THE RELATIONSHIPS BETWEEN THROWING VELOCITY AND MOTOR ABILITY PARAMETERS OF THE HIGH-PERFORMANCE HANDBALL PLAYERS

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INTRODUCTION

Throwing is one of the most important skills in team handball [Mikelsen and Olesen 1976, Joris et a1.1985, Eliasz et a1.1990, Muijen et al.1991,Marczinka 1993]. Two basic factors are of importance with regard to the efficiency of shots: accuracy and throwing velocity. Naturally, the faster the ball is thrown at the goal, the less time defenders and goalkeeper have to save the shot. Handball coaches and scientists who have investigated overarm throwing are in agreement that the main determinants of the ball velocity can be divided into three groups concerning technique of motion, somatic features and motor ability (physical fitness), respectively [Pauwels 1978, Eliasz et al.1990, Muijen et al.1991]. 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. Since changes in the throwing technique among high-performance players are very small, it was assumed as constant during short period of training process.

The aim of the research was to find the relationships between the ball velocity during different types of throws in handball and basic motor ability parameters (muscle strength, arm speed) of players, in order to improve the efficiency of training.

MATERIAL AND METHODS

Twelve high-performance handball players took part in the experiment (six of them were at that moment members of the National Team). The average values of basic parameters of physical characteristics of the subjects were: 89.0$\pm$ 7.8 kg (body mass), 1.88$\pm$ 0.05 m (body height) and 23.3$\pm$ 2.5 years of age. The Shapiro-Wilk test, Pearson's correlation matrix and multiple regression analysis were used (a=0.05).

MEASUREMENT OF M E BALL VELOCITY

In order to assess the overarm throwing performance, a standard handball was used (mass 480 g, circumference 58 cm). The subjects were instructed to throw the ball as fast as possible at a target (50 x 50 cm) placed at a distance of about 6 meters [Pauwels 1978, Eliasz et al., 1990]. Each subject performed trials until three registered throws (i.e. when the ball hit the target) were achieved. The average linear ball velocity was measured over a 2 meter distance using a special photocells system [Eliasz et al.1990]. Handballers performed three of the most popular types of throws: on the spot, with a cross-over step and with an upward jump [Marczinka 1993]. Each session was preceded by 10-minute standard warm-up.

MEASUREMENT OF M E MUSCLE TORQUES UNDER STATIC CONDITIONS

The muscle strength was evaluated on the basis of the sum of muscle torques developed by main muscle groups under static conditions (ISI - isometric strength indicator). The measurement used the isometric muscle torque stand, which enabled the direct measuring of torques for flexors and extensors of elbow, shoulder, knee and hip joints and flexors and extensors of trunk. Angle positions for all joints were 90 deg (with

180 deg full extension) with the exception of the shoulder joint (45 deg). The stand enabled the measurement of each group of muscles with simultaneous elimination of the influence of any other forces [Jaszczuk et al.1987].

MEASUREMENT OF THE MUSCLE TORQUE UNDER DYNAMIC CONDITIONS

The measurements were carried out on the Computerized Exercise System (ARIEL modified in its mechanical part the Arm-Leg Station). Subjects performed simulated throws in the sitting position, propelling the bar of the Arm-Leg Station [Ariel, 1991]. The movement was similar to the last phase before the release of the ball during a real throw. Each subject executed three kinds of tests: maximal speed diagnostic (MSD), isokinetic exercises (IKE) at angular velocities 100, 300 and 500 deg/s, isotonic exercises (ITE) at external torques 10, 30 and 50 N·m.

The following parameters were chosen to further the analysis: maximal angular velocity of the bar measured during MSD, maximal and average mechanical power during IKE and ITE, maximal and average torque developed in IKE, maximal and average angular velocity measured in ITE.

COUNTER-MOVEMENT JUMP

The maximal mechanical power of the lower extremity and trunk was measured during the vertical counter-movement jump performed on a force platform [Dowling and Vamos 1993]. The signal (force) was processed on-line (IBM PC). Five parameters were chosen in order to estimate speed-strength characteristics of the lower extremity of the handball players: Pmax-maximal mechanical power [W], Pave-average mechanical power [W], Hmax-maximal height of the jump [m], t-time of the take-off [s], P/m-maximal power related to body mass [W/kg].

RESULTS

The highest values of linear throwing velocity of the ball has achieved after ,throwing with a cross-over step and the differences between this value and velocities measured during throws on the spot and with an upward jump were statistically significant. The results are shown in Table 1.

Table 1. Maximal value of ball velocity [m/s] during different types of ,throwing (mean values for n= 12).

Thmw	X ± SD	min.	max
on the spot	20.0 ± 1.65	18.1	23.3
with a cross-over step	21.4 ± 1.80	19.5	25.1
with an upward jump	19.5 ± 1.24	17.8	21.1

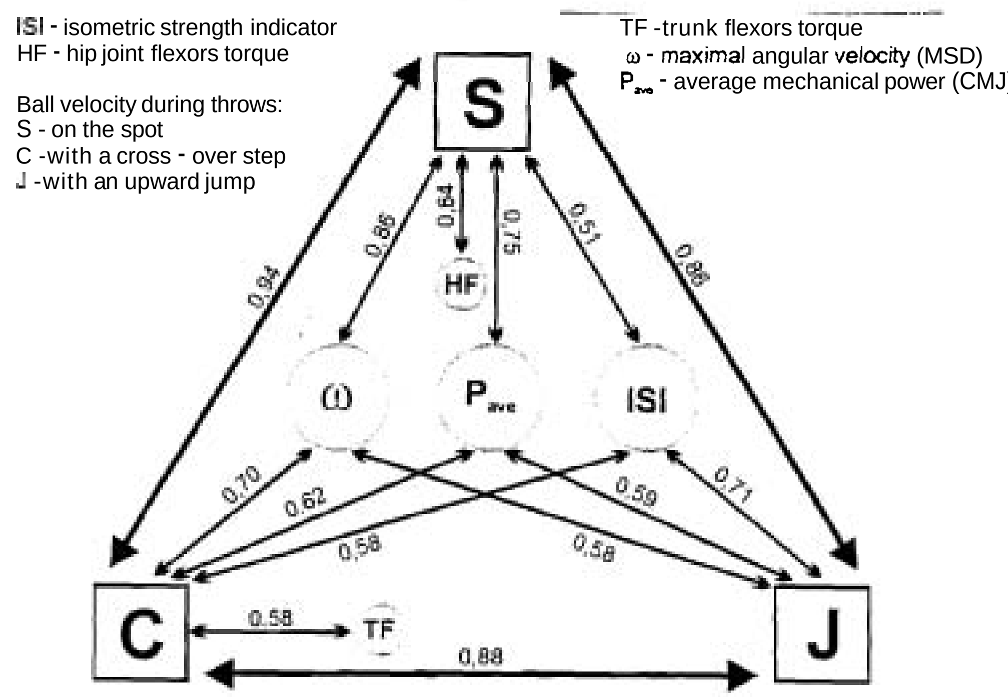

Fig.1 Linear correlation between ball velocity and selected motor ability parameters (for n=12 and α=0.05 r=0.576).

MULTIPLE REGRESSION

Expected values of the ball velocity for three different throwing techniques:

a) throw on the spot (multiple correlation coefficient R = 0.93; R2 = 0.87)
$Ys = 0.023 \times X_5 + 0.001 \times X_4 + 0.011 \times X_3 + 3.42$

b) throw with a cross-over step (multiple correlation coefficient R = 0.82; R2 = 0.68)
$Yc = 0.021 \times X_5 + 0.013 \times X_3 + 0.001 \times X_1 + 1.53$

c) throw with an upward jump (multiple correlation coefficient R = 0.83; R2 = 0.69)
$Yj = 0.003 \times X_1 + 0.001 \times X_4 + 0.006 \times X_3 + 8.93$

where: X1 - isometric strength indicator (ISI), X2 - isometric muscle strength of hip joint flexors, X3 - isometric muscle strength of trunk flexors, X4 - average mechanical power developed during CMJ, X5 - maximal angular velocity of the bar (MSD).

DISCUSSION

Among the many different throws in team handball the most often used during the game is the throw with an upward jump [Eliasz et al., 1990, Marczinka 1993]. Although the ball velocity measured after this kind of throw does not reach the highest value (see

Tab.1) and throwing technique is far more complicated then that of the other analyzed throws jump [Eliasz et al., 1990, Marczinka 1993], the popularity of the throw with jump is due to its efficiency [Eliasz 1993]. The ball velocity values showed in Table 1 are similar to those which have been obtained by others [Mikelsen and Olesen 1976, Filiard 1985, Eliasz et al., 1990], even though the average velocity was measured along two meters distance and the first photocell gate was placed two meters from the thrower. The maximal value of the ball velocity can be measured during release using radar [Mikelsen and Olesen 1976, Pedegana et al., 1982, Filiard 1985, Bartlet et al., 1989] or cinematography (especially 3-D), which is a very time-consuming but still popular method in biomechanics [Atwater 1980, Filiard 1985, Joris et al., 1985, Feltner and Dapena 1986, Muijen et al., 1991, Best et al., 1993, Coleman et a1.1993, Sakuraj et al., 1993, Whiting et al., 1993].

The highest value of ball velocity measured during throw with a cross-over step can be explain on a biomechanical basis. During this type of throw the motion direction of player's center of gravity is consistent with the direction of ball flight, so it has an initial velocity before release. The results of strength assessments (both under static and dynamic conditions) can not be directly compared to others results because the unconventional measurements procedure was applied.

Many researchers who have investigated an overarm throw, have indicated that muscle strength is a very important factor influencing throwing velocity [Pauwels 1978, Pedegana et al., 1982, Amin et al., 1985, Pawlowski and Perrin 1989, Renne et al., 1990, Wooden et a1.1992, Bartlet et al., 1993, Eliasz 1993, Marczinka 1993]. In this work statistical analysis has shown that the muscle strength of trunk flexors is one of the most significant velocity determinant in analyzed throws (this variable is in all presented equations). The abdominal muscles include: rectus abdominis, external and internal oblique muscles. All these muscles, acting together, are involved in forward bending but trunk rotation is caused by one-side shortening action of external and internal oblique muscles. Both type of motions can be observed during throwing before release [Atwater 1980, Joris et a1.1985, Eliasz 1993, Marczinka 1993].

The investigation has some practical applications. There are two main possibilities to improve throwing velocity, probably in all techniques used in handball: (1) by development abdominal muscles strength and (2) by improvement speed of external and internal rotation at the shoulder joint. The last can be achieved, for example, by using a lighter ball during training [Joris et al., 1985, Eliasz 1993]. All these statements need practical verification in the training process.

CONCLUSIONS

1. Statistically significant differences were found between maximal ball velocity during throws with a cross-over step, and ball velocities during other analyzed throws. The highest ball velocity was achieved during the throw with a cross-over step performed by play-makers.

2. Among the motor ability factors, total muscle strength of the body (ISI), strength of trunk flexors (abdominal muscles) and maximal arm (shoulder joint) angular velocity (MSD) have a decisive effect on the ball velocity in analyzed throwing techniques.

3. The maximal arm speed is the most important factor determining ball velocity during the simplest throw on the spot. Muscle strength has greater influence on ball velocity during the technically more complicated throw with an upward jump.

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