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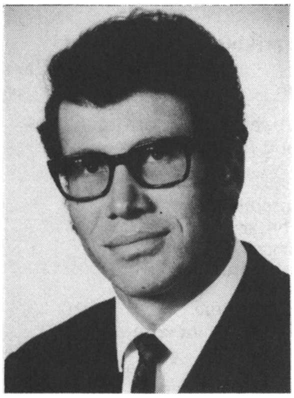

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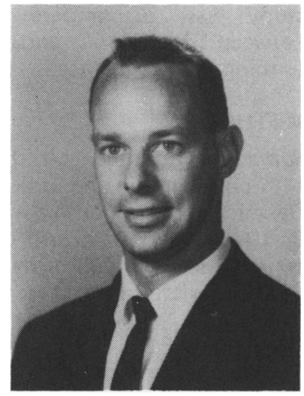

D. A. Kaufmann

ANNOTATION

BIOMECHANICAL ANALYSIS OF SPRINTING: DECATHLETES VERSUS CHAMPIONS

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ABSTRACT

The purpose of this study was to compare some biomechanical variables of decathletes and world class sprinters while running the 100 metre race. Sixteen Swiss national decathletes and three world class American sprinters were filmed by a 16 mm Locam (100 fps) camera at the 70 m mark of the race. The co-ordinates for a 26-point stick figure were digitised and then submitted to analysis by a computer programme which produced quantitative data for 12 biomechanical variables. The data indicated that world-class sprinters differed from decathletes in running the 100 m dash by having (1) an optimal combination of a larger stride length and higher stride frequency (2) a smaller thigh angle at contact which shortens the contact time (3) a larger stride landing angle (4) a greater average acceleration of the thigh angle and (5) a larger trunk angle which contributes to a larger trunk/thigh angle. Although other factors such as culture, training, physique and racial differences may influence differences in performance between American world-class sprinters and Swiss decathletes, these data do indicate that biomechanical variables may contribute to differences in 100 m dash performance.

INTRODUCTION

Many authorities today consider inherent ability to be the prime factor underlying the production of world class performance in the 100 metre sprint. Usually, sprinters who have natural ability try sprint competition and develop without any significant coaching on technique. An important question is: how can the less-endowed sprint athlete approach the performance of the world class sprinter? He can only do this by utilising superior psychological and biomechanical techniques. Fenn (1930) performed probably the first modern cinematographical study of sprinting in 1930. Thirty-four years later Deshon and Nelson (1964) published a fundamental cinematographical analysis of sprint running from which we have patterned our studies.

It was felt that a comparison of the biomechanical variables of decathletes, who are great all-round track and field athletes, and the biomechanical variables of world class sprinters would detect exactly what biomechanical variables make the world class sprinter superior in performance in the 100 m dash. If these variables could be discovered, it would be a great aid to those coaches who are trying to develop less-talented sprinters to achieve maximal performance within their range of potential development. The purpose of this

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study was to compare the biomechanical variables between decathletes and world class sprinters while running the 100 m race.

METHODS

Subjects: The subjects for this study were 16 decathletes who competed in the 100 m dash at the Swiss National Decathlon Championships at Bern, Switzerland, on July 9, 1977 and three world class American sprinters who competed in the 100 m dash at an international meet at Zürich, Switzerland, on August 24, 1977.

Procedure: Four strides were filmed while running the 100 m dash by a 16 mm Locam camera (100 fps) at the 70 m mark of the race.

The co-ordinates for a 26-point stick figure were measured using a Vanguard Film Analyser. These data were digitised by a Hewlett-Packard Digitiser and then submitted to a computer programme which produced quantitative data for 12 variables in scatterplot diagrams. The centre of gravity was determined by the method of Dempster.

Figure 1 depicts the details of the stick figure. Table I presents the symbols, definitions and relative percent of error for the variables measured. On the angular measurements one millimetre error equals one degree on each angle.

RESULTS

Three world class American sprinters, compared with 16 National class Swiss decathlete sprinters demonstrated not only the expected superiority in the 100 m sprint but also demonstrated a longer stride, faster cadence, briefer support phase, smaller landing angle, smaller

TABLE I

Kinematic variables

Symbol	Variable	Definition	Percent of error
S_1 S_2 S_3 S_4	Stride length 1–4	Distance between toes of rear leg and toes of front leg (metres)	1.5 %
$T_{1\ 4}$	Time for four strides	Time elapsed between last surface contact of first stride to last surface contact of fourth stride (seconds)	2 %
T_K	Contact time	Time elasped while support is in contact with surface (seconds)	10 %
γ	Stride landing angle	Angle between horizontal and line from cg of body to toes at moment of first surface contact (t_1/t_3) (degrees)	2 %
λ	Thigh angle	Angle between both thighs at moment of first surface contact (degrees)	15 %
ϵ	Average angular acceleration of thigh	Average angular acceleration of thigh about hip joint during contact time (degrees/sec^2)	3 %
η	Trunk angle	Angle between horizontal and line from midpoint of shoulders to hip at moment of first surface contact (t_1/t_3) (degrees)	2 %
T_{100}	100 metre time	Time elapsed during 100 metre race (seconds)	2 %
ϕ	Trunk/thigh angle	Angle between shoulders-midpoint-hip line and hip-knee line of push-off leg (t_2/t_4) (degrees) at last surface contact	2 %

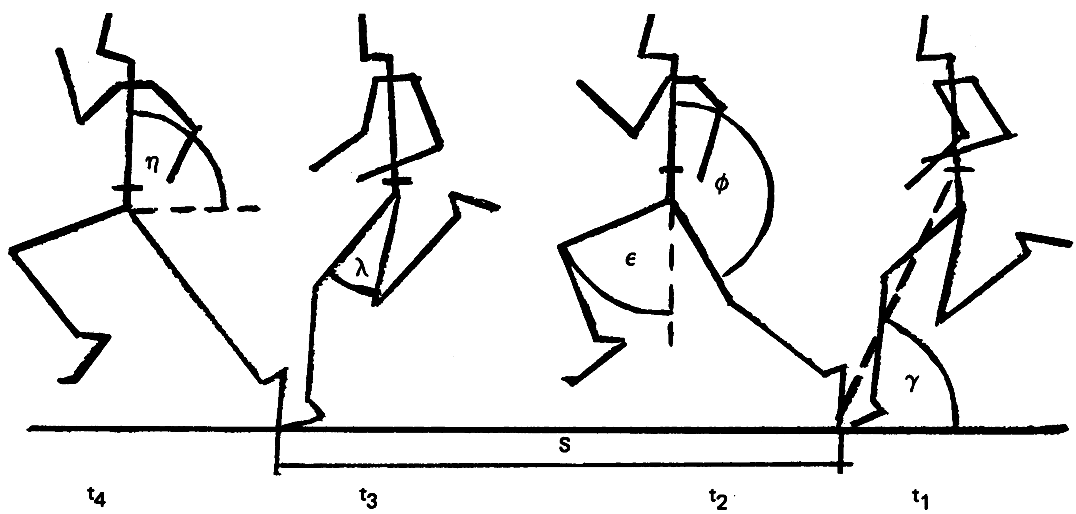

Fig. 1: Kinegram of sprinter depicting biomechanical variables.

thigh angle and contact time, greater thigh acceleration, larger trunk inclination and greater trunk/thigh angle (Figs. 2 to 10). Only in one case, a comparison of thigh angle and stride landing angle, did the world class American sprinters have approximately the same values as the Swiss decathlete sprinters (Fig. 1).

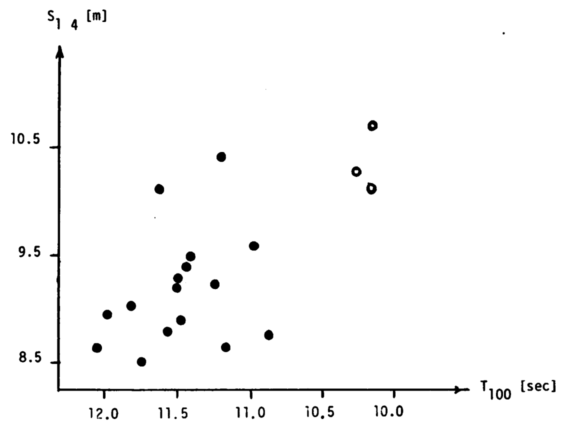

Fig. 2: Relationship between stride length for four strides ($S_{1\ 4}$) and 100 metre time (T_{100}) (● = decathletes, ○ = world class sprinters).

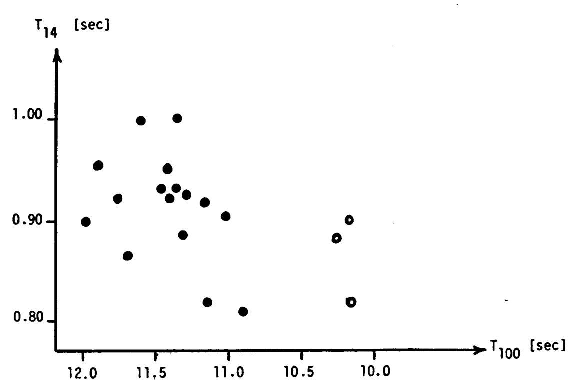

Fig. 3: Relationship between time for four strides (T_{14}) and 100 metre time (T_{100}) (● = decathletes, ○ = world class sprinters).

DISCUSSION

The two main biomechanical factors influencing running speed are stride length and stride frequency. The data in Figs. 2 and 3 confirm this fact as the world class sprinters had both a superior stride length and stride frequency than the decathletes. An often asked question is: which of these two factors is the most important? There is no clear, definite answer to this question, because the two factors affect each other so directly, and there are limits to the positive effects one factor may have on the other. Too long a stride length (over-striding) may decrease stride frequency while too fast a stride frequency may shorten stride length, and both of these conditions can decrease sprinting performance. Optimum use of both these factors must be made for each individual sprinter. The optimal relationship between these factors for an individual sprinter could depend on his standing height, leg length, crural index (ratio of calf length to thigh length), explosiveness of muscular contractions and speed of movement of his limbs. The world class sprinters, due to a large endowment of physical and physiological abilities, probably attain an optimal balance of these two factors, thus achieving great sprinting performance.

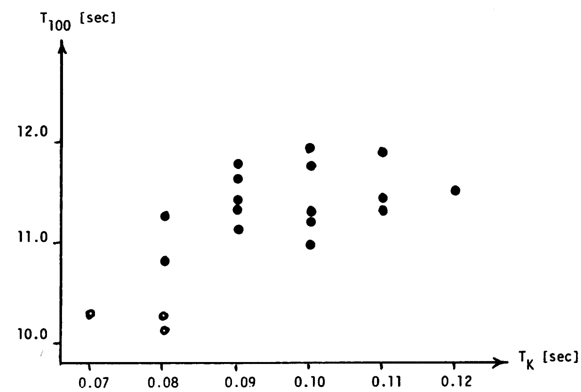

Fig. 4: Relationship between contact time (T_K) and 100 metre time (T_{100}) (● = decathletes, ○ = world class sprinters).

Figure 4 demonstrates that the contact time of the world class sprinter is very short. Since their stride length is also relatively large compared to the decathlete, this indicates that they probably have a greater explosiveness of their push-off against the surface. It is possible that the world class sprinter has the ability to exert great force against the surface with his feet in a shorter time period than the decathlete.

Figure 5 shows that the world class sprinter places his foot at a smaller distance in front of his body's centre of gravity at first surface contact than the decathlete. Conceptually, they keep the cg of the body closer to the point of touch-down of the striding leg. It appears that a possible fault of many sprinters is to have the cg of the body too far back from the toe of his foot, the cg of the body is lower resulting in a smaller stride landing angle, and this could affect the contact time.

Figure 6 shows that some of the decathletes had the same relationship between the thigh angle and stride landing angle as the three world class sprinters. Our experience indicates that the better sprinters have a

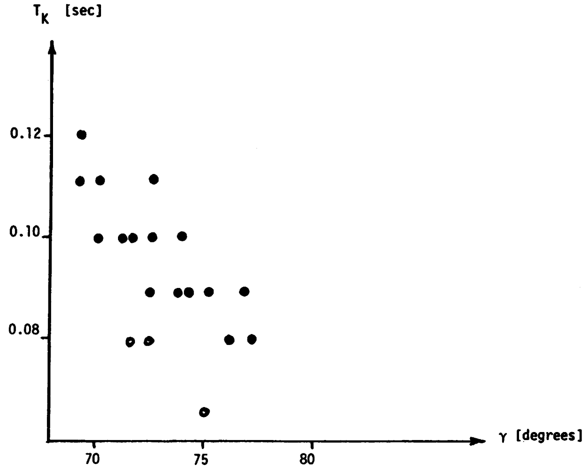

Fig. 5: Relationship between stride landing angle (γ) and contact time (T_K) (● = decathlete, ○ = world class sprinters).

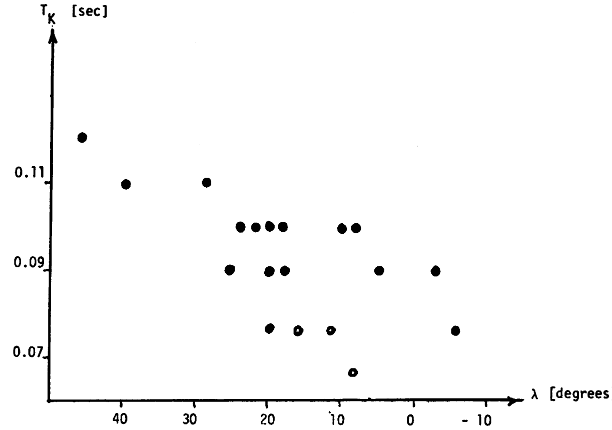

Fig. 7: Relationship between thigh angle (λ) and contact time (T_K) (● = decathletes, ○ = world class sprinters).

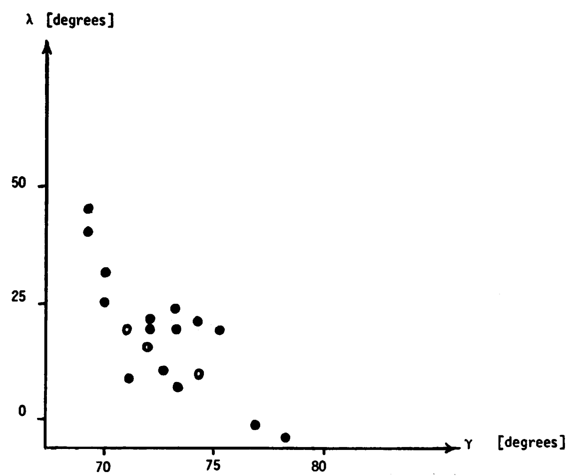

Fig. 6: Relationship between thigh angle (λ) and stride landing angle (γ) (● = decathletes, ○ = world class sprinters).

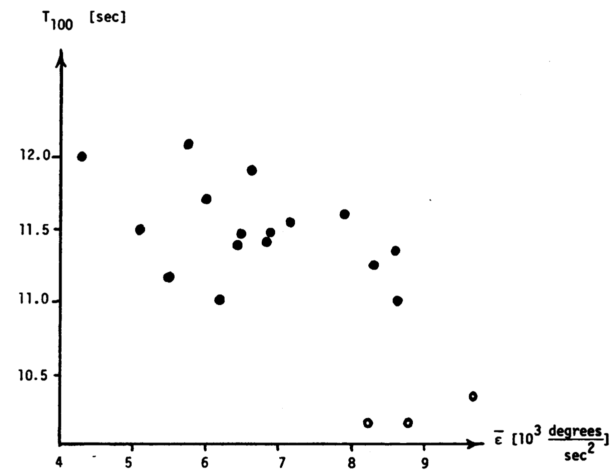

Fig. 8: Relationship between 100 metre time (T_{100}) and average acceleration of thigh angle (ε) (● = decathletes, ○ = world class sprinters).

smaller thigh angle (ranging from 0° to 20°) than slower sprinters. It is possible that this smaller thigh angle helps to increase the stride landing angle and also to decrease the contact time (see Fig. 7) and finally to increase the sprinting speed.

Figure 8 demonstrates that the world class sprinters who had superior times for the 100 m race also had a greater forward lean of the trunk angle.

Figure 10 demonstrates that the world class sprinters had a longer average stride length and a larger trunk/thigh angle than the decathletes. The larger trunk angle contributes to a larger trunk/thigh angle, and both of these factors contribute to a larger average stride length and finally a faster time in the 100 m race.

Because it was not possible to film more than three world class sprinters, and an N of three is small and not comparable to an N of 16, it is possible that the plotted data is insignificant. However, we feel that the descriptive data presented will lead other researchers to further test our observations. Also, since each of these two groups comes from a different country where coaching techniques may differ, it is possible that differences in technique may be due to different training emphases in

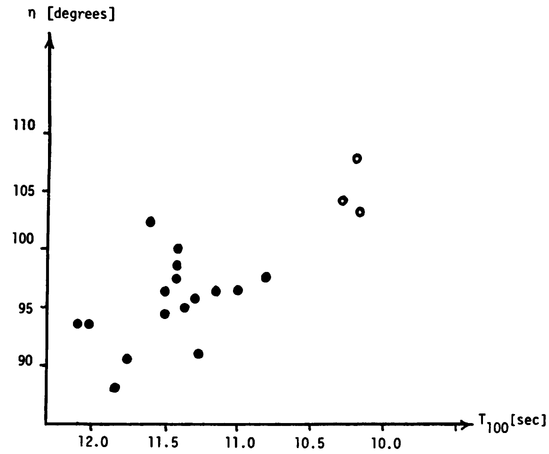

Fig. 9: Relationship between trunk angle (η) and 100 metre time (T_{100}) (● = decathletes, ○ = world class sprinters).

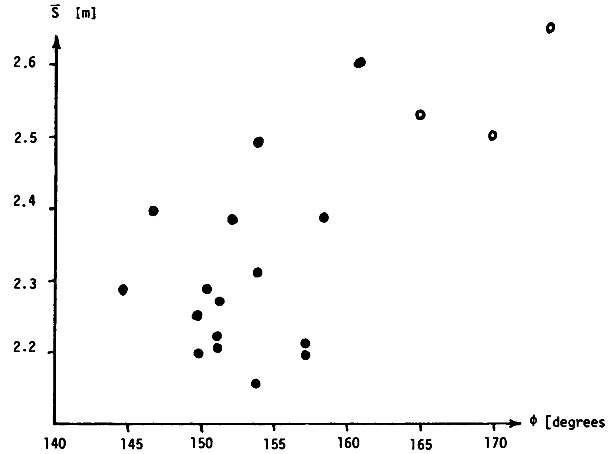

Fig. 10: Relationship between average stride length (S) and trunk/thigh angle (φ) (● = decathletes, ○ = world class sprinters).

their respective countries. These data indicate that for the subjects in this study world class sprinters differ from decathletes in running the 100 m run by having:

1. an optimal combination of a larger stride length and higher stride frequency,
2. a smaller thigh angle at contact which shortens the contact time,
3. a larger stride landing angle,
4. a greater average acceleration of the thigh angle,
5. a larger trunk angle which contributes to a larger trunk/thigh angle.

Since these biomechanical variables appear to distinguish world class sprinters from dechatlete class sprinters, it is plausible that coaches should evaluate these variables in their sprinters and determine ways to improve them in order to maximise sprinting speed.

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