee angle (fig. f)
- Knee lift, angle thigh-back (fig. g)
- Rotational speed (thigh) (fig. h)
- Rotational speed (lower leg) (fig. i)
- Horizontal velocity (foot) (fig. j)
- Reaction force: Vertical (fig. k)
- Reaction force: Horizontal (fig. l)

**Fig. 116 Biomechanical comparison:** I. World Best (9.8) II. Average (10.3) III. College Sprint

**Max speed, biomechanical force for a world class sprinter**

Fig 117 shows the vertical and horizontal so-called reaction force from the track for a world class sprinter. The contact time in the ground phase is only approx. 83ms and the vertical force as high as 450kp (= 4500N) in the tought down. There is a brief “power spike”, which shortly subsides followed by an increasing force to approx. 350kp. The forces are measured with the pressure plate.

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1) Processed from Leichtathletic training 12/99-24. Fig 120j och k (Exercise and Sport, 84)
2) Drawings (Author.). Diagrammet processed from Ralph Mann, -Leichtathl. train. 12/99, 24
Ralph Mann and Paul Sprague

15 U.S. sprinters of high class was filmed at top speed after 40m acceleration distance. Filming with 150bilder/sek and computer analysis revealed the following facts about the muscles that dominate the different phases in a sprinter’s stride.

1. Hip extensors (gluteus, hamstring) and knee flexors (hamstring) dominated when the leg pendulate’s downwards (Fig. 119, A - Td) against the ground and during the ground phase’s first part, Td - B. This suggests sprinter attempt to reduce the brake at the foot-strike by these muscles pull the body over the touchdown point (Author better: With these muscles rotate the legs so that the body is driven over the touchdown point *)

To achieve this requires considerable muscular effort from the hamstring. Here is also the greatest risk of injury. Statistically has an elite sprinter greater risk of injury than a less good sprinter according to the researchers.

2. The ground phase’s center (B) the hip extensors (gluteus) is changed to the hip flexors to rotate the torso forward, **) Hamstring dominate the end of take-off to according to scientists prevent knee hyperextension .***)

3. It was found that the contribution from the ankle extensors (the gastrocnemius and soleus) to the take-off power, is slightly less than previously thought. Ankle strength was namely also important for to suppress the foot-strike to prevent excessive great sinkage. Similarly seems knee (quadriceps) absorbing ****).

The researchers argued in summary that:

**Hip extensors and flexors provides the greatest contribution to high running speed.**

Important is also the body’s location at fotisättningen, with an optimal distance, foot - center of gravity (see p. 53, fig 116E). For just the right step length, the foot is placed in front of the body, giving rise to an inevitable brake. This can be reduced by the foot’s horizontal speed in the running direction is reduced to

*) Tom Tellez denies strongly the expression “pull”. in his description of sprint technique occurs simple terms: “Naturally strike the ground and push,” make cycling movements “, etc.

**) The rotation of upper leg is braked, which should lead to the trunk is rotated forward. This technique detail, which probably occurs naturally in human running and walking, can not function, if running is regarded as a “drag”, an otherwise ordinary explanation today of running technique.

***) Subsequent research (Wiemann and Tidof) explains instead hamstring muscle group with m.adduktor magnus starring role in the take-off. Eg hamstring works as knee and hip extensors. see page 56).

****) Ankle- and knee- extensors as such contributes to a floating running, see p. 51, fig 113th In order to have time to develop sufficient power during the short time touchdown occurs, contributing stored elastic energy and stretch reflex to this. *

| 119 | 15 top-ranked U.S. sprinters were investigated in max speed 2). Upper graphs show power moment and the lower reaction force from ground as measured by pressure plate. |

\[<\text{Diagram}\]
Sprinter technique is explained in a simple way of German bio-mechanics, mainly thanks to a new anatomical approach. It has been demonstrated that the posterior thigh muscles **hamstring (ha)** and **adductor magnus (am)**, in a natural motion works as hip extensors and that these muscles in the take-off at the upright running position also could extend the knee joint. A comparative study (see page 55) between sports students without specific training and elite sprinters showed that, among other things.

Fig 117 shows a model of **gluteus maximus (gm)** and the posterior leg muscles hip extension function. You can metaphorically think of muscles as "reins". If these be abbreviated, the leg is brought backwards and its rotational speed at touchdown increases (see page 53). This reduces the horizontal deceleration at the front ground phase (see detailed analysis, sid.57). The movement is accelerating during the trailing phase and hamstrings is continuing its work with the help of stored elastic energy all the way up to "heel kick" after the take-off. When the foot lands in path **am** is disconnected while gm together with the front thigh muscles and ankle extensors are cushioning the impact and prevents excessive sinkage (ie. maintains "fluency", author.).

Figure 118 provides a further description of muscle function. Here you can clearly see how ha and am are shortening (please measure by yourself with a ruler, author.) While the model shows the muscles that dominate the work. (Darker = more toned dominance). At the end of the stance phase (see also page 57) am is connected and help ha to extend in both hip- and knee joint. The front thigh muscles (rf and vm) take part only slightly, which overturns all previous ideas of an accentuated role of these muscles, as extensors in the upright sprint position (except first accelerating section of the 100m race (see page 51).

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**Fig 117** Schematic model of **m.gluteus maximus, hamstring and m.adductor magnus hip extending function.**

**Fig 118** The figure schematically show the stance phase at maximum speed sprinter model Long "rotation in the hip joint" + "Push". Pelvis tilted forward, the APT position (see page 50). The principle of the hamstrings and adductor magnus. The more gray muscles, the more it is activated. For example:

1. Hamstring with darker tone is active during touch down and the whole stance phase. Its muscular attachments approaching each other ie. maskeln shortened throughout stance phase. If you look at it as a simple mechanical machine it will feature:
   The whole leg, which forms a lever with hip as rotation axis, is and rotated (screwed) backwards by the muscle power.
2. Gluteus and quadriceps is active in beginning and adductor magnus in the late stance phase.

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1) Processed from Die Lehre der Leichtathletic, -94, 8.  
2) modif. Wieman. Die Lehre der Leichtathletic, -89, 27 

(Woodley, Mercer. Hamstring muscles: Architecture and Innervation.) 54
Film Analysis of 100m races at the Tokyo World Championships -91

A film analysis 1) of 100m races at the Tokyo World Championships -91 showed:

1. Changes in stride length and step frequency followed a pattern, which allowed to keep the speed to the finish.
2. In the final, Lewis had a shorter stride length and higher cadence than Burrell.
3. In order to achieve high speed sprint requires high speed in the leg backward movement before the touchdown.

High hip extension speed is more crucial than the knee or ankle extension shows a comparison between elite and university-level sprinter.

E.D. Lemain & D.G.E. Robertsson

High-speed filming (100bilder/sek) and computer processing 2) (speed, acceleration, momentum, energy and power) of the top-ranked elite printers from Canada and the U.S. showed (see Figure 118), among others:

a. Hip flexor worked concentrically during forward swing and then developed 4100w.

b. The power output was 3200w for hip extensors (concentric work), when the foot pendulate’s downwards against ground.

c. Knee absorbs (eccentric) when the foot lands (the so-called. foot-strike) with effect 2500W followed by only 200w at beginning of the knee extension.*

d. Knee flexors (hamstrings): 4800w in the takeoff! This muscle activity is needed, explains these researchers, in order to prevent knee hyperextension.**

The researchers concluded of the the survey:

It should be higher priority than in the past for training of hip muscularity before training of the knee and ankle-joint muscles.

A.O.Korneljuk, National Coach U.S.S.R -81

113 sprinters incl. national elite participated in the survey which extensive 600 different biomechanical factors. It was found among others that at the foot-strike, and the first part of the ground phase (fig.118c), developed maximum force torque in the ankle and hip. Ankle will then take up the eccentric force****) with the 8400w. The researchers concluded that the ankle had a crucial role.

Main technical requirements to achieve high top speed, according to researchers:

1. Reduction of the brake in the first part of ground phase
2. Emphasize the role of hip extensor to reduce the speed loss in the ground phase.
3. High acceleration of the thighs so that they cross each other with the highest possible speed****

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*) The last low value indicates that the quadriceps mainly have a dampening function ie. helps to prevent a large sinkage during braking phase
**) Wieman and Tidof have another more compelling explanation (p. 56).
****) Heel kick close to the seat, among other things, contributes to this. see also p. 53;
*****) Is also called amortisation. The ankle suppresses elastic and prevents excessive sinkage (p. 51).

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1) Processed from a new stud. in Athletics, London 7(92, 1, s. 47-52
2) Canadian study. Processed from Track and Field Journal, 13-17,-89

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Fig 118 Dominant muscle groups during the phases of sprinter stride
German EMG analysis of sprint running

EMG test *) to indicate “muscular effort” was performed on 12 sprinters of the German elite class incl. German champions and were compared with 25 sports students, the these latter without sprint experience. The compilation (Fig. 122) in graph form, we will now analyze. 1)

Phase 1-8: Large activity remaining in the adducts magnus (am) and hamstring (ha). This and mechanical energy leads to an automatic hækkind. ***)

Phase 4-12: Front thigh muscle, m.rectus femoris (rf) and am giving force to the knee lift

Phase 5-9: Ankle flexor m.tibialis anterior (ta) is activated to bend the ankle at heel kick. The foot’s center of gravity will then more close to the axis of rotation of the hip joint which lead to higher rotational speed at the forwards commuting of the knee

Phase 9-16: The knee joint is “opened” with a “relaxed” help of m.vastus medialis (vm)

Phase 12: Gluteus (gl), am and ha brakes the knee lift and start the downwawds commuting.

Phase 12-16: Knee joint is opened by the lower leg’s iner-

Phase 16: Stabilized (fixed) of the knee joint explosive by

vm assisted by am and ha. An important technique detail means that just before touch-
down ta bends the ankle and the gastrocnemius (ga) becomes tense.

Phase 17: ta relaxes and ga extends ankle so outer edge of the footplate is dipped in the track.****)

Phase 18: At ground phase front part gl, vm, rm and ga is dampening and avoid excessive sinkage.

Phase 14-20: ha rotates the leg back down and gives the
foot a speed close to zero prior to landing. ha
is continuing work throughout the ground phase.

(see fig.121, p. 56)

Phase 19-20: Ground phase’s posterior with the take-off. ha get help of am and these muscles also ex-
tends in the knee joint.

Phase 13-17: During the start steps before the upright posture the quadriceps dominates as the knee and hip extensors (Wieman, p. 51) with vm as representative from the vastus muscle group in this EMG study.

*) EMG measures the pulse rate (10-120 discharges / sec)

***) Thus you should not deliberately emphasize this. This would only imply a tight race. The diagramme indicates a relaxed running by the German champion. Muscle effort is sparingly optimized and occurs in the right contractions’ succession ie. with better coordi-
nation than other sprinters.

****) Here it is important with relaxed knee joint (according to Tom
tellez). Commuting out of the bone is then faster, which when it will be braked since just before landing creates an intense “stretch shor-
tening” (p. 15) for force to backward speed increase of the foot.

*****Down commuting of the leg occurs with an accelerated motion, but with the “feel of waiting on the runway” before the explosive action just above the runway and “Naturally strike the ground” according Tom Tellez is excellent education to learn the correct rhythm in the recovery phase. The commuting must be very relaxed but with a clear accelerated movement at end. This seems the German champion succeeds excellent in contrast to the other, which seems force violently with, among others. overactivity by am. which is whipping in his leg from an elevated position (the risk of injury increases then too dramatically).

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**Fig 122 EMG test 2) of 12 German elite sprinters (**p.rec.10:57 on average), black bars. German champion (**p.rec. 10:40), gray bars.**

1) The tree lower modif, Schöllhorn .95-43. These lacks measure values and levels may therefore not be compared with upper values.

2) The fow upper diagrams modif. Leichtathletik .94, 7 och .94, 8 samt Schöllhorn, .95, 41-42
Wheel model for sprinter running

![Wheel model for sprinter running](image)

**Fig 123 Wheelmodel for sprinter running**

Vector Force Analysis

Important conclusions by biomechanical research of sprinter running. Trainings forms

![Important conclusions](image)

**Fig 124 Some specific strengthening exercises for the sprinter speed**

The wheel can be used as a model for the sprint race. With our previous sense of the “spells” that rotates in the hip and ankle as elastic “steel shank” should we construct our model as Figure 123 shows. Higher situated wheel axle (h2) is equivalent to a higher center of gravity mode and multi-spokes higher step frequency (Fig 123b). The pendulum rhythm in sprinter running, with a rapid and accelerating touch down and ground phase followed by a calmly gathering pendulum phase (*) (see p. 53, fig 116D) correspond to a gear wheel, som step by step cogs around. (**)

The figure 125a below shows occurrence of the brake force and fig 125b the importance of the pendulum leg impulse (Fp) and foot’s force (Ft) in the “touch down”. In fig.125c the braking force have been created by the weight resistance at specific training of strength for sprinter running. Figure 124a-d shows examples of such a strength training.

The biomechanical researches about sprinter running from different countries like USA, UK, Russia, Canada and Germany, which we have treated here, have been consistent conclusions that:

- **Hip extensors and flexors are most important for the development of high speed running.**
- You should find specific training techniques to train the strength particularly in the posterior thigh muscle group (see example fig.124a-d and p.59, 60, 76 and 77)

**) Called. “Recovery phase” **) “bicycling movements”, “Naturally strike the ground”, “Wait for the ground”, “relax your shoulders and kneejoints” excellent teaching tips by Tom Tellez about the perfect pendulum rhythm acc. our

Important conclusions by biomechanical research of sprinter running. Trainings forms

![Important conclusions](image)

**Fig 124 Some specific strengthening exercises for the sprinter speed**

When the foot is landing in the track (“touch down”) we have the following components to study:

F AnnotationsRequired[braking horizontal friction force]
Fs = AnnotationsRequired[force (from “pivoting rod”), reaction force from the track]
Ft = AnnotationsRequired[forces at touch down]
Ft = AnnotationsRequired[reaction force from pendulum leg]
Fy = AnnotationsRequired[force component in vertical direction]
G = AnnotationsRequired[gravitational force]
Fy = AnnotationsRequired[force component]

**Fig 125a shows emergence of the brake power (Fμ).**

**Fig 125b shows the importance of pendulum leg impulse (Fp) and the foot force against the track (Ft), at touch down. Below we can as comparison also study a pressure graph of maximum speed sprint.**

**Fig 125c shows analysis of the forces in branch specific weight training. Example: Resistance running, sprinter running in a power sprint machine.**
4.2 Tactics example for 100m. Sprint models. Pelvis posture. Powersprint®, specific strength training for sprint and jumping.

**Acceleration I (Drive phase)**

Fig. 126 shows training of the acceleration phase in the deep position shortly after start. The foot is behind the center of gravity with the trunk in about 45° inclination. Edge of foot sole meets the ground first. The push-off occurs first with the leg, after the foot edge insertion and heel contact, is Rotated (“screwed”) over big toe possibly help of the adductor magnus. (cfr. skate sprint1). Pelvis tilts backwards explosively to PPT position (see page 50). Muscle work is switched to the quadriceps, which ending the push off with hamstring as antagonist (acc. Wiemann works hamstring here isometrically. (Page 49). In this very short and rapid steps (a-b) stretch-shortening phase function works (see page function 15) in which the elastic energy together with stretch reflex and muscle-specific force brings about the “start force” in the pushing action. This phase of the race usually called drive phase. In the next steps the runner’s touch downs are gradually closer to the body’s center of gravity (Fig. 127) and the angle of the knee, hip and wrist “opens” and the sprint model, characterized by a long rotation of the hip joint with a relatively incomplete knee extension (see page 50 and the following).

**Acceleration II - Max speed. Sprint model:**

**APT-mode. “Long rotation in hip joint”**.

Figure 127 shows the technique in “Acceleration II” with progressively more upright posture, until maximum speed is reached. Maximum speed is built up by that touch down is done with a sense of “waiting for” the ground smoothly while step frequency and speed increases. The foot should not be flogged from an elevated position in the ground. At low altitude starts the “natural strike” against the ground with muscle preload for imparting elastic energy (“elastic catapult” charging). At relaxed sprint the foot naturally is turned angled down and out and the edge of the foot meets the track first. It is important to find the right location at touch down ie moderately high center of gravity location where the foot hits the track gradually longer in front topt. Then, when finally max speed is reached(fig 128, 129), the foot is landing optimally in front of the center of gravity. Muscle work now could occur as technique model: “Long rotation in the hip joint” with Pelvis forward tilted, APT mode (see page 50). a-d : The whole leg is Rotated backward by the force of mainly gluteus, hamstring and the adductor magnus. Hamstring extend hip in such a rapidly rotating and accelerated motion as possible. Then Pelvis all the time are forward-tilted (APT mode, page 50), the leg, using the posterior muscular chain force, is rotated long behind the hip even with a certain - albeit incomplete final knee extension (“Push”). This applies particular in max pfase (Figure 129). Some sprinters also in the world elite level, is using this technology throughout the race. This and following technique model use relatively high knee lifts with early knee forward swing (early heel passage of the support leg knee)
Max phase during the end, 1/2 or 1/3 part:

Sprint model: PPT-ATP mode. “Short-long rotation in the hip”.

This technique is a backward tilting of Pelvis during the swing phase, see fig.131(f-g) to PPT mode in the touchdown (a-b). Here occur also a “stretch-shortening cycle” of the swing leg’s hamstring before “whip the ground” (g-a). With focus on PPT mode, the leg then is backwards rotated in the hip joint for a shorter way. The explanation is this pelvis posture (Figs 130, 131) which causes that the femur can not be rotated far behind the hip. Typical for this Sprint model is also a uncompleted knee extension. However, this backward rotation of the leg can also as an alternative be performed in a longer distance to produce large horizontal force. Bolt e.g. seems to use such a technique, as shown in the following:

a-b: Because of the high pressure (see diagram fig. 130) that occurs when the machine is attacked, the fixed ankle joint (should be seen as a “stiff” elastic steel shank) will be slightly compressed. The heel is (see the picture below) pressed against the track an touch it.

c-d: Pelvis, as an “extra lever”, is started tilting slightly forward. The final push-off is done as previously during the drive phase, with that the leg, after the foot edge insertion and heel contact, is rotated (“screwed”) over the big toe - this possible with help of the adductor magnus. During the push-off continues forward tilting of the pelvis again, (sure it requires considerable strength from erector spine) which supports both muscular strength, primarily from the hamstring and adductor magnus, both individually a longer rotation of the leg behind the hip. Important is a certain “locked knee-joint”, so that leg forms an elastic leverage before final push-off. Immediately after this, again pelvis is pressed to PPT mode (e) which coordinates with a quickly knee lift. Longer rotation can shape a “bigger wheel” (page 56) - “high speed ratio” for maximum speed.

**Fig. 130** At touch down the heel is pressed quickly down by the high pressure (a’-b’) and touches the track. Analysis of the maximum speed. Sprint model: PPT-ATP mode. Picture shows “Shorter rotation in the hip joint”
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 musculature. 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 paralell 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.

In the approach you sometimes can use a combination of “ATP” - and “PPT- models (Author) (illustrated here and previously on pages 58-59)

Often in an alternating step rhythm in harmony with the coordination of the last three strides and take-off.

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.

Fig. 149a

Fig. 149b

Step rhythm: “short”-“long”-“short” “Feet Runs Underneath the body and then passing” (Auth. talk with Joe Douglas Stihne -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. Recommended author: Ralph Boston’s coach Tom Ecker, Stihne 1982. 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 - 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 Buntin 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)

Fig. 149c

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