HAMMER-ATHLETE RELATIONSHIP DURING THE HAMMER THROW

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The present study analysed the movements of the athlete-hammer system in space, including phenomena that affect the functional course of the implement's circumferential velocity. The path of the spatial trajectory of the hammer head and pertinent anthropometric points were evaluated from the viewpoint of individual turns, the double and single support phase, and the delivery. For each throw the tangental and normal acceleration components and the forces acting on the implement were studied. It was determined that the positive factors, causing an increase in the velocity of the hammer head, included:

1. Vigorous leg action, with the feet continuously turning in a uninterrupted manner and never held in a static double-support position.
2. The gradual temporal shortenting of the single-support phase to make the single and double support phases of the last two turns of equal length.
3. The rotating of the trunk ahead of the pelvis, with a shift of the center of the shoulder connecting line toward the right hip-joint.
4. The turning of the shoulder axis ahead of the hammer-wire axis.
5. The vertical lifting of the hip-joints against the direction of the vertical motion of the grip and hammer head.
6. An obtuse angle, greater than 110 degrees, between the shoulder and hammer-wire axis, with the highest possible position of the implement ranging from 1.60 to 2.00 meters at the start of the delivery phase.

REVIEW OF LITERATURE

Generally, pertinent literature agrees that during the hammer throw the velocity of the hammer-head is increased mainly during the double-support phase, when the implement is descending, with the pelvis axis leading the shoulder axis and the shoulder axis in turn leading the hammer-wire axis (6, 7, 5, 9, 1). The throw proper is executed with three or four turns, seperated by the right foot plant. However, there is disagreement about the instant when the turn begins.

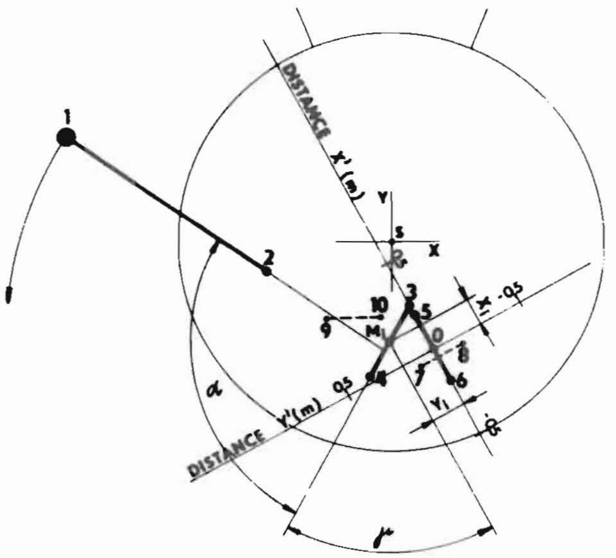

Figure 1. Projection of the anthropometric points to a planform ground plan. The position of point M (point equidistant from shoulder joints) is defined by means of a coordinate system X , Y with the start O in the center of the connecting line of the hip joints. α - angle between the shoulder axis and the axis of the hammer wire, μ - angle between shoulder axis and hip axis.

Schmolinski (7) takes the beginning of the turn to be the right-foot take-off, Arierl (1) assumes the turn starts with hammer head passing in the lowest position, and Susanka (8, 9, 10, 11) starts the turn just before the first take-off of the right foot. It is agreed that a gradual increase of the hammer velocity occurs throughout the course of the turns and during the release phase, which starts with the moment the double-support position is assumed. Several authors (1, 11, 4), using different approaches have attempted to develop three-dimensional reconstructions of the movement geometry. All of the above analyses seem to suggest that the trajectory of the hammer movement and the support phase do not necessarily limit the changes in the functional course of the implement's circumferential velocity. Acceleration may also occur in the single-support poaition while the hammer is rising.

PROCEDURE

The hammer throwers used in this study were competitors in the hammer throw of the first World Championships in Athletics held in Helsinki in 1983, and several other performers filmed at international competitions. Two phase-locked Photo-Sonics Biomechanics 500 cameras were placed 15.00 m behind and 21.00 m to the right side of the throwers with both camera lens axis horizontal and intersecting in the center of the throwing circle 1.80 m above the surface of the circle and at 90.0 degrees to each other. The cameras were operated with an exposure time of 1/2400 seconds and at 200 frames per second.

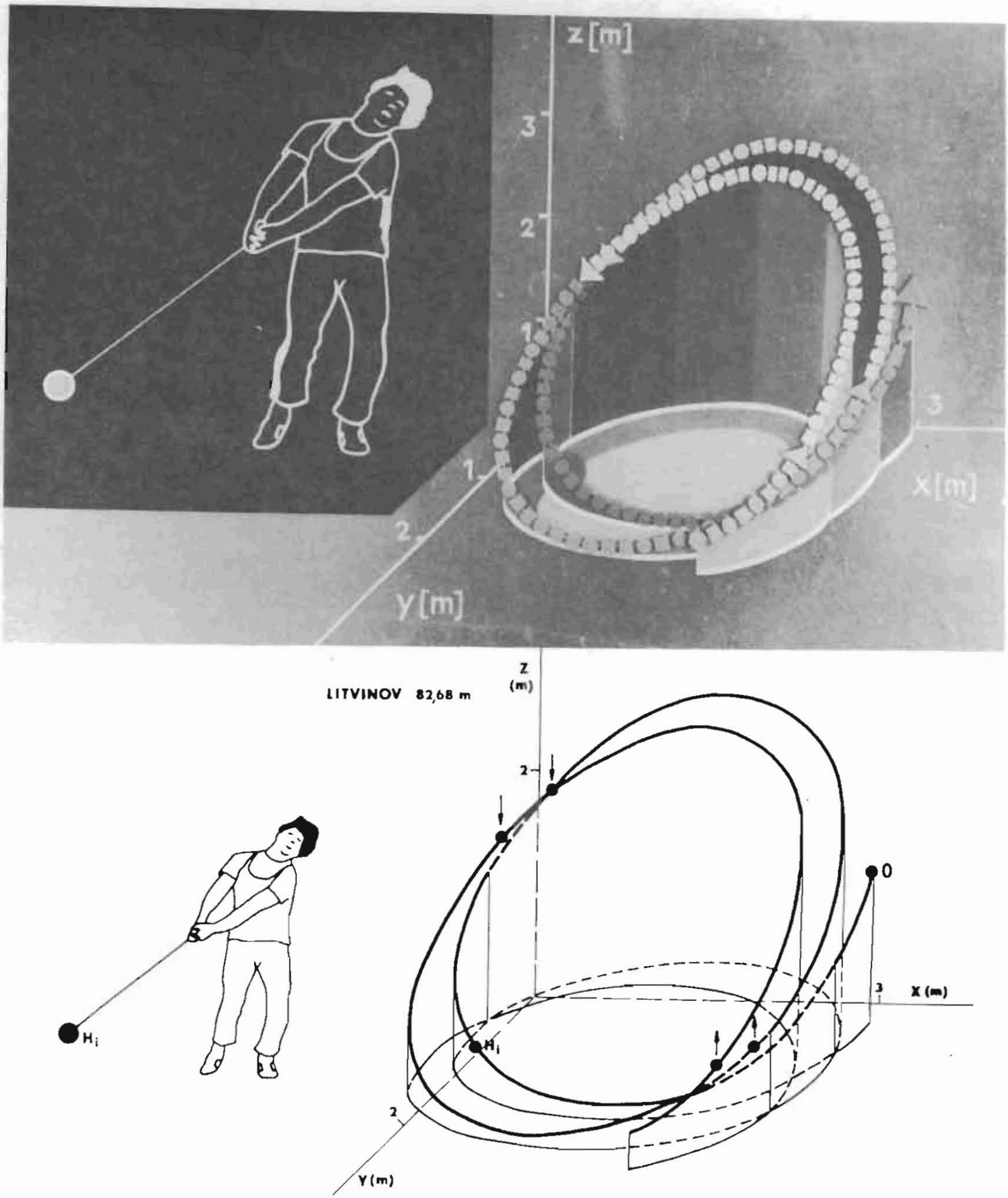

Figure 2. The trajectory of the hammer head (for timing see Tabe 1 & 2)
↑ = right foot landing, ↓ = right foot take-off

1. Timing (duration of double and single support phases) of motion in the hammer throw - 3 turns

Name	Performance (m)	1st turn Double (s)	1st turn Single (s)	2nd turn Double (s)	2nd turn Single (s)	3rd turn Double (s)	3rd turn Single (s)	Delivery Double (s)
SEDYKH	85.60	0.69	0.26	0.28	0.22	0.23	0.19	0.27
TOMASZEWSKI	73.94	0.77	0.34	0.21	0.33	0.19	0.27	0.26

Table 2. Timing (duration of double and single support phases) of motion in the hammer throw - 4 turns

Name	Performance (m)	1st turn Double (s)	1st turn Single (s)	2nd turn Double (s)	2nd turn Single (s)	3rd turn Double (s)	3rd turn Single (s)	4th turn Double (s)	4th turn Single (s)	Delivery Double (s)
LITVINOV	82.68	0.79	0.33	0.33	0.24	0.25	0.23	0.20	0.20	0.23
McKENZIE	69.24	0.89	0.33	0.33	0.27	0.22	0.29	0.19	0.33	0.20

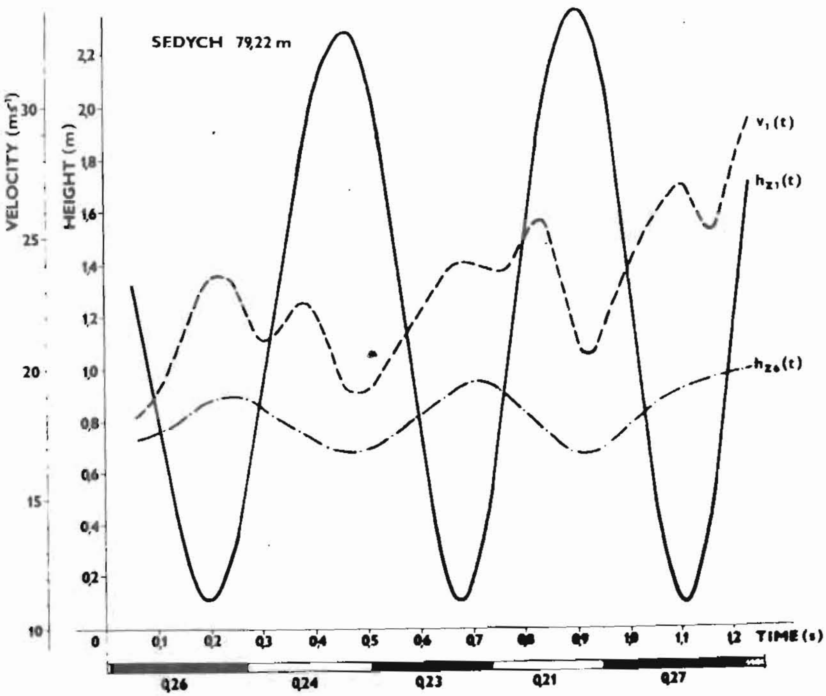

Figure 3. The hammer-head velocity V_1 (t). The vertical changes: h_{z1} (t) C... of hammer, h_{z6} (t) center of rotation of left hip-joint.
double-support phase   single-support phase

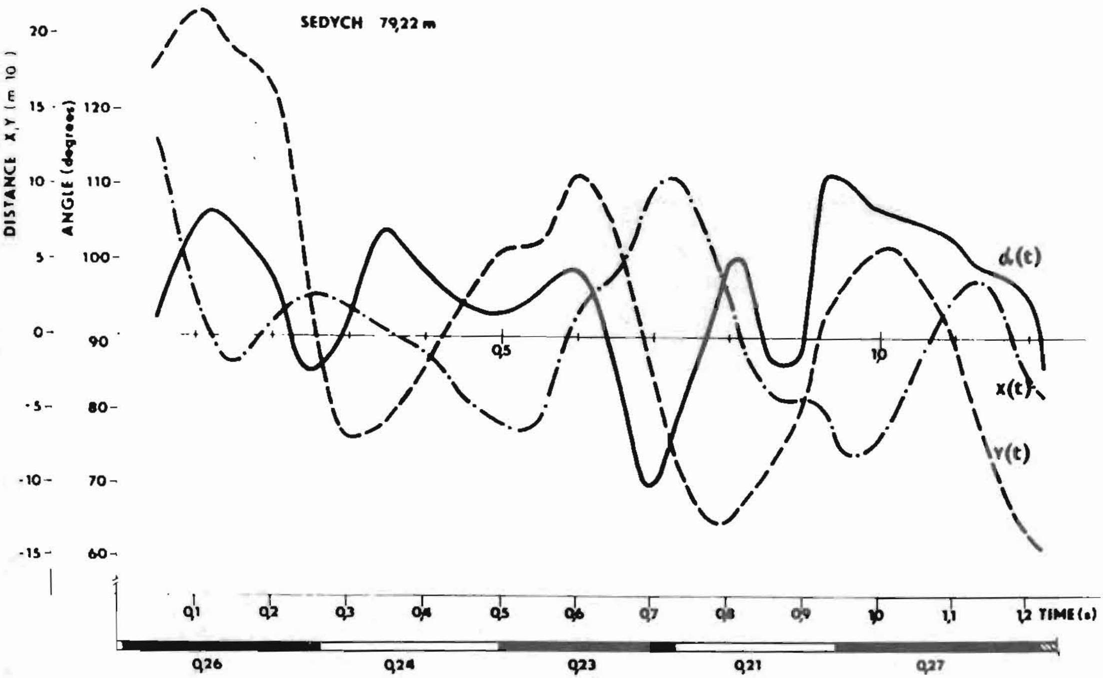

Figure 4. The position of the connecting line of the shoulder joints (M_i x_i, y_i) vis-a-vis the center of the connecting line of the hip joints and their axis.

$+x_i$ = shoulder motion against direction of hammer motion
$-x_i$ = shoulder motion in direction of hammer motion
$+y_i$ = deflection of shoulders ahead of pelvis toward hammer
$-y_i$ = deflection of shoulders behind pelvis
$\alpha(t)$ = see Figure 1.

After a preliminary study, the following points were chosen for measurement and evaluation. All the points under scrutiny may be identified in Figure 1, which is a view of the hammer throw from above. Each point is identified by a number as follows: 1. the hammer head center of mass(CM), 2. the grip CM, 3. the right shoulder joint, 4. the left shoulder joint (with 3-4 defined as the axis of the shoulders), 5. the right hip joint, 6. the left hip joint (with 5-6 defined as the axis of the pelvis), 7. the toes of the left foot, 8. the heel of the left foot, 9. the toes of the right foot, 10. the heel of the right foot (with 7-8 and 9-10 defined as the position of the left and right foot respectively).

The coordinates of the points were digitized from the film of the two phase-locked cameras using a semi-automatic PCD/Vanguard analyser, at 20.0 ms intervals. Subjective error for each frame was determined by repeated evaluation of that frame. The method of reconstructing the position of the points in space is described by Susanka and Diblik (8), with an example of three dimensional reconstruction in Figure 2. For smoothing datum the cubic spline was used.

The throws analysed were from two groups of hammer throwers seperated by ability. The lower ability group ranged in performance from 68.00 to 75.00 meters (m), while the high performance group ranged from 79.00 to 86.00m. For purposes of generalization and illustration a 79.22m throw by Y.Sedykh, from the World Championships was used. The performance of Sedykh seems to meet the demands for correct technique execution (Fig.3,4,5). Discussion refers to right handed throwers and, by definition, the start of the turn occurs just before the first take-off of the right foot.

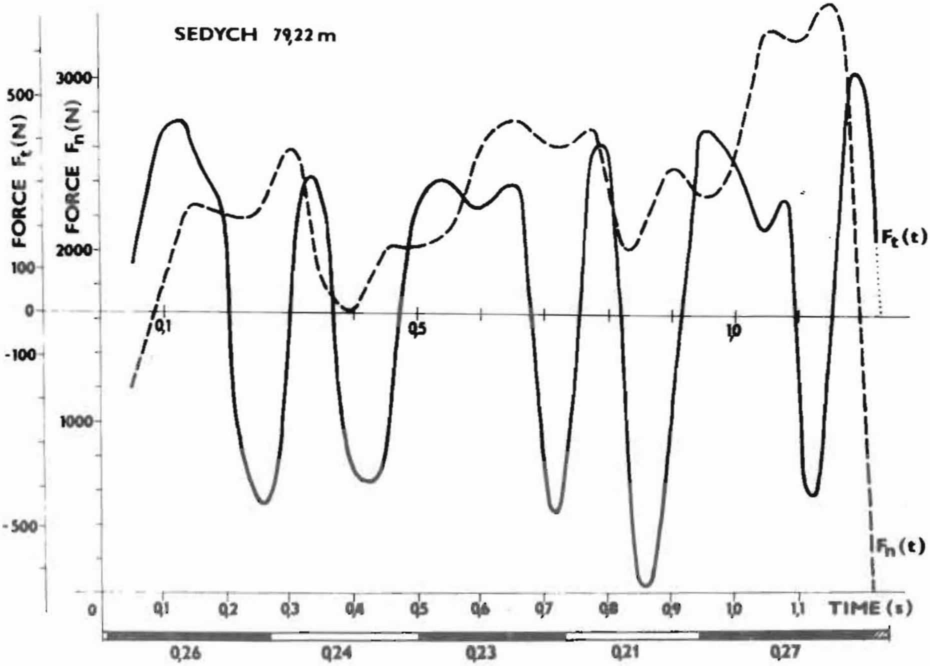

Figure 5. The tangental force $F_t(t)$ and the normal force $F_n(t)$ during the last two turns and the delivery.

RESULTS and DISCUSSION

The hammer head (hammer) acceleration occured 20 to 60 milliseconds(ms) before the double support position and 50 to 70 ms after achieving the maximum height. The hammer was not accelerated at the beginning of the descending path. Velocity of the hammer, for each turn, increased within the range of 6.00 to 9.00 m/s. On the other hand some velocity losses ranged between 4.00 to 7.00 m/s.

From a temporal point of view the duration of the individual movement-cycles are shorter for the best athletes. Also, in the last two turns before the delivery, the best athletes had an equal or close to equal time for the double and single support phases, while the double support phase was shorter than the single support phase for the other athletes (Table 1 and 2).

The movement of the athlete's trunk changed with the technique of the throw. There were changes in the shoulder axis as illustrated in Figure 1 and 4. Almost throughout the throw the athletes lead with the hip (with the pelvis turned slightly more than the shoulder axis in the direction of the throw). This positive angle of the pelvis, in the direction of the throw, was present during all but a 50 to 70 ms interval while the hammer was at its lowest point, at which time the angle of the pelvis was slightly negative. The angle of the pelvis was also slightly negative during the final phase of the release. Acceleration of the hammer increased during each double support phase as the shoulder axis was shifted ahead of the pelvis axis. On the other hand acceleration of the hammer decreased when the function of x(t)(Fig.4) was decreasing or, in other words, when the angle between the shoulder axis and direction of hammer wire decreased, hammer acceleration decreased. During this time the pelvis moved ahead of the shoulders in preparation for the next double support phase, or one could say that the sholders moved or were deflected behind the pelvis, y(t)(Fig.4).

The hammer head accelerated whenever the angle between the shoulder axis and the direction of the wire exceeded 90.0 degrees. The shoulders lead the hammer wire by as much as 110.0 degrees during each rotation cycle and as much as 116.0 degrees during the delivery phase (Fig.4). Some athletes accelerated the hammer during its rising path, while in a single support phase, with the pelvis ahead of the shoulders and the function x(t) decreasing (Fig 4).

The hammer was accelerated as the body CM was raised from 0.20 to 0.30m during each turn (Fig.3). The better athletes had a greater body CM fluctuation during each turn. The normal force of the hammer (the force at 90.0 degrees to the shoulder axis) was increased during the double support phase and the first part of the single support phase of each turn. The tangental force (in or against the direction of the hammer) was of a much smaller magnitude, fluctuating to approximate highs (in a positive and negative direction) of 500.00 N (Fig.5).

The nature of the delivery phase of the hammer throw was determined by three variables, at the instant the right foot landed for the final support. These variables are: (1) the vertical position of the hammer; (2) the position of the hammer in relation to the shoulder axis; and (3) the position of the shoulder axis in relationship to the pelvis axis. Measurements and analysis indicated that the most favorable set of the above mentioned variables was a delivery in which the hammer was low, the shoulder axis was well ahead of the direction of the hammer wire, and the pelvis axis was well ahead of the shoulders axis (up to 30.0 degrees).

Aside from the above, other points may be of practical value to the teacher, coach and athlete. It seems that the path of the hammer head during the throw should take the longest path possible, ranging between 3.60 to 4.20m of planform distance for the best throwers. The vertical lift should increase gradually, reachiong a superelevation position of 2.00 to 2.80m. Acceleration of the hammer should occur before the double support phase while the hammer is descending. In the last two turns, the double and single support phases should be of equal length and of continuous smooth motion. Also, the better hammer throwers seem to have a longer delivery phase, lasting from 10 to 40 ms longer than that of throwers of a lower ability.

REFERENCES

1. Ariel, G.B., Wells, R.M., and Harman, E., "Biomechanical Analysis of Hammer Throwing." Unpublished research report. Amherst:CBAI, 1978.
2. Black,I.S."Hammer Throw."Track and Field Quarterly Review,80.27-28, 1980.
3. Bakarinov,J. Fantalis,A. and Tschebotarev,V. "Metanie Molota." Legjaka Atletika, 4, 8-11. 1984.
4. Dapena, J. "The Patterns of Hammer Speed During a Hammer Throw and Influence of Gravity on its Fluctuations." Journal of Biomechanics, 17, 553-559. 1984.
5. Pataki, L. and Slanka, M. "Zrychlovanie Kladiva v Obratkach." Teorie a Praxe Telesne Vychovy, 25, 490-494. 1977.
6. Samozvetov, A. "The Acceleration of the Hammer." The Throws(Edit by F.Wilt) Los Altos: Tafnews. 1974.
7. Schmolenski, G. Track and Field. Leipzig:Sportverlag. 1976.
8. Susanka, P. and Diblik, J. "Raumkinematographie." Acta Universitatis Carolinae Gymnica, 8, 5-12. 1972.
9. Susanka, P. and Stepanek, J. "Shot Put and Throwing." In Series of the Film: Champions Style. Prague 78, Praha: Kratky Film. 1978.
10. Susanka, P., Stepanek, J., Tsarouchas, E., Pataki, L., Roztocil, V., and Simon, J. "Shot Put and Throwing." In Series of the Films: Champions Style II. Athens '82, Praha: Kratky Film. 1983.
11. Susanka, P., Stepanek, J. and Pataki, L. "Hammer Throw." In Series of Biomechanical Analysis: Champions Style III. Helsinki '83, Praha: Kratky Film. 1984.