A BIOMECHANICAL ANALYSIS OF THROWS WITH DIFFERENT WEIGHT AND LENGTH HAMMERS

By Dr. Klaus Bartonietz

Germany's throwing expert, Dr. Bartonietz, presents a long-term biomechanical investigation of the hammer throw technique, based on data from world's leading exponents, and stresses the need to consider kinetic energy aspects in the use of different weight and length implements. The article is a slightly edited version of the author's address to the Technique in Athletics Conference in Germany 1990. Re-printed with permission from Modern Athlete and Coach.

In 1986 the world record in the hammer throw reached 86.74m. In the near future the implement can be expected to be thrown close to the 90m mark. The record performances of the former Soviet throwers have been accompanied by improvements in other international athletes and female hammer exponents are preparing to enter the circle. All this has resulted in an ever increasing interest in the biomechanics of the hammer throw in training with hammers of various weights and lengths and led to our study to determine the effectiveness of different training hammers.

METHODS AND PROCEDURES

Throws of Litvinov, Sedych and other top athletes were filmed with two synchronized cameras in competition and training. A NAC motion analyzer was used to determine the space coordinates of the hammer head and the body of the thrower in order to calculate the time related velocity, acceleration, angular velocity, the radius of the hammer's path, as well as several other parameters.

We estimate the mistakes in the determination of the coordinates for the hammer head ±5 mm and assumed that with a stable frequency and equal phase running of the two cameras there will be a measuring mistake in the velocity values of $\pm 0.05 ms^{-1}$ and in the acceleration values of $0.5 ms^{-1}$. The estimation of the accuracy was corroborated by a comparison of the calculated force values for the hammer head with the directly measured values on a dynamometrical hammer handle. Training throws with hammer masses ranging from 5 to 17.5kg and lengths between 1.22 to 0.45m were investigated.

RESULTS AND DISCUSSION

It must be taken into consideration in the analysis of a hammer throwing movement that it is the athlete who exerts at the end force on the grip. The acting of the hammer head components on the total force summoned up by the athlete are not identical with the forces acting on the hammer handle. According to the investigations carried out by Sataki and Slamka (1977), the acceleration forces acting on the hammer grip were 2.9 times larger than the acceleration forces on the hammer head.

From the physical relations between linear and angular velocities, radius, linear and angular acceleration of the hammer movement, it becomes obvious that the thrower must strive for an optimum relationship between the radius of the hammer path and the angular velocity of the hammer movement, so that on the one hand the peripheral velocity is as high as possible and, on the other hand, the balance can be kept.

Figure 1 shows clearly the existing dependences between the peripheral velocity, the radius of the hammer path and the angular velocity of the hammer. Let us assume that limits are set to the radius extension, so the improvement of the release velocity - e.g. from 28 to 31 ms^{-1} (for a throw about 90m) is linked with a raising of the angular velocity by 2 rad s^{-1}.

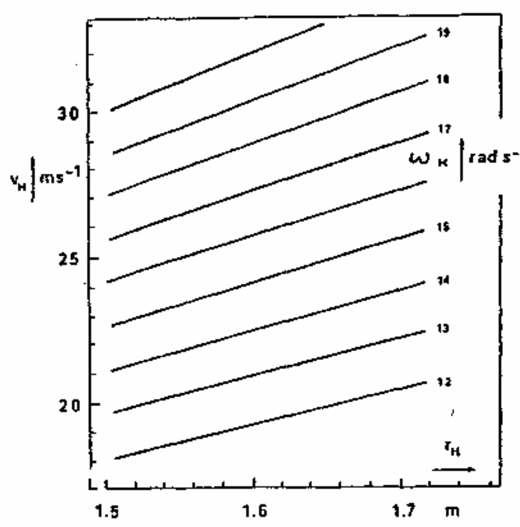


FIG. 1: Relationship between the hammer velocity (v_H), radius (r_H) and angular velocity (W_H).

The real relationship between these parameters is exemplarily illustrated by figure 2. The presentation begins with the transition to the first turn at the end of the last arm swing and ends in the release. The sections of double-support phases are set in bold type.

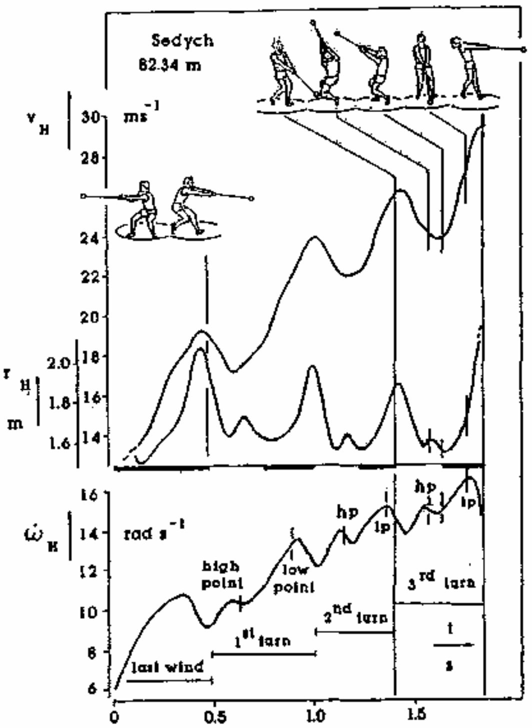


FIG. 2: Time related changes of the velocity, radius and angular velocity of the hammer.

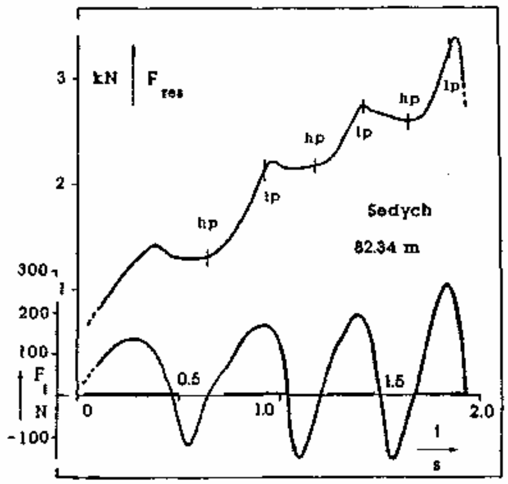
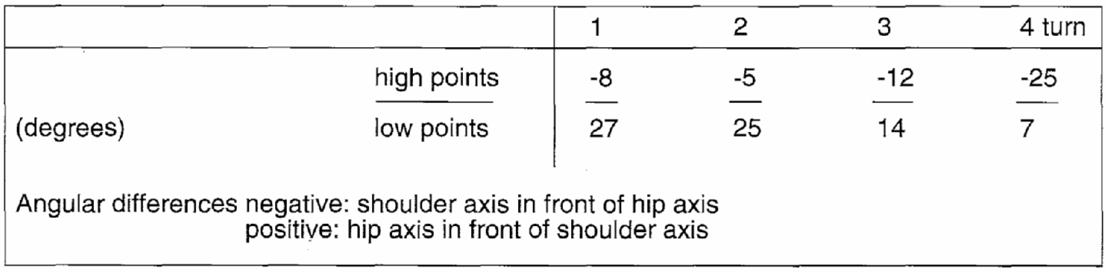


FIG. 3: Time related changes of the resulting force (F_{res}) and tangential component (F_t)

The figure points out that an increase in peripheral velocity during each separate turn is achieved by a radius extension. The angular velocity of the hammer and also of the thrower decrease at the end of the acceleration phases in the turn.

From turn to turn the increase of the hammer head's velocity and of the growing backward lean of the thrower's body are responsible for a decreasing radius.

The from turn to turn growing forces, which must be generated by the thrower, are shown in figure 3. The momentary maximal acceleration and its centripetal components that compose the resulting force are achieved in the range of the low points of the hammer path. The leg muscle groups are therefore responsible for the impetus, while the trunk and the arms transfer the forces to the hammer head. The angular differences between the shoulder axis and the hip axis ("wind-ups"), which must be relatively constantly maintained in the turns, is an expression of an effective impetus work. Stronger "winds" reduce the radius of the hammer path and thus the way of acceleration.



		1	2	3	4 turn
	high points	-8	-5	-12	-25
(degrees)	low points	27	25	14	7

Angular differences negative: shoulder axis in front of hip axis
positive: hip axis in front of shoulder axis

Table 1: Differences between the shoulder and hip axis in the high and low points of the hammer path. (S. Litvinov 86.04m)

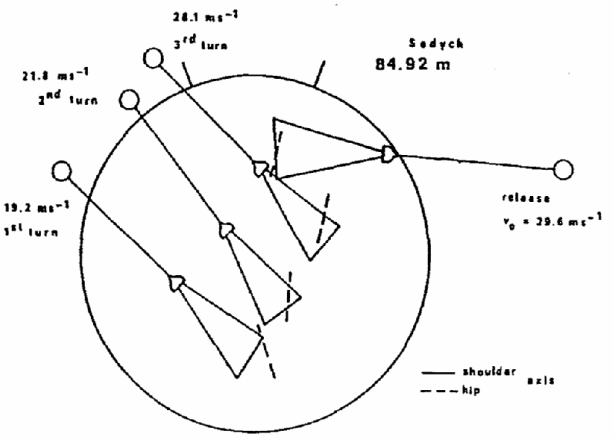


FIG. 4: Position of hammer, arms, shoulders and hip axis, as well as the velocity of the hammer at the beginning of the double support phase and at the release.

Figure 4 and table 1 show the corresponding data. A relatively constant "wind-up" of 30° at the beginning of the 2nd and 3rd double-support phases can be seen in the throw of Sedych.

Training must be directed to develop a perfect technique in interaction with the necessary development of strength capacities, which includes the use of a large portion of heavy implements in training. However, investigations of training throws with different weight and length hammers has indicated that coaches and athletes must take into consideration the fact that the working conditions of the muscle groups involved in driving are submitted to changes when heavier and shorter hammers are employed.

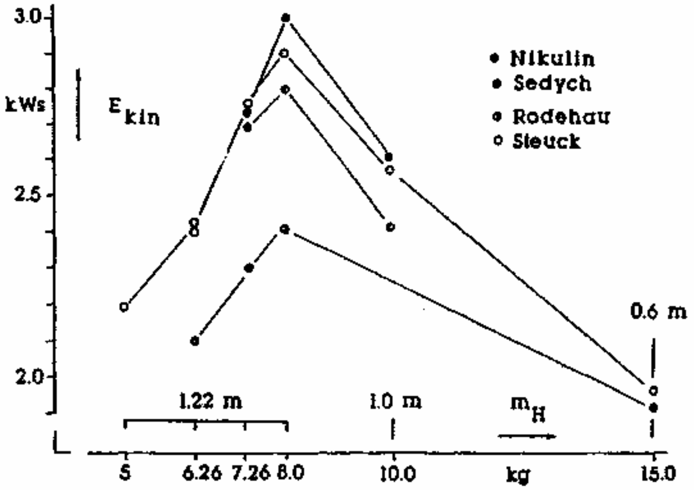


FIG. 5: The kinetic energy of hammers with different masses and length. The athletes used for this example include: Nikulin, Sedych, Rodehan and Steuck.

The kinetic energy of the hammer, one of the most important biomechanical parameters, increases only when the hammer mass is below 8kg. Throws with heavy hammers in the 9 to 17.5kg range and shortened wires lead to decreasing kinetic energy. From the biomechanical viewpoint the percentage reduction of the hammer length must be below the percentage increase of the hammer mass. This allows the heavy and short implements to have a positive effect in the development of specific strength capacities.

Mass kg	Length m	Maximum resulting forces kN%	
5	1.22	2.3	84
6.26	1.22	2.4	88
7.26	1.22	2.7	100
8	1.22	2.8	104
10	1.00	2.9	107
15	0.60	2.95	109

Table 2: Maximum resulting forces in throwing different weight and length hammers (average values for 32 top throwers).

The data in table 2 and figure 5 indicate that lower than competition mass hammers are effective in the development movement patterns for high speed. These throws allow an athlete to realize a higher angular velocity and a longer path of acceleration. As a result of lower external resistance kinetic energy, power output and forces are at a low level.

SUMMARY

Our investigation during some years of training indicated that the specific movement patterns and the corresponding biomechanical parameters of the throws with various weight and length hammers do not automatically change throws with the competition implement. The intended changes occur only when technique is constantly taken into consideration in the use of different implements.