



HAL
open science

An innovative protocol for on-field biomechanical analysis of the hammer throw

Giuseppe Cecchelli, Floren Colloud, Laurent Gajny, Jean Slawinski

► **To cite this version:**

Giuseppe Cecchelli, Floren Colloud, Laurent Gajny, Jean Slawinski. An innovative protocol for on-field biomechanical analysis of the hammer throw. 2024. hal-04738054

HAL Id: hal-04738054

<https://hal.science/hal-04738054v1>

Preprint submitted on 15 Oct 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

An innovative protocol for on-field biomechanical analysis of the hammer throw

Giuseppe Cecchelli *

French Institute of Sport (INSEP), Laboratory Sport, Expertise and Performance (EA 7370), Paris, France

Arts et Métiers Institute of Technology, Institut de Biomécanique Humaine Georges Charpak, Paris, France

Floren Colloud

Arts et Métiers Institute of Technology, Institut de Biomécanique Humaine Georges Charpak, Paris, France

Laurent Gajny

Arts et Métiers Institute of Technology, Institut de Biomécanique Humaine Georges Charpak, Paris, France

Jean Slawinski

French Institute of Sport (INSEP), Laboratory Sport, Expertise and Performance (EA 7370), Paris, France

*Corresponding author. Email: giuseppe.cecchelli@insep.fr

Keywords: On-field analysis, Kinematics, Computer Vision.

1. Introduction

The biomechanical analysis of hammer throws has historically been conducted using video analysis, facilitating the 3D reconstruction of the hammer's trajectory. The primary technique is the Direct Linear Transformation (DLT) method, notably used by the IAAF for biomechanical measurements during major championships (Pavlović 2020; IAAF World Championships reports (Berlin 2009; Daegu 2011; London 2017; Dinsdale et al. 2018)). However, it requires manual frame-by-frame digitization of the hammer's position, complex calibration, and considerable processing time. For effective and regular monitoring of high-level athletes, in competition or training, a new protocol is necessary.

This new protocol relies on eliminating the need for manual frame-by-frame digitization of the hammer's position in the image plane. This study aims to develop a method for reconstructing the hammer's 3D trajectory and validating computed ejection parameters. Theoretical performance in free fall, using ejection parameters, should match measured results, considering aerodynamic friction that reduces actual performance.

2. Methods

2.1 Cameras Calibration

The hammer's trajectory reconstruction relies on a 4-camera system (GoPro Hero 11 and GoPro Hero 12), stereo-calibrated as per Zhang (2000). The cameras are positioned inside the throw cage. Calibration involves using a checkerboard pattern (800×600mm; 11×8 squares of 77×77mm). The intrinsic calibrations of the cameras and extrinsic calibrations of the system are decoupled as described by Kelley (2014). Intrinsic parameters are calculated from 5 calibration images per camera where the checkerboard occupies a significant portion of the camera view. Extrinsic parameters are computed from 14 images where the checkerboard is visible in 3D to at least 2 cameras: enabling the calculation of extrinsic parameters. Matlab's Stereo Calibrator App library facilitates the computation of calibration parameters.

2.2 Hammer tracking

An algorithm has been specifically developed to track the hammer in the image reference frame. This algorithm is based on the segmentation algorithm Fast SAM developed by Zhao et al. (2023). Fast SAM is used to segment the hammer to obtain a segmentation mask. The contour of this mask is then extracted, and the ellipse minimizing the gap between the ellipse and the contour in the least squares sense is calculated. The centre of the ellipse is then designated as the point corresponding to the position of the hammer in the image reference frame.

The tracking is performed incrementally: by knowing the position of the hammer in image $n-2$ (M_{n-2}) and in image $n-1$ (M_{n-1}), the segmentation mask of the hammer in image n is searched within a bounding box centered at $(M_{n-1} + (M_{n-1} - M_{n-2}))$. The size of the box is adjusted based on the size of the minor and major axes of the previously calculated ellipse. Using this algorithm, the hammer's position is tracked in each image reference frame for each camera throughout the throw.

2.3 trajectory reconstruction

Using the intrinsic parameters, the hammer's trajectory in each image reference frame is undistorted to remove the distortion induced by the cameras. Then, the 3D trajectory is reconstructed by triangulating the synchronized hammer positions from various image reference frames using the extrinsic parameters.

2.4 Trajectory interpretation

The reconstructed trajectory is filtered using a low-pass filter with a cutoff frequency of 15 Hz. From this trajectory, various biomechanical parameters of the throw can be calculated, including ejection parameters: velocity, angle, and height at release. Consistency of ejection data is assessed by calculating the difference

between measured distance and the range predicted in free fall (Dapena et al. 2003).

2.5 Data collection

The data were collected during a national championship. The selected throwers for the study are those of international level. 23 throws: 67.18 ± 3.34 m were analyzed among women and 26 throws: 71.85 ± 5.66 m among men.

3. Results and discussion

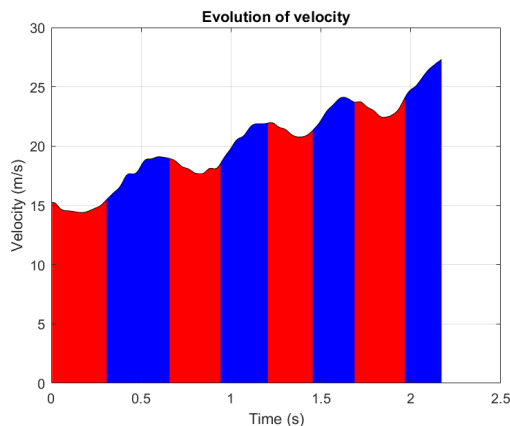


Figure 1. Evolution of the velocity of the hammer in a 4 turns throw performed by one female elite participant during a national championship for a throw at 69.70m (blue: double support phases, red: single support phases)

In the context of this study, the distance predicted in free fall was 2.30 ± 0.76 m (A) longer than the official distance of the throw for men and 4.11 ± 1.21 m (C) longer for women. Dapena et al. (2003) demonstrated that the distance predicted in free fall was 4.30 ± 2.64 m (B) longer than the official distance of the throw for men (for 23 throws: 72.82 ± 7.43 m) and 8.82 ± 3.20 m (D) longer for women (for 6 throws: 67.78 ± 4.02 m). Predicted values are higher than measured ones because the hammer is not in free fall and is slowed by air friction.

Using the equations of the range predicted in free fall, for throws of predicted distance in the neighbourhood of 70m (with an ejection angle of 45° : optimal ejection angle and an ejection height of 1.25m : mean ejection height in our recorded data), the difference between (A) and (B) corresponds to an ejection velocity difference of 1.7%, which rises to 3% between (C) and (D).

This difference can be attributed to methodological and processing discrepancies. Dapena employs two cameras recording throws at a frequency of 50Hz, whereas our cameras operate at a frequency of 240Hz. This implies a different processing approach: Dapena

must fit a Quintic spline function to the raw three-dimensional successive locations of the hammer.

4. Conclusions

In this study, we presented a new protocol for analyzing hammer throw biomechanics using advanced camera technology and tracking algorithms. This protocol was employed to analyze the disparity between the measured performance and the range predicted in free fall. Future research will focus on validating the protocol and integrating thrower kinematics into the analysis.

Funding

Giuseppe Cecchelli received a PhD scholarship, CIFRE contract, funded by the French Athletics Federation and the French Association of Research and Technology

Conflict of Interest Statement

None

References

- Dapena, J., Gutiérrez-Dávila, M., Soto, V. & Rojas, F. (2003). Prediction of distance in hammer throwing. *Journal of Sports Sciences*, 21(1), 21-28. DOI: 10.1080/0264041031000070921
- Dinsdale, A., Thomas, A., Bissas, A., & Merlino, S. (2018). Biomechanical Report for the IAAF World Championships 2017
- Pavlović, R. (2020). Differences in kinematic parameters between male and female hammer throw finalists of the World Championship in Daegu in 2011. *Pedagogy of Physical Culture and Sports*, 24(5), 255-263. DOI: 10.15561/26649837.2020.0506
- Xu Zhao, W., Ding, W., An, Y., Du, Y., Yu, T., Li, M., Tang, M., & Wang, J. (2023). Fast segment anything. arXiv preprint arXiv:2306.12156.
- Zhang, Z. (2000). A flexible new technique for camera calibration. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 22(11), 1330-1334. DOI: 10.1109/34.888718

Received date:06/04/2024

Accepted date: 28/06/2024

Published date: XX/XX/2024

Volume: 1

Publication year: 2024