# A THREE-DIMENSIONAL KINEMATIC ANALYSIS OF HANDBALL THROWS

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**INTRODUCTION:** The success of a shot in a game of team handball very often depends on the throwing velocity. The faster the ball is thrown at the goal, the less time defenders and goalkeeper has to save the shot. Among the many different throws in team handball the most popular types of throw are: on the spot, with cross-over step and with an upward jump (Marczinka, 1993). Regarding throwing velocity, the highest value of this parameter is achieved when throwing with a cross-over step (Eliasz et al., 1990), whereas the technique of motion is the simplest when throwing on the spot (Marczinka, 1993). The main factors affecting a ball's velocity can be divided into three groups concerning somatic features, motor abilities and technique of motion (Muijen et al., 1991, Eliasz & Wit, 1996). Throwing technique can be improved by the training process, but for high performance players this progress is very difficult to achieve. In order to improve the efficiency of the process scientists and coaches should define the most important characteristics of throwing technique and then develop them during training. The first step leading to this goal is to identify the main parameters of handball throwing technique.
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:** Ten high-performance handball field players took part in the experiment. The average values of the basic parameters of physical characteristics of the subjects were: 86.5 ±9.8 kg body mass, 1.89 ±0.09 m body height and 22.4 ±1.8 years of age. The subjects were videotaped by two cameras at 60 Hz (CamCoder Panasonic) throwing on the spot from a distance of 7 m (penalty shot) to the an unguarded handball goal. The cameras were placed perpendicularly at distances of 14.3 m to the right of and 31.0 m behind the player. Three-dimensional coordinates of 16 points of each subject with a ball were calculated by combining the images from both cameras. Each throw was digitized and analyzed using the Ariel Performance Analysis System (APAS). Fifty sequences were digitized: 30 frames prior to and 20 frames after the ball release. Statistical analysis of the results was carried out with the use of Statistica v. 5.0 software.

**RESULTS AND DISCUSSION:** The following kinematic parameters were defined: duration of the movement, linear displacement of body segments, and their derivatives - linear velocities, linear mechanical energy and horizontal component of momentum. The analysis of throwing technique was based on those vales.
Linear velocity of the ball was 24.45 ±1.97 m/s (range: 21.11-28.50 m/s), horizontal linear displacement of the hand with a ball (XY plane) - 1.74 m ± 0.14 m (1.60-2.10 m). Although the sampling frequency used (60 fr/s) is lower than that used by

Whiting et al., (1991) for javelin throws (100 fr/s), a lower release velocity in team handball (24 m/s) compared to javelin throws (30 m/s) enabled the use of a lower frame rate. Accepting a simplified view that hand velocity reflects the velocity of the ball, the results obtained by the video analysis were slightly different from those measured by a photocell system (Eliasz et al. 1990).
In handball throwing, the hip, trunk, shoulder, upper arm, forearm and hand generate maximum linear mechanical energy around the ball release events for all segments between the start and end of the action. The energy generated by the trunk was transferred to the shoulder complex (r=0.9157), while the energy of the shoulder was transferred to the upper arm (r=0.8315), next to the forearm (r=0,9190), and eventually to the hand (r=0.9925).

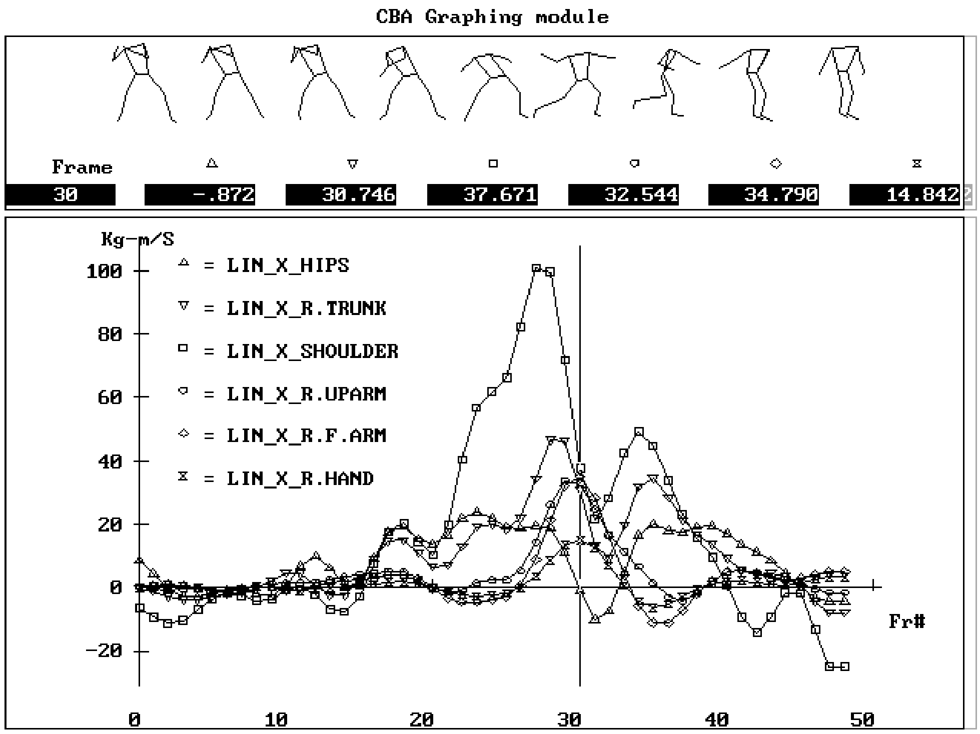


Fig. 1. Time-series of various resultants of body segments momentum during handball throwing performed by Player 1 (b.m.=92 kg, b.h.=1.97 m).

Significant correlation was found only between values of mechanical energy delivered by the upper arm and the horizontal ball velocity (r=0.8001), which is in agreement with the results of a volleyball spike study reported by Coleman et al., (1993).
During the period from the start of the counter-movement to the last 20 frames after ball release, numerous events take place. In principle, the horizontal ball velocity during handball throwing depends on the total horizontal momentum of the body. The momentum values for the hip, trunk, shoulder, upper arm, forearm and

hand are presented in Figure 1. These data indicate that players tended to have great momentum in all segments at 30-70 ms prior to release. Handball players reached their maximum momentum at nearly the same time interval as for baseball pitching (Escamilla et al., 1998) or for the penalty throw in water polo (Feltner and Taylor, 1997). The direct contribution of the momentum of selected individual segments to ball velocity is given by the equation:

$V = 11.98 – 0.15Hi + 0.5T – 0.01S – 0.44UpA + 1.62FA – 1.86Ha$ ($R^2 = 0.9219$). Significant ($p<0.05$) contributions of segment momentum to the expected value of ball velocity are: upper arm – 9.6%, forearm – 54.4%, hand – 26.4% (Doolittle method).

Other key moments are the segment-to-segment momentum transfer ratio. When absolute momentum values are sufficiently large, the transfer ratio appears as an additional important factor in the assessment of the handball throwing technique. After normalizing the ball velocity to the subject's body mass, the correlation between the velocity and the momentum Hip/Trunk ratio is $r = 0.8156$ ($p<0.040$) and for the Trunk/Upper Arm ratio $r = 0.5654$ ($p<0.0890$).

During handball throwing, the hip delivered maximum momentum at 23.45 ±7.03 kG*m/s. The positive momentum usually peaked 0.238 ms before ball release. That role of the hip is to initiate the movement of the upper body part, to generate a large value of the momentum and to transfer the momentum from the lower limbs to the trunk during the counter-movement. It should be emphasized that the hip plays an essential role in the throw performance since it provides, in the moment of arresting the movement, a solid base of support for upper body during the standing throw. This point was raised by Best et al., (1993) when they discussed the foot pattern movement in 3D analysis of javelin throwing technique.

Figure 1 also presents time series data for the momentum of segments for Player 1. The order in which these parameters reach maximum values is hip-trunk-shoulder-upper arm-forearm-hand. This is in accordance with biomechanical principles, as well as with previous findings (Best et al., 1993, Whiting et al., 1991). In this study, the optimal timing of these events has not been established, due to a small number of subjects, too low frequency of cameras (Graham-Smith&Lees 1997) and a high between-subject variability. Those observations are in line with the findings of other authors, with the exception of hip movement and the duration of the pre-release period. In our subjects, the maximum of the negative momentum occurs when the post-hip segments attained their respective maximum positive momentum. Moreover, Best et al. (1993) presented data showing where the elbow peak velocity is shifted to the javelin release by 0.06-0.12s. In handball-players that shift seems to be shorter (0.017-0.068s).

**CONCLUSIONS:** In conclusion, momentum analysis can be used to estimate the efficacy of the throwing technique. Elite handball players seem to differ in the absolute maximal linear momentum (x component) and the co-ordination in the body segments during the ball throwing event. The important role of the hip/trunk and trunk/upper arm momentum ratio for handball throwing to be maximally effective is to be stressed.

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