KINEMATIC AND KINETIC COMPARISONS BETWEEN SPOT, CROSSOVER AND UPWARD JUMP THROWINGS IN HANDBALL

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Throwing is one of the most important skills in handball in which two basic factors are of importance with regard to the efficiency of shots i.e. accuracy and velocity. A 2-Dimensional analysis of different throws i.e. on the spot, with a cross-over step, and with upward jump has been undertaken. Eighteen high-performance handball players took part in this study. The average values of basic parameters of physical characteristics of subjects were: 80.2 ± 6.1 Kg (body mass), 184.8 ± 4 cm (body height), and 19.79 ± 0.63 years of age. The main aim of present study was to establish a valuable kinematic and kinetic comparison between different types of throws in handball. Statistically significant differences were found between maximal ball velocity during throws with cross-over step and ball velocity during other analyzed throws. In addition to the high velocity in this throw, the energy and power consumptions were also higher in magnitude comparing with other throws. The results obtained by this study agreed well with the results reported by other researchers.

KEY WORDS: comparisons, kinematic, kinetic, different throws, handball

INTRODUCTION: Throwing is one of the most important skills in team sports like handball, Basketball, and soccer (Mikelsen and Olesen 1976; Joris et al., 1985, Eliasz et al., 1990; Muijen et al., 1991; Marczinka, 1993). Two basic factors are of importance with regard to the difference of shots: accuracy and throwing velocity. Although the technique of motion and the fitness level can be improved by the training process (Eliasz, 1993), morphological factors are, in the main part, determined genetically. The success of a shot in a handball game very often depends upon the throwing velocity and the manner of throwing. It is true that the way of throwing can also be determinant. Among the many different throws, the most popular types of throwing are: on the spot, with crossover step, and with an upward jump (Marczinka, 1993). It has been reported that the highest throwing velocity can be achieved with a crossover step (Eliasz, 1990), while the motion technique is the simplest when throwing on the spot (Marczinka, 1993). It has also been believed that the factors affecting the ball velocity can be divided into three groups such as somatic features, motor abilities, and motion technique (Muijnet et al., 1996).
The purpose of this study was to quantify selected kinematic variables of handball throwing and in particular, to establish the relationships between athletes' movement patterns and throwing velocity.

METHODS: The process of player position and motion acquisition in the present study consisted of several steps: camera position and calibration, video recording, video digitization, digital video processing and post-processing of obtained motion data.
In order to investigate the different velocities in different throwing, 18 male handball professionals have volunteered to this study. 12 were belonging to national team and other six were top elite players and all of them were right handed. The age distribution ranged from 21 to 32 years, their body mass ranged 70 to 89 Kg, and their body height ranged 181 to 193.4 cm.
The subjects were video taped by one camera (Kodak) at 120 Hz for two-dimensional analysis. The camera was placed at 7 meters to the right of players. Each throw was digitized and analyzed using Winanalyz software. More than 250 sequences were digitized. The data corresponding to every five frames have been considered for presenting the displacements, velocities and accelerations.

The mean value, standard deviation and coefficient of variance were calculated for each parameter. The Pearson's correlation and multiple regression analysis were used (α = 0.05). Anthropometric measurements were carried out according to Martin's method. The length of palm, forearm, arm and fingers were measured using a caliper with 10^{-2} cm. In order to assess the over arm-throwing performance, a standard ball of 480 g and of 58 cm of circumference has been chosen. The subjects were instructed to throw the ball as fast as possible to a target placed at a distance of five meters. The ball velocity was determined by the Motion Analyzer System (Mikro-Mak), with enough precision. This system offered two types of tracking, that is, manual and automatic. We were allowed either manual or automatic recovery of player positions for each player on each of frames from the digital video sequence.
Although relaxed requirements considering the system accuracy reduce the manual work by several orders of magnitude as compared to biomechanic motion analysis systems, manual tracking remains a time consuming and tedious task.

FORMALISM: The mean force applied by the muscle group of hand can be readily estimated. In fact the work can be defined (Holiday & Reznik, 2000) as:

$$W=\int_0^d \bar{F}\, dX = \bar{F} d \tag{1}$$

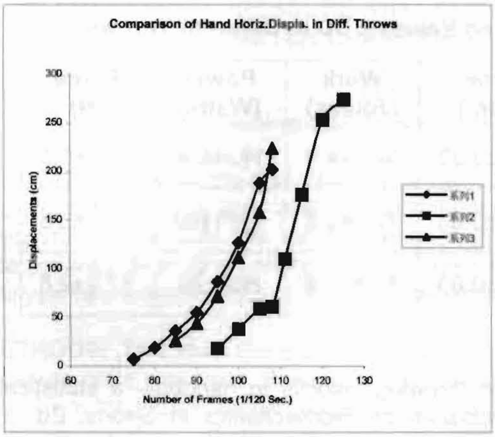
d, is the displacement of hand before the ball is thrown. This work is transferred to ball kinetic energy:

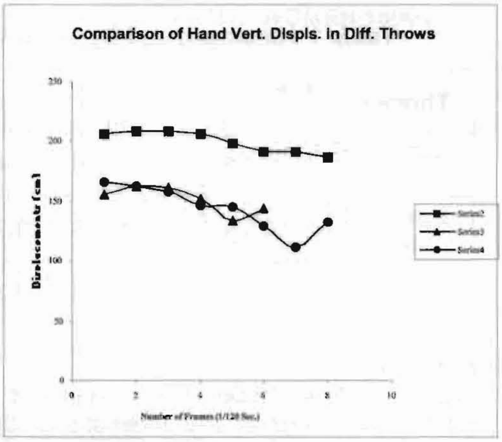
$$\bar{F} d = \frac{1}{2} m_B V_B^2 \tag{2}$$

Whereas, the mean muscle force can be deduced as (Shahbazi et al. 2002);

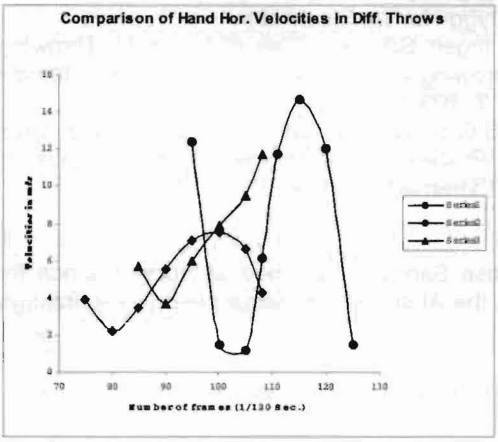
$$\bar{F} = \frac{m_B V_B^2}{2d} \tag{3}$$

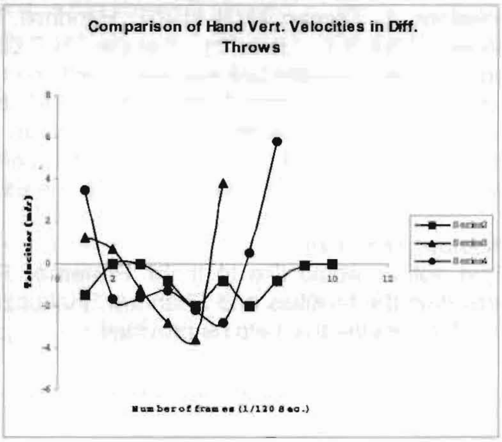
RESULTS AND DISCUTIONS: In our study the highest value of linear velocity of the ball has been achieved from crossover step throw and the difference between this value and the velocities measured during throws with spot and upward jump were statistically significant. Although the ball velocity measured in this kind of throw is higher than the value of velocity in upward jump, but still the popularity of throw with jump is due to its efficiency (Eliasz 1993). The variation of displacements and velocities in X and Y-axis are shown in Figure 1, 2, 3, and 4 respectively. The highest value of ball velocity in throw with a crossover step can be explained on biomechanical basis. In this type of throw the direction of player's center of gravity motion is consistent with the direction of ball velocity, which in turn provides an initial velocity before release that is why the velocity in this throw has higher magnitude.
In Table 1, the kinematic and dynamic mean values with standard deviations are given. As we can notice, the velocity, applied force and energy and finally the power consumption in cross-over step throw are higher in magnitudes comparing with other throws. It seems logical, because in spot throw, body manifests minimum movements, therefore consumes minimum power and energy. On the contrary, in cross-over step throw body is in its maximal activity giving, in addition, an initial velocity to ball at release moment.





Figures 1 & 2 In left (Series 2) the horizontal variation of displacement in crossover step is significant and in right (Series 2) the vertical variation of displacement is also significant comparing with two other throws.





Figures 3 & 4 In left (Series 2) the horizontal variation of velocity in crossover step is significant and in right (Series 4) the vertical variation of velocity is also significant comparing with other two throws.

CONCLUSIONS: The kinematic and kinetic comparisons of different throws revealed that the velocity in cross-over step throw is higher than the other throws but in spot throw the accuracy is much better. Force, energy, and power magnitudes are higher in cross-over throw but they are lesser in upward jump and least in spot throw. The achieved results agreed well with the results reported by other researchers.

Table 1 Kinematic and Dynamic Mean Values ± SD in Different Throws.

Throws	Velocity (m/s)	Distance (m)	Time (Sec.)	Work (Joules)	Power (Watts)	Force (N)
Cross-Over	19.8±1.8	0.97±0.06	0.42±0.03	94.3±4.9	1924±56	97.2±5.5
Upward Jump	17.7±1.4	0.97±0.06	0.22±0.03	75.2±3.3	1371±48	77.5±3.8
Spot	15.2±1.3	0.97±0.06	0.38±0.03	55.6±2.9	869±39	57.2±2.8

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