SPEED AND TECHNIQUE INTERREACTION IN SPRINTING

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Biomechanical investigations in sport in most cases deal with measurements of kinematic and kinetic parameters of athlete's movements. We assume these parameters to be the biomechanical variables of sports technique. Under the term "sports technique" we understand the set of motion actions which, performed in orderly sequence and according to biomechanical principles, serve the utilization of motorial and structural potential of man, to achieve the best sports result.

Thus understood technique of sprinting was an object of numerous biomechanical investigations (Hoffman 1967, Ballreich 1976, Mann and Herman 1985, Zukow and Szabanov 1983, Mero and Komi 1985 and others). Sprinting, perhaps a little less than long and middle distance running, is a natural movement whose technique is hardly limited by equipment or by sports regulations. Considering the investigation of sprinting technique from this point of view, one may ask a question: Is it possible to increase velocity by teaching the new way of performing the motion actions according to biomechanical variables required for sprinting with different velocities?

The high velocity of running is a result of: (1) muscle's ability to exert force at high velocity of shortening and efficiency of metabolic processes at limited O_2 consumption or (2) efficiency of energetic and neuro-muscular processes at limited O_2 consumption and efficient technique of movement.

If the first assumption is right, then one must search for talented athletes with efficient metabolic processes in the so called fourth area (unaerobic and non lactic acid; Volkov and Koriagin 1977), with a high efficiency of nerve conduction velocity (NCV), with right proportion of type IIA muscle fibers to type I (Mero and Komi 1985) and so on. Such a talented candidate will be made perfect by speed-force practice and the technique of sprinting will develop in a natural way parallel with running velocity which increases as a consequence of the practice characterized above. Then, one can say that the technique is a consequence of the velocity of running. In the second case, the technique practice is required as well as the speed-force practice and the adaptation of technique influences positively the velocity of running. Technique and potential velocity influence each other.

If we accept the first assumption then the biomechanical investigation has mainly the cognitive value. While accepting the other, we are obliged to transform the obtained data of sports technique into the information applicable in the teaching process.

The most common datum on running are the step length and step frequency. There is a high positive relationship between these two variables and running velocity according to the formula.

$$v = l_S \cdot f,$$

where v = velocity of running
L_S = step length
f = step frequency.

On the other hand, these are typical subject - dependent variables; a tall athlete will have a relatively longer step length with lower step frequency than a short athlete. Hoffman (1967) wrote that for sprinters the step length index as a quotient of step length and leg length was about 2.11, the average step length was 1.14 times the athlete's height and both of these indexes correlate with the velocity of running.

Two practicing runners are compared: a 13 year old girl with best record on 100 m equal to 12.9 s and an experienced competitor with best result on 100 m 10.7 s. They have the step length indexes accordingly 1.18 and 1.06. From this point of view the male is note as efficient because he does not utilize his potential step length. The total step length is composed of L_1 - take off distance, $_2$ - flight distance and L_3 - landing distance (Hay 1985). The increase of the take off distance (L_1) depends on full extension of the knee joint - but the recommeded angle at the end of take off is about 160^0 and depends on hyperextension in the hip joint. Mann and Herman (1985) agree that maximum hyperextension is not advised. The flight distance (L_2) depends on resultant velocity and the angle of release (Figure 1). If the angle of release increases - at the same velocity - then the flight distance increases.

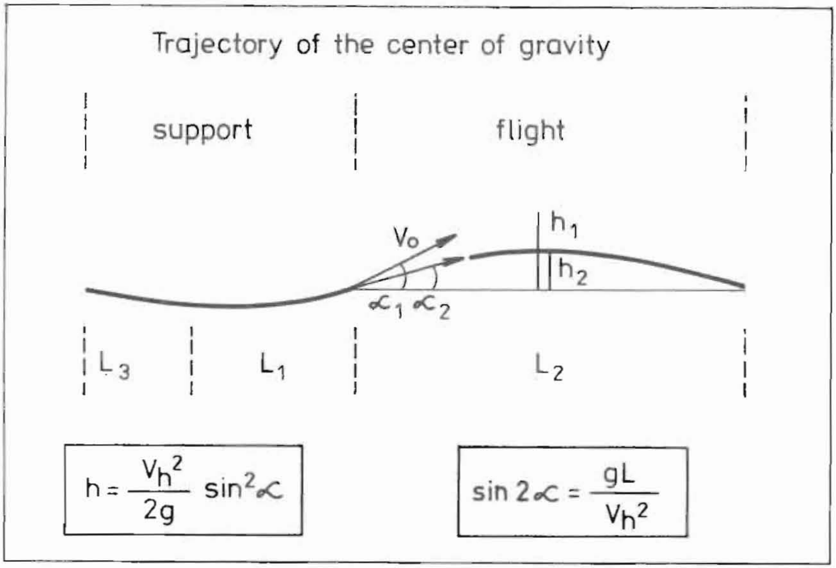

Figure 1. Three components of the stride length (L) and the calculation of the height of the center of mass (h) in the flight phase.

However, this will increase the raise of the center of mass (h) which is not preferred. It is advised to maintain the same step length and to diminish the center of mass raise (h), which of course demands from the running velocity increase (Figure 2). For example: diminishing the angle of release by one degree, at an unchanged step length 2.20 m, demands increasing the velocity of running by 0.8 m/s, which results in shortening the step time by 0.02 s.

The landing distance (L_3) covers the so called braking phase. This distance depends on the way placement of the foot and on the knee joint extension. Mann and Herman (1985) found that this distance should not approach maximum. The comparison between the 13 years old girl and the sprinter, in term of this parameter, is shown in Figure 3. According to this criterion the sprinter has advantage. The coach's questions are going to be as follows: Can the speed-force practice influence these parameters? To what extent can these parameters be influenced by teaching the technique?

Improvemednt of selected biomechanical variables of running, like the angle of release, without shortening step length or without changing the range of extension in knee (which is mostly connected with muscles dynamics), lies in the area of speed-force practice and results in changing the technique variables as a consequence. The improvement of some elements may diminish others (for example the total step length and the length of its portions). Requiring less than maximum extension of the leg joints during take off phase, or flater flight, or active foot placing at touch down can bring some disadvantage, when it is not associated with improvement of the motoric features of man.

Another element of technique in sprinting is the swing phase of the leg. It is performed with maximum flexion in the hip and knee and the velocity of the leg swing is highly correlated with running velocity. From the principle of conservation of angular momentum it follows, that the angular velocity increases when moment of inertia decreases.

$$I\ w = \text{const.}$$

In Figure 4 there are data of the leg moment of inertia changes during the swing phase. The coefficient of the diminishing moment of inertia (I) is higher in the girl than in the sprinter. The maximum velocity of the leg swing, ie. angular velocity of the center of mass of the leg was 17.4 rad/s for the girl and a little higher for the sprinter. The analysis of kinetic energy of rotational movement ($\frac{1}{2}\ Iw^2$) of the leg shows that the highest work of the swing was done by muscles when the moment of inertia (I) its minimum. Tolloczko (1985) carried out an experiment with the swing of an unloaded leg. The author concluded that the angular velocities of the leg are maximum during sprinting. There are no other (similar in range) tasks with such high velocity. Then the author suggested that inefficiently velocity of the swing leg may be the limiting factor of sprinting velocity.

Is it fruitful to teach the leg swing with I min? At which level of practice is it recommended? At which level does it depend on muscle strength and joint flexibility? These are the obvious next questions about substance of information contained in biomechanical variables used in the process of teaching the technique of sprinting.

Probably some other doubts may arise when considering the shortening of the landing distance (L_3) and beginning the knee flexion before the foot placing instant. This phase causes some braking force. Mann and Herman (1985) wrote that such movements correlate with the velocity of running. The experiment by Zukow and Szabanov (1982), which lasted one month and was devoted to the special program of technique practice, shows that better technique is associated with decreasing the first impact of the vertical reaction force. Both of the above mentioned papers suggested that diminishing the braking phase influenced positively the velocity of running.

To what extent is such suggestion right? This question is closely connected with accumulation and utilization of elastic energy in muscles (Cavagna et al. 1971, Komi 1979 et al.). In order to accumulate elastic energy, eccentric work is required, i.e. the loading of the muscle during its activation and stretching. The analysis of angular changes in the knee and hip for the girl and sprinter revealed that stretching occurs in the vasti during the first half of the support phase (Figure 5). The two joint muscles i.e. hamstrings and gluteus maximus contract during the support phase while rectus femoris probably together with iliopsoas are stretched. From the elastic energy accumulation

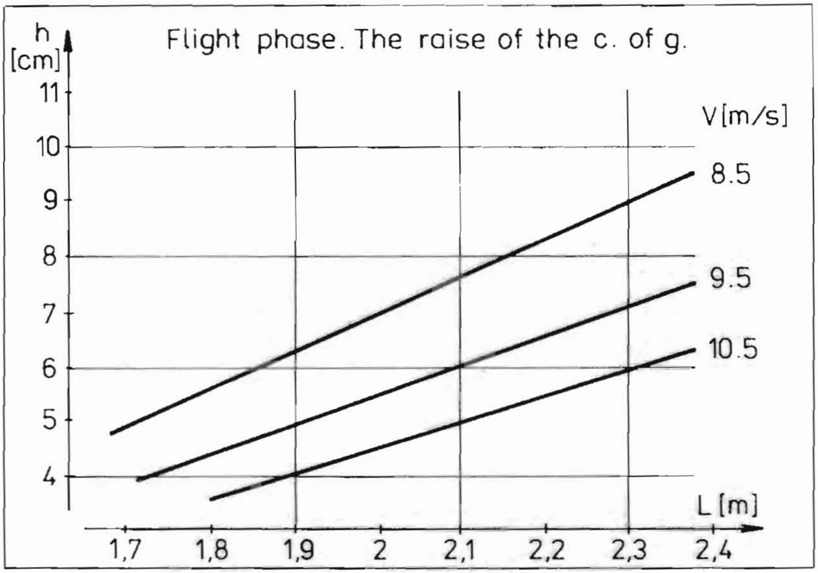

Figure 2. Relationship of the rise of the center of mass (h) during the flight phase & stride length (L) with changing velocity.

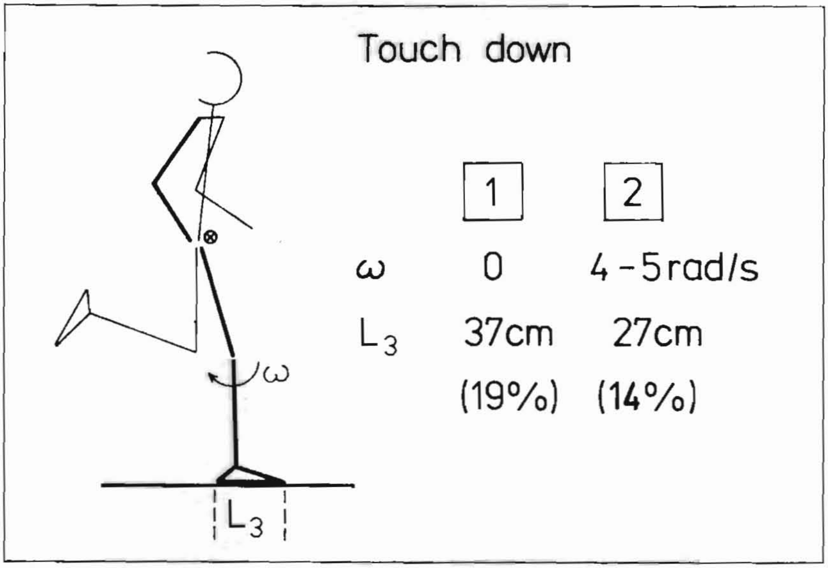

Figure 3. The absolute and relative landing distance (L_3) and the angular velocity (W) of knee flexion at foot strike for a 13 year old girl [1] and an experienced sprinter [2].

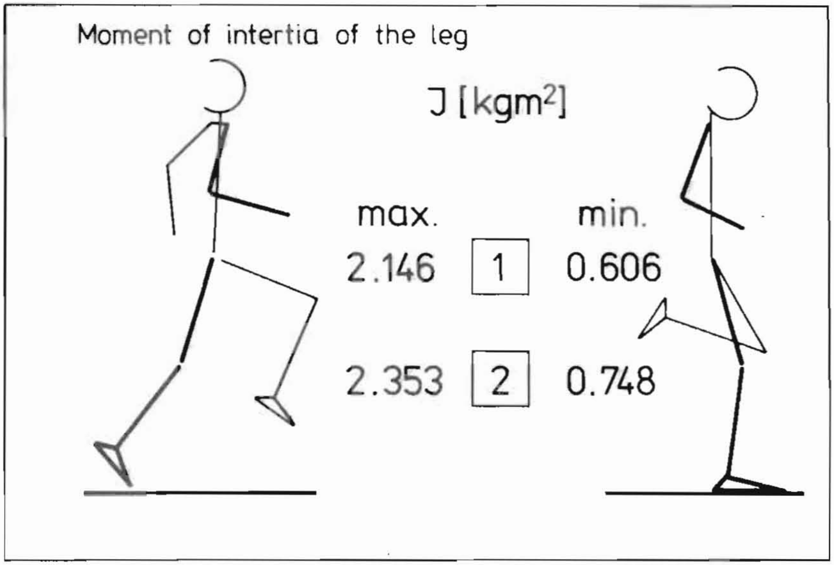

Figure 4. Maximum and minimum moment of inertia (I) for subject [1] and [2] .

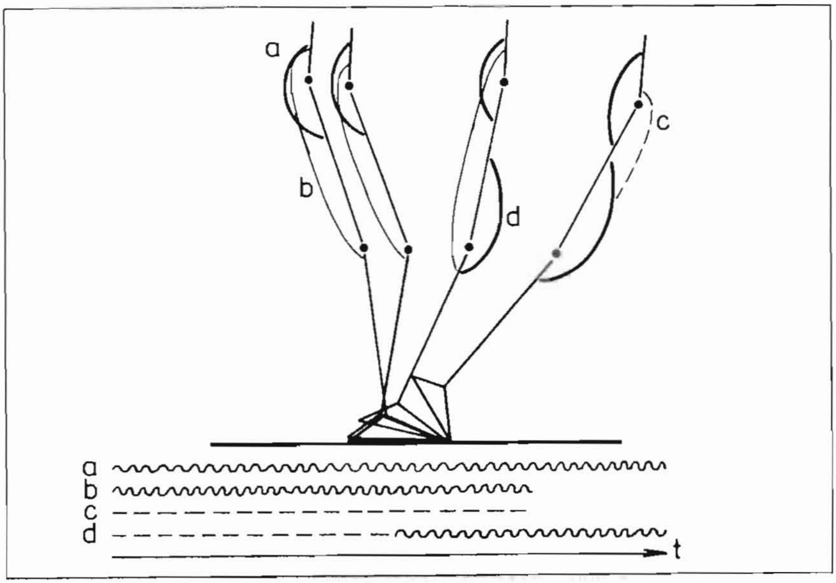

Figure 5. The probable change in muscle length during the support phase (t) in sprinting, with approximate calculations based on hip and knee angle changes. (a) gluteus maximus, (b) hamstrings, (c) rectus femoris and (d) vasti. ∿∿∿∿ = contracting – – – – = stretching

point of view the braking phase is very useful (see comparison of squat jump vs. counter movement jump, Bosco 1982 and others). The decreasing of running velocity is probably well rewarded by elastic energy accumulated in the vasti. The range of movement in the knee joint is small (15-25°), which means that muscle stretching is probably also limited. In this case the difference in velocity between concentric movement and eccentric-concentric is very high (43%) and consequently more favorable for the latter sequence of the movement (Bober et al. 1985). In addition to the elastic energy utilization during the shortening phase that is during the take off phase (L_3) which lasts about 50 ms, there is additional muscle activation. The stretch reflex of the muscle spindles additionally activates the muscle with delay. In the light of this consideration the linear relationship between the landing distance (L_3) and the velocity of running seem to have a nonlinear relationship. Here again, it is not obvious to which extent the teaching process of this element of technique is recommended and how much this technique depends on speed-strength practice.

CONCLUSION

These few remarks on biomechanical variables do not deny the biomechanical investigation of sports technique. Just the opposite, the information of biomechanical variables was basic for conclusions as well for doubts. It is not easy to formulate the teaching program of the technique of sprinting. On the other hand, there is no doubt that teaching technique should go parallel with speed-strength practice and that biomechanical parameters should match the level of speed. In teaching particularly, the measurement and evaluation of biomechanical variables should be continuously carried out because they are interrelated with the potential speed of man.

REFERENCES

R.Ballreich
Model for estimating the influence of stride length and stride frequency on the time in sprint events.
In: P.V.Komi (Ed), Biomechanics V-B, 1976, pp. 208-212, Baltimore, University Park Press.

T.Bober, J.G.Hay, C.A.Putnam and G.G.Woodworth
Factors influencing the angular velocity of a human limb segment.
Unpublished paper, 1985.

C.Bosco
Stretching-shortening cycle in skeletal muscle function.
Studies in Sport, Physical Education and Health 15
University of Jyvaskyla, Jyvaskyla, 1982.

G.A.Cavagna, L.Komarek and S.Mazzoleni
The mechanics of sprint running.
Journal of Physiology, 1971, nr 217, pp. 709-721.

K.Hoffmann
Długość i częstotliwość kroku czołowych sprinterów świata (Stride length and stride frequency of the world class sprinters).
Monografia Nr 17, WSWF Poznań, 1967, pp. 344-353.

P.V.Komi
Neuromuscular performance: factors influencing force and speed production.
Scandinavian Journal of Sports Sciences, 1979, vol. 1, nr 1, pp. 2-15.

R.Mann and J.Herman
Kinematic analysis of Olimpic sprint performance: Men's 200 meters.
Int. Journal of Sport Biomechanics 1985, 1, pp. 151-162.

A.Mero and P.V.Komi
Effect of supramaximal velocity on biomechanical variables in sprinting.
Int. Journal of Sport Biomechanics, 1985, 1, pp. 240-252.

T.Tołłoczko
Biomechaniczne czynniki warunkujące prędkość biegu sprinterskiego (Biomechanical factors limiting sprint velocity).
Doctor thesis, AWF we Wrocławiu, 1985.

W.J.Wołkow and M.Koriagin
Z badań nad kryterium obciążeń treningowych (From the investigation of the criterion of sports practice loads).
Sport Wyczynowy 1977, nr 7.

I.L.Żukow and B.W.Szabanow
Effectivness of utilization of some kind of easy steering of sprinter's preparation (in Russian).
Teoria i Praktika Fiziczeskoj Kultury, 1983, nr 7, pp.9-12.