THE COMPARSION OF CURVATURE RADIUS IN DIFFERENT PERFORMANCES OF HAMMER THROW

Ching-Wen Lee, Gin-Chang Liu, Der-Chia Lin & Chenfu Huang
National Taiwan Normal University, Taipei, Taiwan

The purpose of this study was to compare the curvature radius of different performance (63.20m and 68.46m) of hammer throw. The subject, who is the present record holder in Taiwan, has 9 years of experience in hammer throw. Two Peak-Performance high-speed video cameras operating at 120Hz were used simultaneously to record the performances of the subject. The results indicated that the patterns were completely different between two performances of hammer throw. The better performance was more periodic than the other. Based on the results of this study, it has been suggested that other sport events that include aspects of rotation may also benefit by adjustment of the pattern from their curvature radius.

KEY WORDS: hammer throw, orbit, curvature radius

INTRODUCTION: Hammer throw is one of several track and field events. In competition, athletes have to throw the hammer, including hammerhead, cable and handle, as far as possible. The total mass of the hammer is 7.26kg (16lb), the length of the cable and handle is 117.5~121.5cm. At present, the world record is 86.74m., which was set by Yuriy Swdykh in 1986.

The hammer thrower commences the performance by rotating the hammer 2 or 3 turns around his body with both feet firmly planted on the ground. The thrower then rotates his body, gripping the hammer in his hands, while accelerating to high speed. After 3 or 4 turns, the thrower releases the hammer at very high velocity. When thrower rotates his body with the hammer, his left foot remains in contact with the ground, while the right foot, steps off the ground, returning to the ground again in each turn. These actions can be described as single-support and double-support phases.

The orbit (see Figure1) of hammer head, with a highest point and lowest point, is a tilted spiral during the rotation in each turn. From the high point to the low point, this tends to increase the hammer velocity. On the other hand, from the low point to the high point, it tends to decrease the hammer velocity. Dapena (1984) has indicated that gravity is an important causal factor for the velocity fluctuation, because the maximum and minimum velocity in each turn coincides roughly with the low and high points of the hammer orbit, respectively. Dapena (1986) also indicated that the vertical force exerted by the ground, on the thrower and gravity, determines the vertical acceleration of the center of mass of the thrower-hammer system.

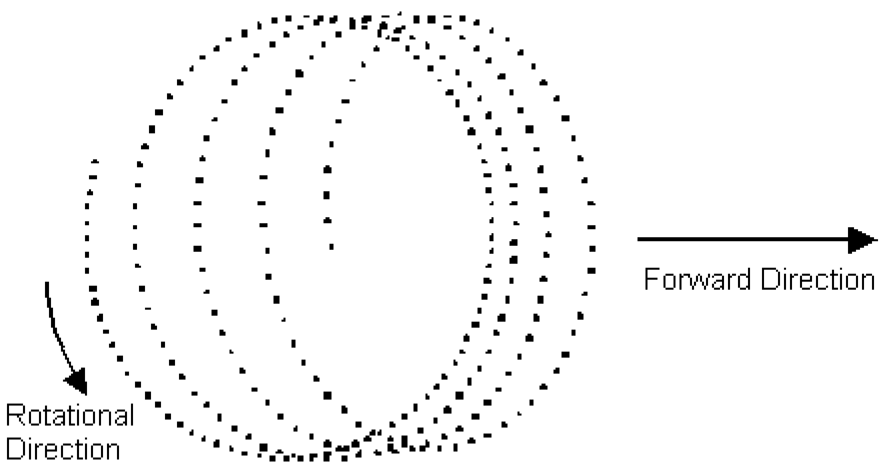

Figure1 - The orbit of the hammer head during the four turns.

In addition to those factors, which influence the hammer throwing, athletes alternately pull the hammer ahead and behind the position of the centroid of the hammer path. This also appears to be an important factor during the throwing phase. Therefore, the purpose of this study was to compare the curvature radius of different hammer throwing performances.

METHODS: The athlete who holds the present record for hammer-throw in Taiwan served as the subject. Two trials, 68.46m and 63.20m, were selected for analysis in this study. Two-Peak Performance high-speed video cameras were operated at 120Hz, and were synchronized to record the performances of hammer throw. A calibration frame with 25 control points was set up in the throwing area and used to videotape the performance after the subject finished throwing. The parameters, velocity and acceleration at specific instant, were obtained by direct linear transformation (DLT) calibration. The digitizing frames included the hammerhead in the four turns. Based on the differential rules and methods of vector of kinematics, the relative equations of curvature radius were derived alternately as follows.

Where

$\vec{r}$ = position vector

ρ = curvature radius

v = velocity

a = acceleration

$\vec{T}$ = unit tangent vector

$$\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$$

$$\frac{d\vec{r}}{dt} = \vec{v} = x'\vec{i} + y'\vec{j} + z'\vec{k}$$

$$\frac{d\vec{v}}{dt} = \vec{a} = \frac{dv}{dt}\vec{T} + v\frac{d\vec{T}}{dt} = \frac{dv}{dt}\vec{T} + v\left(\frac{v}{\rho}\vec{N}\right) = \frac{dv}{dt}\vec{T} + \frac{v^2}{\rho}\vec{N}$$

$$\because \vec{v} = v\vec{T}$$

$$\vec{a} \times \vec{v} = (v'\vec{T} + \frac{v^2}{\rho}\vec{N}) \times v\vec{T} = \frac{v^3}{\rho}(\vec{N} + \vec{T})$$

$$\left|\vec{a} \times \vec{v}\right| = \frac{v^3}{\rho}\left|\vec{N} + \vec{T}\right| \qquad and \qquad \left|\vec{N} + \vec{T}\right| = 1$$

$$\therefore \rho = \frac{v^3}{\left|\vec{a} \times \vec{v}\right|}$$

RESULTS AND DISCUSSION: The orbit of hammerhead during the hammer throw appears to be a circle, but in reality, the curvature radius of the orbit, are not the same in every position of the performance. Athletes have to increase the hammer velocity gradually by alternately shortening and lengthening the distance between the hammerhead and centroid of its orbit (Dapena & Feltner, 1989). The subject in this study used a four-turn technique, and each turn was identified from lowest point to next lowest point. The results are shown in Figure2 and Figure3, and the patterns of the hammer throwing were observed throughout the curvature radius of the four turns.

Figure2 showed that the curvature radius of total four turns for the two trials that were selected. The time of turn2, turn3, and turn4 were the same, but the distance of the better performance was 5.28m further than the other performance. With the exception of the first turn, curvature radius of lower performance one showed in 'a' gradually becomes larger, and then small. Near the end of each turn, the curvature radius becomes larger again. In higher performance one shown in 'b' of Figure2, the pattern of changing the length of curvature radius was more likely periodic in each turn. At beginning of each turn, the curvature radius was in the sequence of small, large, small, and then large again.

Figure3 showed the curvature radius of whole trial on two different performances, the curve line showing that the change of curvature radius length fluctuated considerably for the better trial as shown in b-part and it was smoother for the other trial as shown in a-part. It probably could be explained that the better trial generated more concentric acceleration. The changes in the radius of the hammer path were mainly due to the changes in the posture of the athlete from one turn to another. The different curvature radius of the hammer throw is probably caused by the changes of posture when athletes turn the whole body with the hammerhead. ‘Countering with the shoulders’ and ‘countering with the hips’ are different postures during early turn (Dapena & Feltner, 1989). However, the coverage of hands pulling the cable and feet against the ground during turning, are also related to the curvature radius. The reason for this generation of a different pattern of hammer throws by the same thrower is due to use of the different order of the technique mentioned previously.

In this study, the data has demonstrated the pattern of the change of the curvature radius, and also length throughout the hammer throw, and has also identified significant features of its pattern for the improved performance. These results could also provide information for athletes and coaches in training.

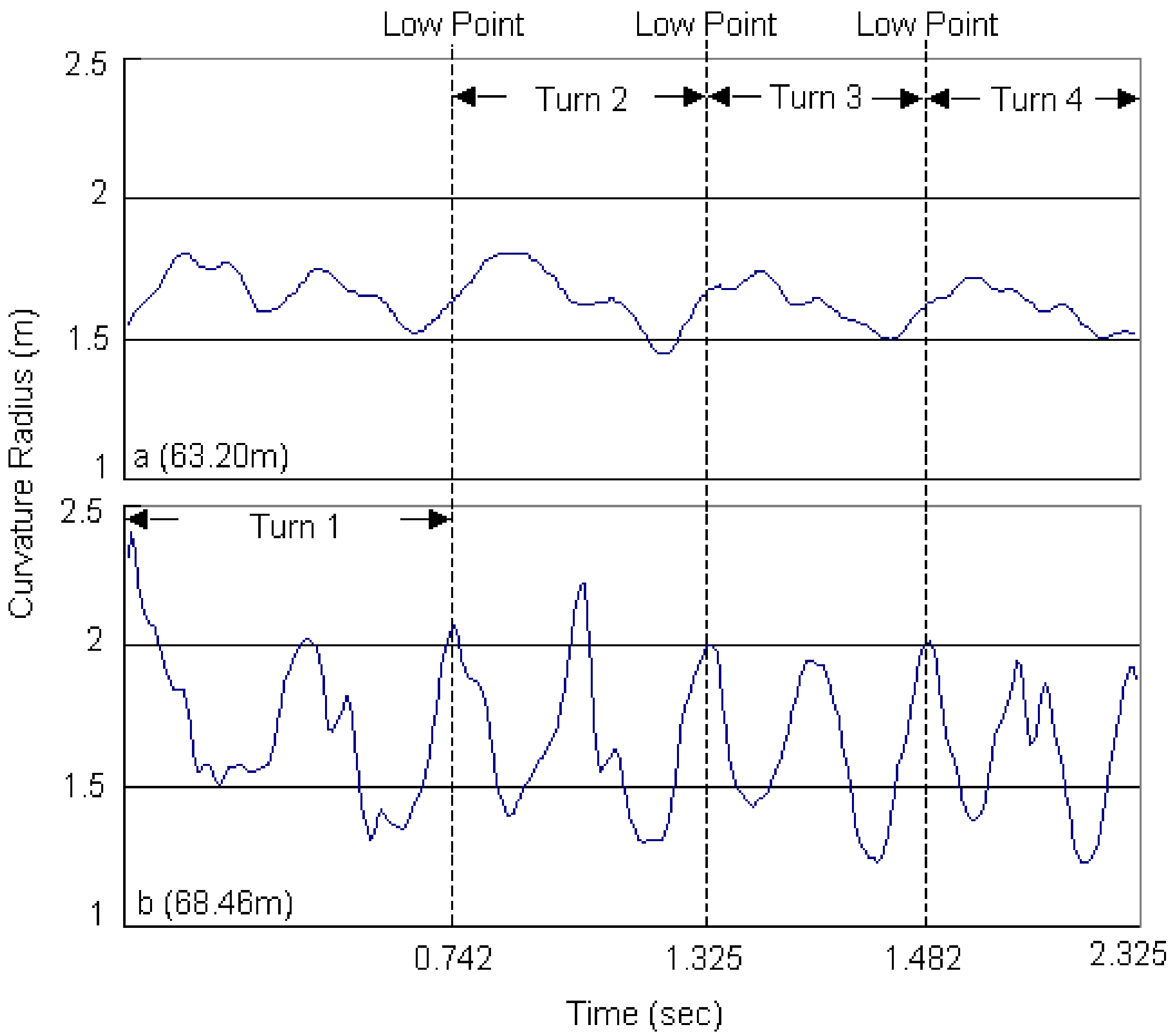

Figure 2 - The cruvature radius of four turns of different performance (a:63.20m, b:68.46m) during hammer throw.

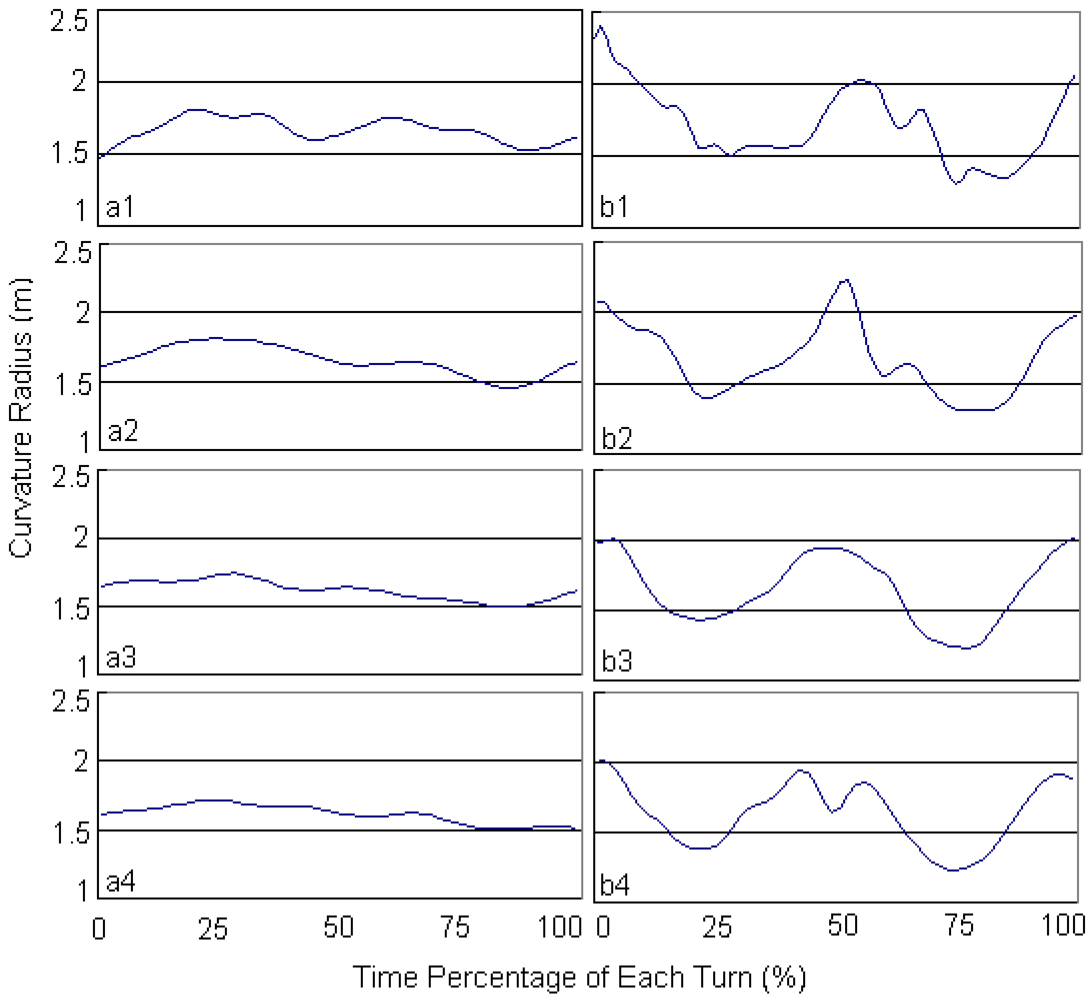

Figure 3 - The cruvature radius of each turn (1~4:turn 1~turn 4) of different performance (a: 63.20m, b: 68.46m) during hammer throw.

CONCLUSION: To compare the different performance of hammer throw from cruvature radius, the results indicated that the pattern of the change in curvature radius length is significantly different, the performance of better one is more periodic and more fluctuation. Theoretically, the fluctuation of curvature radius was caused by the change of concentric acceleration which generated by athlete. Thus, the method of the present study was suggested to use for better understanding the pattern of the sport events related to the rotation.

REFERENCES:

Dapena, J. & Feltner, M.E. (1989). Influence of the direction of the cable force and of the radius of the hammer path on speed fluctuations during hammer throwing. *Journal of Biomechanics*, **22**(6/7), 565-575.

Dapena, J. (1986). A kinematic study of center of mass motions in the hammer throw. *Journal of Biomechanics*, **19**(2), 147-158.

Dapena, J. (1984). The pattern of hammer speed during a hammer throw and influence of gravity on its fluctuations. *Journal of Biomechanics*, **17**(8), 553-559.