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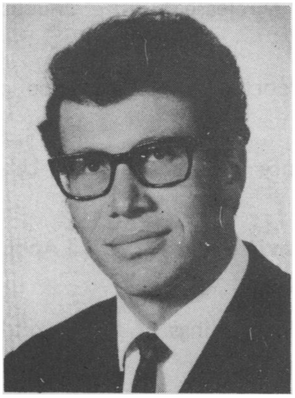

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CINEMATOGRAPHICAL ANALYSIS OF JAVELIN THROWING TECHNIQUES OF DECATHLETES

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ABSTRACT

The purpose of this study was to analyse by correlational methods the biomechanical factors involved in achieving the maximal distance thrown in the javelin event. Twelve Swiss decathletes and two world class javelin specialists were filmed by a high speed (102 fps) 16 mm camera throwing a total of 20 trials. The co-ordinates of the resulting cyclograms were processed by a computer programme and the results submitted to correlational analysis. The highest correlation was 0.76 between velocity at release and distance thrown. Other negative correlations were found between distance thrown and angle of the javelin with the horizontal (0.52) and distance thrown and throwing hand to contralateral foot distance during the last strides (0.67). Javelin specialists, who had longer throws than decathletes ($\bar{x}$ = 79.03 m versus 54.29 m), had a smaller difference between the angle of attack and angle of release. The results suggest that in order to attain maximal distance thrown the javelin thrower should achieve positive acceleration during the running approach, effective thrusting with the right leg on the penultimate stride and carry the javelin during the last strides at the optimal angle of release (32 to 36 degrees).

Key words: Cinematographical, Decathletes, Javelin throw.

INTRODUCTION

The present study was undertaken to analyse by correlational methods the main biomechanical factors related to the maximal distance thrown for the javelin event. Correlations, although not demonstrating definite causes and effects, are concepts of relationships. The authors are hopeful that the knowledge of these relationships between technical parts can help javelin coaches and competitors understand the integration of detailed movements into the complete javelin technique, and perhaps help to prevent some injuries.

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METHODS

The data for this study were collected at the National Swiss Decathlon Competition held on 27th-28th May, 1978, at Weinfelden, Switzerland. Twelve decathletes throwing a total of 17 trials and two world class javelin specialists throwing three trials at another meet were filmed with a 16 mm highspeed Locam camera (102 fps) at a right angle to the plane of action.

The cyclograms were analysed on a Vanguard Film Analyser which transferred the co-ordinate measures to a Hewlett Packard digitiser. A one percent error of measurement was calculated for the cyclogramic

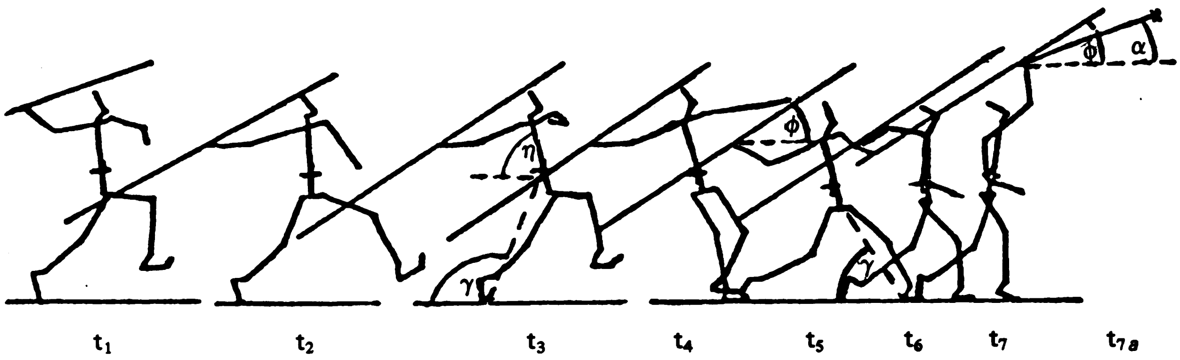

Fig. 1: 26 point kinegram. Body positions used in the analysis of the javelin throw.

Key:

- t_1 *Instant of last surface contact of fourth to last stride.*
- t_2 *Instant of last surface contact of third to last stride.*
- t_3 *Instant of last surface contact by push-off stride (second to last stride).*
- t_4 *Instant of first surface contact by last stride before release.*
- t_5 *Instant of first surface contact of support leg (last stride).*
- t_6 *Instant when throwing elbow reaches height of shoulder axis.*
- t_7 *Instant of last hand contact with javelin at release.*
- t_{7a} *Instant of point of hand grip on javelin after 50 msec from position t_7.*
  Angle between horizontal and a line from centre of gravity.
- η *Angle of trunk to the horizontal.*
- ϕ *Angle of carry.*
- α *Angle of release.*

analysis. Data were fed into a computer programme which gave a printout of 15 linear and angular variables during seven body positions, four variables during six time sequences and seven separate variables. In total 74 variables were submitted to correlational analysis. Since the sampling procedures were neither random nor independent, the assumptions of statistical inference are not tenable, hence, the results were described without significance testing.

RESULTS

Only those correlations that have instructional significance are reported here.

Table I presents the data on the decathletes. All but one of the subjects threw the javelin with their right arms, and hence, our descriptions are for right-handed throwers.

Figure 1 presents the details of the 26 point cyclograms taken from the film.

Table II presents the correlations between distance thrown and nine other variables. The velocity of the javelin at release (Vo) resulted in a correlation of 0.757 with distance thrown which corresponds to the mechanical models where the distance thrown is proportional to V^2. Although this is to be expected, it is important to note that only about one-half (100 r^2) of the common variance could be accounted for by this relationship, leaving the remainder to be explained in other ways. The negative correlations between distance thrown and angle of the javelin with the horizontal at

TABLE I

Subject data

Subject	Age (yr)	Ht (cm)	Wt (kg)	Trial	Distance (m)
1	27	1.82	70	1	56.50
				2	59.24
2	20	1.86	80	1	44.26
3	27	1.83	78	1	49.28
4	20	1.89	82	1	52.80
5	22	1.82	88	1	49.50
6	19	1.85	75	1	48.00
7	22	1.85	80	1	67.14
8	22	1.88	80	1	58.94
				2	58.00
9	20	1.97	84	1	45.50
				2	47.50
10	22	1.88	82	1	62.02
				2	59.50
11	20	1.90	82	1	51.00
12	23	1.83	78	1	50.00
				2	49.76

t_5, t_6, and t_7 indicates that on the longest throws the javelin angle with the horizontal at time periods t_5 to t_7 was small, approaching the optimal angle of release. This means that the better throwers had a lower angle of attack of the javelin. No thrower had an angle of attack below the theorised optimal angle of release, therefore, this suggests for greater distance thrown the javelin would be carried during t_5 to t_7 as close as possible to the theorised optimal angle of release which was determined to range from 32 to 36 degrees (Wyttenbach, 1979). It has been discovered in comparing throws between decathletes and two javelin specialisls, one a one-time world record holder (Nigg et al, 1974; Wyttenbach, 1979), that the specialists who had far superior distances thrown ($\bar{x}$ = 79.03 m versus 54.29 m) had a very small difference between the angle of the javelin with the horizontal during positions t_5 to t_7 and the angle of release of the javelin than the decathletes.

TABLE II

Correlations with distance thrown (N = 17)

Symbol	Name	Definition	Correlation
V_O	Velocity at Release	Velocity of Javelin's centre of gravity at Release	.757
ϕ_{t5}	Angle of Carry t_5	Angle of Javelin with Horizontal at t_5	–.516
ϕ_{t6}	Angle of Carry t_6	Angle of Javelin with Horizontal at t_6	–.670
ϕ	Angle of Attack	Angle of Javelin with Horizontal at t_7	–.604
$d\ HH_{t4}$	Hand-Hip Distance t_4	Distance from Hand (R) to Hip at t_4	–.476
$d\ HF_{t5}$	Hand-Foot Distance t_5	Distance from Hand (R) to Toe (L) at t_5	–.446
$d\ HF_{t6}$	Hand-Foot Distance t_6	Distance from Hand (R) to Toe (L) at t_6	–.440
$d\ HF_{t7}$	Hand-Foot Distance t_7	Distance from Hand (R) to Toe (L) at t_7	–.563
$t_{4\text{-}7}$	Time $_{4\text{-}7}$	Time Elapsed from t_4 to t_7	–.442

Another important factor is the difference between the angle of attack (attitude angle) and the angle of release. Figure 2 presents a plot of the relationship between the difference between the angle of attack (angle of the horizontal with the javelin) and angle of release (angle of horizontal with the path of the centre of gravity of the javelin) and the distance thrown between decathletes and two javelin specialists. Here we see that the javelin specialists had the longest throws and also the smallest difference between the angle of attack (ϕ) and the angle of release (α).

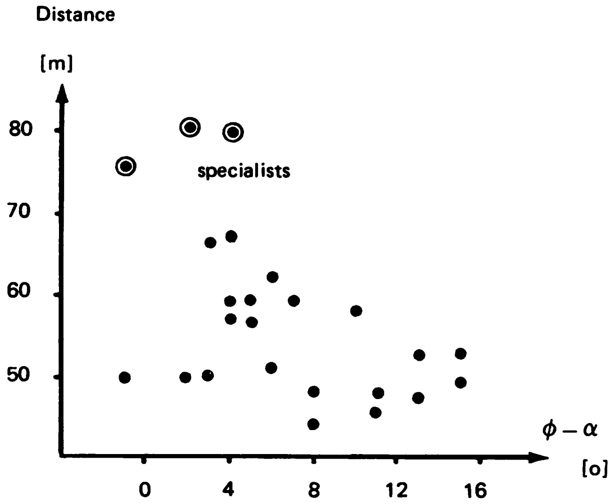

Fig. 2: Relationship between difference of angle of attack (ϕ) and angle of release (α) of javelin and distance thrown for decathlete and specialist javelin throwers.

The negative correlation between the throwing hand to contralateral hip distance and the distance thrown at position t_4 may mean that the better throwers shortened this distance at this position in order to attain a maximal distance thrown. The same meaning may hold true for the negative correlation for throwing hand to contralateral foot distances during positions t_5 to t_7. The shortening of this distance can be accomplished by pushing the right leg forward and not by flexing the throwing arm. Shortening both these distances during positions t_4 and t_5 to t_7 may enable the thrower to sum the consecutive torques exerted at the ankle, knee, hip and pelvic trunk region using the left leg as a stabilising but pivoting, near straight-legged support against the ground (positions t_5 to t_7).

Table III presents the intercorrelations between the velocity of the javelin at release and 15 other variables.

The positive correlation between the trunk angle at t_3 and velocity of the javelin at release means that since only one-fourth (100 r^2 = 24%) of variances of trunk angle and javelin velocity is common there is just a slight positive tendency for larger trunk angles to be associated with greater release velocity. This may indicate that the better throwers thrusted vigorously forward with the pushing leg (left) at this position (t_3).

The positive correlation for the angle between the centre of gravity (cg) of the body and the left (support) heel at positions t_5 to t_7 indicates that the better throwers have a larger angle during these positions meaning that the throwers may ride their centre of gravity of the body high over their pivoting support (left) leg possibly, in order to sum the consecutive

TABLE III

Correlations with velocity of javelin at release (N = 17)

Symbols	Name	Definition	Correlation
η_{t3}	Trunk Angle t_3	Angle of Trunk with horizontal at t_3	.488
γ_{t5}	cg-Heel Angle t_5	Angle between Line from the Body to Heel (L) and Horizontal at t_5	.480
γ_{t6}	cg-Heel Angle t_6	Angle between Line from cg of Body to Heel (L) and Horizontal at t_6	.485
γ_{t7}	cg-Heel Angle t_7	Angle between Line from cg of Body to Heel (L) and Horizontal at t_7	.490
γ_{t3}	cg-Toe Angle t_3	Angle between Line from cg of Body to Toes (L) at t_3	.558
ϕ_{t5}	Angle of Carry t_5	Angle of Javelin with Horizontal at t_5	–.472
ϕ_{t6}	Angle of Carry t_6	Angle of Javelin with Horizontal at t_6	–.565
ϕ	Angle of Carry t_7	Angle of Javelin with Horizontal at t_7	–.629
H_{t6}	Cg Height t_6	Perpendicular Height of cg of Body above Ground at t_6	–.471
$d\ HF_{t6}$	Hand-Foot Distance t_6	Distance from Hand (R) to Toe (L) at t_6	–.423
$d\ HF_{t7}$	Hand-Foot Distance t_7	Distance from Hand (R) to Toe (L) at t_7	–.561
v_{t5}	cg Velocity t_5	Velocity of cg of Body at t_5	.476
v_{t6}	cg Velocity t_6	Velocity of cg of Body at t_6	.476
v_{t7}	cg Velocity t_7	Velocity of cg of Body at t_7	.461

muscular torques at the ankle, knee, hip and pelvic-trunk region. This may be the result of a vigorous thrust of the right leg at t_4 to t_7. Theoretically, the better the push forward with the right leg at t_4 to t_7, the greater the angle between the centre of gravity of the body and the heel of the left foot at t_7 which may increase the net power of the javelin at release.

The positive correlation between the angle of the centre of gravity of the body and the toes of the left foot at t_3 with the velocity of release of the javelin may indicate that the throws with the faster releases of the javelin had higher angles between the centre of gravity of the body and the toes of the left foot at t_3. This suggests a forward rather than upward push of the left leg at t_3.

The negative correlations between the angle of the javelin with the horizontal at positions t_5 to t_7 with velocity of the javelin at release means that the closer this angle is to the theorised optimal angle of release, the greater the velocity of release of the javelin. In scanning our data, we find that no decathlete javelin thrower or javelin specialists carried the javelin at positions t_5 to t_7 lower than their optimal angle of release of the javelin. The technical error at positions t_5 to t_7 may be carrying the javelin higher than the optimal angle of release.

The negative correlation between the height of the centre of gravity of the body and the velocity of release of the javelin at position t_6 may mean that on the throws with the faster releases of the javelin the angle of the left leg with the ground is large causing a rising of the body's centre of gravity. This may mean that the right leg at position t_6 must push forward forcefully in order to bring the centre of gravity of the body up over the left leg for effective power application to the javelin at release.

The negative correlation between the distance from the right hand to the left foot at position t_6 and t_7 with the velocity of the javelin at release indicates that this distance shortens on the throws with the fastest velocity of release. This probably means that the better throwers push more effectively with their pushing leg (right) at positions t_5 to t_7.

The positive correlations between the velocity of the centre of gravity of the body at positions t_5 and t_7 and velocity of the javelin at release indicates that the better throwers are moving at an optimal rate during this time. It is the opinion of the authors that most decathlete javelin throwers do not move fast enough at positions t_3 and t_6 and hence do not attain the necessary explosion at position t_7. Since these conclusions are based on correlational analysis, these views are cautiously expressed as possible hypotheses.

DISCUSSION

It is well-known that the two primary factors that determine the distance thrown of the javelin are

1. the magnitude of the velocity at release and
2. the angle of release.

The question is what main technical movements facilitate the maximal magnitude of velocity at release and the optimal angle of release? Our data suggest that the running approach of the body controlled by the leg torques is an essential factor in achieving the best magnitude of velocity at release. The run must achieve positive accelerations throughout the approach and peak at release of the javelin. Failure to accelerate the body during the approach to the point of release prevents the thrower from attaining maximal power at release. This means the thrower must be sure to push effectively with his left foot at t_3 and then with his right foot at t_4

to t_6. This agrees with Witchey (1972) who claims that the horizontal velocity of the right iliac crest during the power phase is related positively to the length of the horizontal distance thrown. Conceptually, the thrower must throw with his legs and not with his arms. Although the final throwing movement is by the upper limb about the shoulder joint, the leg thrusts controlling the approach greatly affect the velocity of release of the javelin.

Our data also suggest that the angle of the carry of the javelin during positions t_4 to t_7 is very important. The difference between the angle of attack and the angle of release should be small. During these positions the thrower must carry the javelin at the optimal angle of release which studies at our laboratory (Nigg et al, 1974; Wyttenbach, 1979) indicate ranges from 32° to 36°. Ranson (1972) claims the optimal angle of release should range from 35° to 41°. It is possible that he attained higher values for this variable than we did because of different wind conditions. The typical fault appears to be that at position t_4 the thrower leans his trunk backward which in turn drops his throwing arm and alters the angle of his grip. As a result he tends to raise the angle of the carry of the javelin and fails to release it at the theorised optimal angle of release. Conceptually, the thrower should try to carry the javelin parallel with the theorised optimal angle of release. Ideally, the angle of attack should coincide with the optimal angle of release. In the throwing movement the application of the forces to the javelin must be directly through the long axis of the javelin which should be angled at the theorised optimal angle of release. In other words, the thrower tries to pull the tail of the javelin up through the point in space where the grip was and on through the point in space where the point of the javelin was. The typical error may be that the thrower drops the tail of the javelin as he pulls it up and through, in effect increasing the angle of attack above the optimal angle of release.

Although the correlations reported had technique value, the correlation matrix was very large, and it is possible some of the reported correlations may be high due to chance. Hence, the authors urge caution in placing too much reliance on the generalisations from the data.

Although the statistics in this study do not show a cause-and-effect relationship, they do suggest that the most important variables affecting maximum performances are positive acceleration during the running approach, effective thrusting with the left leg at the instant of last surface contact by push-off stride (t_3) and similarly effective thrusting with the right leg at first surface contact of last stride before release (t_4) i.e., when throwing elbow reaches height of shoulder axis (t_6) and carrying the javelin during the first surface contact of support leg (t_5) and to the instant of last hand contact with javelin at release (t_7) as close as possible to the optimal angle of release (32° to 36°).

Since during the running acceleration there is a great build-up of torques at the ankle, knee, hip, and intervertebral joints which culminate during the final leg thrust and throw; therefore, these joints are susceptible to possible injury. The authors suggest in the Javelin Throwers' Weight Training Programme that a reasonable emphasis be put on the development of the musculature controlling these joints in order to prevent injury in these vital areas.

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