3D KINEMATICAL ANALYSIS OF THE HAMMER THROW IN COMPETITIONS

Luciano Allegretti Mercadante[1], Rafael Pombo Menezes[1], Thomaz Persinotti Martini[1], Jorge Luiz Alves Trabanco[2], Ricardo Machado Leite de Barros[1]

[1] Laboratory of Instrumentation for Biomechanics, State University of Campinas, Campinas, Brazil

[2] Department of Geotecnic and Transports, State University of Campinas, Campinas, Brazil

This study analyzes 14 throws accomplished in Brazilian competitions and it compares with available international results in the literature. It calculates the angle, the velocity and the height of release of the hammer and the velocity curves in function of the time, starting from the 3D trajectory of the head of the hammer. The analyses relate the difference between Brazilian (averages of 55.38m male and 52.05m female) and international results (averages of 79.44m male and 70.60m female) and the release velocity (Brazilian averages of 24.59m/s male and 23.59m/s female, and international of 29.60m/s male and 28.89m/s female). The velocity curves in function of the time of the international releases show that the accelerations are higher and the deceleration lower during the turns, when compared with a Brazilian throw.

KEY WORDS: biomechanics of sport, kinematical analysis, release of the hammer.

INTRODUCTION:

The hammer throw is characterized by complex actions. The three main parameters that determine thrown distance are the velocity of release, the angle between the velocity vector and the horizontal plane and the height of the hammer at the instant of the release. The release velocity should be maximum. The optimal angle ranges from 43° to 44°, depending on the athlete's height (Dapena, 1984). Besides these discrete variables, it is also important to analyze the position and the velocity curves in function of the time, in order to better understand the throw.

In training situations, Bartonietz (2004) analyzed the kinematics of throws of high level athletes describing the release variables and Dapena (1984;1986) included the analysis of the center of mass of the thrower and thrower-hammer system. In competition situations, Gutierrez, Soto & Rojas (2002) presented 3D kinematics analysis of the best throws of the finalists of Seville Athletics World Championship 1999. No paper was found in the literature analyzing the 3D kinematics of Brazilian high-level throwers.

The analysis of hammer throw is challenging due to the methodological problems involved in measuring the variables, particularly during competitions. The 3D kinematical analysis system should provide accurate measures in a large volume, automatic or, at least, semi-automatic tracking of the hammer head, high-resolution synchronization of the cameras, without interfering in the competition.

The aim of this work was the kinematical analysis of Brazilian hammer throws during actual competitions and the comparison of the results with the data described in the literature.

METHOD:

Data Collection: Three of the most important Brazilian official competitions in the year of 2006 were analyzed in March, May and August. Six Brazilian throwers (three males and three females) were analyzed. Of each one, the best throw in each competition was analyzed. Considering that one male athlete did not participate in two competitions and one female athlete did not participate in one competition, 14 throws were analyzed overall.

The DVideo System (Figueroa, Leite & Barros, 2003) was used for the 3D kinematical analysis. The system consisted of three digital video cameras (Panasonic, model PV-GS15LB-S, 60 Hz) connected on line to one notebook and the corresponding software. The cameras were positioned approximately 70 meters away from the throw area, recording the

throw through the throw cage aperture viewing the throw through the cage aperture avoiding grid occlusion.
For the calibration of the cameras, 30 control points were used. Their coordinates were measured using topographical equipment with accuracy of 5" for angular measures and 5mm + 3ppm for distance measures. The synchronization of the cameras was based on the method proposed by Barros et al. (2006). The accuracy of the synchronization method is of 1 ms. The tracking of the hammer head was obtained automatically in 86% of the frames.

Data Analysis: The coordinates of the hammer head were smoothed using a low-pass second order Butterworth with cutoff frequency of 6Hz, selected after spectral analysis. The velocity curves were obtained by numerical derivation. The hammer head height (h_o) and the angle (a_o) of the velocity vector with the horizontal plane were calculated at the release instant.

RESULTS:

Table 1 presents the results of the release variables of the hammer head: angle (a_o), velocity (v_o) and height (h_o), the reached distance (d), and the results of the three first places in Seville Athletics World Championship 1999, presented by Gutierrez, Soto & Rojas (2002).

Table 1 Date of the events, ranking in the competition and the thrower's identification (A,B,C,D,E,F), release variables (a_o,v_o,h_o) and reached distance (d) of the Brazilians and Seville Athletics World Championship 1999 throws

	Male					Female				
	Place	a_0 (°)	v_0 (m/s)	h_0 (m)	d (m)	Place	a_0 (°)	v_0 (m/s)	h_0 (m)	d (m)
March	1°/A	40.8	24.8	1.23	60.28	1°/D	38.7	24.7	1.94	55.56
2006	2°/B	37.0	24.7	1.07	54.23	2°/E	39.5	24.4	1.27	55.21
	3°/C	32.0	26.0	1.14	52.90	3º/F	38.8	21.4	1.59	43.57
May	1°/B	37.1	25.2	1.54	56.96	1º/F	40.9	22.1	1.29	50.31
2006	2°/C	37.5	23.1	1.64	51.21					
August	1°/B	37.3	24.6	1.29	57.13	1°/D	39.7	25.8	1.25	58.14
2006	2°/C	39.0	23.8	1.44	55.01	2°/E	32.4	24.0	0.94	52.70
						3°/F	42.7	22.6	1.39	48.90
Mean		37.2	24.6	1.34	55.38		38.9	23.6	1.38	52.05
std		± 2.7	± 0.9	± 0.21	± 3.01		± 3.2	± 1.6	± 0.31	± 4.91
Seville	1°	40.53	29.43	1.77	80.24	1°	40.85	29.75	1.63	74.21
1999	2°	36.58	29.85	1.43	79.05	2°	39.68	29.27	1.75	72.56
	3°	37.91	29.52	1.51	79.03	3°	38.20	27.64	1.61	65.02
Mean		38.34	29.60	1.57	79.44		39.58	28.89	1.66	70.60
std		± 2.01	± 0.22	± 0.18	± 0.69		± 1.33	± 1.11	± 0.07	± 4.90

Table 2 presents the mean (above) and the standard deviation (below) of the release variables for the three bests male athletes (A,B,C) and female (D,E,F). The letter n indicates the number of competition that the thrower participated.

Table 2 Averages and standard deviation of the release variables and the reached distance of throwers male A,B,C and female D,E,F, and the number of competitions that the thrower participated (n)

	Male						Female				
	n	a_0 (°)	v_0 (m/s)	h_0 (m)	d (m)		n	a_0 (°)	v_0 (m/s)	h_0 (m)	d (m)
A	1	40.79	24.79	1.23	60.28	D	2	39.19	25.27	1.59	56.85
								± 0.66	± 0.78	± 0.49	± 1.82
B	3	37.14	24.82	1.30	56.11	E	2	35.91	24.23	1.10	53.95
		± 0.15	± 0.31	± 0.23	± 1.63			± 5.03	± 0.25	± 0.23	± 1.77
C	3	36.18	24.30	1.41	53.04	F	3	40.81	22.05	1.42	47.59
		± 3.69	± 1.53	± 0.25	± 1.90			± 1.92	± 0.58	± 0.15	± 3.55

Figure 1 presents the velocity curve in function of time of one throw (82.34m) by the world record setting thrower Yuriy Sedykh, extracted from Bartonietz (2004), and the velocity curve of the best Brazilian throw (60.28m). V1, V2, V3, V4, V5, V6 and V7, identifies, respectively, the minimum and maximum values of velocity to each turn.

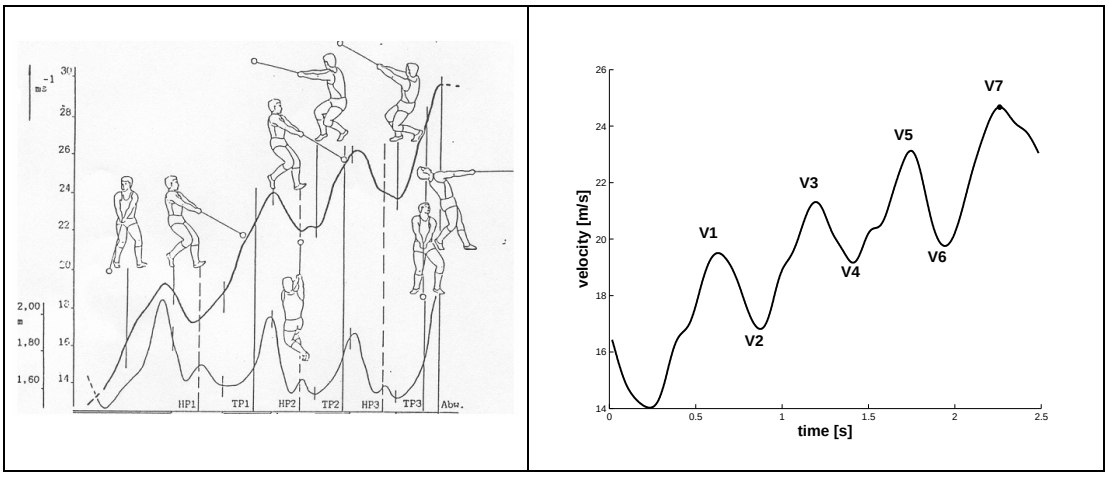

Figure 1: Curves of velocity in function of the time of a throw of Yuriy Sedykh, (left) extracted of Bartonietz (2004), and of the best Brazilian throw.

In Table 3 the values of V1, V2, V3, V4, V5, V6 and V7 of the best Brazilian throw (60.28m) and one throw of Yuriy Sedykh (82.34m) are presented. The values of Yuriy Sedykh's throw were estimated from the graph in Figure 1.

Table 3 Values maximum and minimum of the velocity (m/s) during the turns accomplished in the best Brazilian throw (L) of 60.28m and of one throw of the Yuriy Sedykh of 82.34m.

	V1	V2	V3	V4	V5	V6	V7	V2-V1	V4-V3	V6-V5	V3-V2	V5-V4	V7-V6
L	19.5	16.8	21.3	19.2	23.1	19.7	24.8	-2.7	-2.1	-3.4	4.5	3.9	5.1
YS	19.2	17.1	24.0	22.0	26.0	23.8	29.6	-2.1	-2.0	-2.2	6.9	4.0	5.8

DISCUSSION:

The distances reached by Brazilian throws are much shorter than the world class throwers analysed in Seville. The main parameter associated to this difference was the velocity (Brazilian averages of 24.59m/s male and 23.59m/s female, and international of 29.60m/s male and 28.89m/s female). All throwers, including the Seville ones, presented release angle lower then the optimal predicted value in Dapena (1986). The release height and angle of Brazilian Throwers were similar to the world class athletes.
It is known that the release velocity is reached by the increment of velocity in each turn. Each turn presents a phase of double support of the feet that allows the thrower to accelerate the hammer, and one of simple support, when the hammer acceleration decreases. The initial velocities V1 of the first turn are similar, but all Brazilian throws presented a deflection of the velocity curve after a peak greater that that presented by Yuri. The acceleration decreases during the simple supports of Yuriy Sedykh's throw are always smaller than that presented by Brazilians.

CONCLUSION:

This study presents the methodology that allows one to quantify the release variables of the throw and the curves of velocity in function of time, characterizing the throw in competition. The comparison between Brazilian and international throwers shows the Brazilian throwers have difficulty in to reach better results due to low release velocities, when compared to the finalists of Seville 1999, and during the turns when compared to Yuriy Sedykh's throw. This research offers coaches who seek better results information to optimise the throw.

REFERENCES:

Barros, R.M.L., Russomano, T.G., Brenzikofer, R. & Figueroa, P.J. (2006). A Method to Sinchronize Video Cameras Using the Audio Band. *Jounal of Biomechanics*, 39(4), 776-780.

Bartonietz, K. (2004). Arremesso de martelo: problemas e perspectives. In Zatsiorsky, V.M., *Biomecânica no Esporte*. (pp 358-380). Rio de Janeiro: Guanabara-Koogan

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.

Dapena, J. (1986). A Kinematics Study of Center of Mass Motion in the Hammer Throw. *Jounal of Biomechanics*, 19(2), 147-158.

Figueroa, P.J., Leite, N. & Barros, R.M.L. (2003). A Flexible Software for Tracking of Markers used in Human Motion Analysis. *Computer Methods and Programs in Biomedicine*, 72, 155-165.

Figueroa, P.J., Leite, N. & Barros, R.M.L. (2006). Tracking soccer players aiming their kinematical motion analysis. *Computer Vision and Image Understanding*, 101(2), 122-135.

Gutierrez, M., Soto, V.M. & Rojas, F.J. (2002). A biomechanical analysis of the individual techniques of the hammer throw finalists in the Seville Athletics World Championship 1999. *IAAF Handbook,* 17(2), 15-26.

Acknowledgement

Programa PRODOC do Centro de Aperfeiçoamento de Pessoal de Nível Superior – CAPES (processo 3300301704p6) e Fundação de Amparo à Pesquisa do Estado de São Paulo – Fapesp (processo 05/53262-6).