No differences in contact times were found in the right and left strides across the 3 trials. The mean time was 1.262 sec at the beginning of the workout and decreased to 1.19 sec over 30 yrs of step bench aerobics as shown in Figure 3. The increase in contact time with the bench was the result of the subjects standing on the bench and using a more ballistic technique on the right leg as the exercise progressed. Also, this change of technique was reflected in increases in the double support phase duration, which was indicated by action forces during step bench aerobics. In special aerobic dance, the main muscle groups under static conditions. The isometric muscle torque stand (locally made) was used to make the measurements, which enabled the direct measuring of torques for flexors and extensors of elbow, shoulder, knee and hip joints and flexors and extensors of trunk (Jaszczuk et al. 1987).

DETERMINANTS OF THE THROWING VELOCITY IN HANDBALL - A STATISTICAL MODEL

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INTRODUCTION

Ball velocity is one of the most important factors which has a decisive effect on scoring in team games, like handball, baseball, cricket, water polo, volleyball, soccer etc. (Atwater 1980, Joris et al. 1986, Eliasz et al. 1990, Marcznka 1993). Basically scientists are in agreement that the main determinants of the ball's velocity can be divided into three groups: technique of motion, somatic features and motor ability (Pauwels 1978, Muijen et al. 1991). However, the technique of motion and the fitness level can be improved by the training process, whereas morphological factors are, in the main part, genetically determined. Thus, the information about the degree of influence of each factor on the ball velocity appears substantial, in order to answer the question: proper selection or proper training has a better effect on ball velocity measured during throwing. Among experienced players it is particularly difficult to make progress in this area without the special approach to exercises and training methods. The first step leading to this task is to specify the most important characteristics which affect ball velocity and develop them during training.

The aim of the research was to find the influence of the basic anthropometrical and motor ability parameters on ball velocity during throws in handball where the throwing technique remains consistent. These relationships seem to be very important for coaches, in order to improve the selection quality and the efficiency of training methods.

METHODS

Twelve high-performance handball field players took part in the experiment. The average values of basic parameters of physical characteristics of the subjects were: 89.0±7.8 kg body mass, 1.88±0.05 m body height and 23.3±2.5 years of age.

Anthropometric measurements were carried out according to Martin's method. The following somatic indices were used: length (body height, upper and lower extremity, arm, forearm, palm and fingers of the predominant hand), skeleton width (shoulder, pelvis, palm), musculature (arm and forearm circumference) and adiposity (three skin folds). For each player we used 26 somatic characteristics. 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. The average linear ball velocity was measured over a 2 meter distance using a special photocells system (Eliasz et al. 1990). The muscle strength was evaluated on the basis of torques developed by main muscle groups under static conditions. The isometric muscle torque stand (locally made) was used to make the measurements, which enabled the direct measuring of torques for flexors and extensors of elbow, shoulder, knee and hip joints and flexors and extensors of trunk (Jaszczuk et al. 1987).
The measurement of the muscle torque under dynamic conditions were carried out on the CES ARIEL modified in its mechanical part. Subjects performed simulated throws in the sitting position, propelling the bar of the Arm-Leg Station. Each subject executed 3 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. During the vertical counter-movement jump performed on a force platform maximal height of the jump and maximal mechanical power of the lower extremity and trunk were measured. The signal (force) was processed on-line using IBM PC.

**Statistical methods**

The mean value, standard deviation and coefficient of variance were calculated for each parameter. A normality of distributions were examined using the Shapiro-Wilk test. At the next stage the Pearson's correlation matrix and multiple regression analysis were used ($\alpha=0.05$). The row data were recalculated to values in T-scale and according to the Doolittle method the contribution to throwing velocity was calculated for each factor: motor (M) and anthropometric (A). The best regression subset was assigned using Fisher's discriminating method. The regression hyperplane parameters were estimated, which divided players according to throwing velocity criterion.

**RESULTS**

Multiple regression analysis has shown that the most important throwing velocity determinants are: range of fingers, shoulder width and length of hand - among anthropometrical factors and isometric muscle strength of trunk flexors, maximal angular velocity of the bar measured in MSD and average mechanical power developed in CMJ - among motor abilities. Expected value of the ball velocity ($Y$) is stated the following equation:

$$Y = 0.018 X_1 + 0.733 X_2 + 0.039 X_3 - 0.332 X_4 + 0.006 X_5 - 2.854$$

where: $X_1$ - maximal angular velocity (MSD), $X_2$ - range of fingers, $X_3$ - average power (CMJ), $X_4$ - shoulder width, $X_5$ - isometric muscle strength of trunk flexors
For these five parameters the multiple correlation coefficient is: $R=0.982$ ($R^2=0.963$).

The proportional contribution of these factors in expected value of the ball velocity is:

- $X_1 = 36\%$; $X_2 = 41\%$; $X_3 = 3\%$; $X_4 = 6\%$; $X_5 = 11\%$.

After recalculation to T-values the final equation contains two main factors: anthropometric (A) and motor (M):

$$Y = 0.017 A + 0.072 M$$

$R=0.857$, $R^2=0.735$

The proportional contribution of these factors in expected value of ball velocity is 11.9% and 61.4%, respectively.

Using Fisher's discrimination method, according to ball velocity criterion, the subjects were divided into two groups, consisting of nine (mean velocity) and three people (high velocity). It is shown on figure 1. The hyperplane parameters are as follows:

$$0.149 M + 0.051 A - 23.821 = 0$$

Fig. 1. The hyperplane divides players into two groups. The right side of the graph represents the ball with high velocity.

The results summarized great influence on the throwing velocity. The authors investigated an overall important factor influencing throwing velocity: muscles: abdominal and shoulder muscles, which influence shoulder and leg speed. The authors found that the most important factor influencing throwing before release was the shoulder and leg power. From a practical point of view the subjects were divided into two groups: (1) by improving the speed and (2) by improving the power.

Among the anthropometric factors shoulder length are correlated significantly less than relatively small.

The expected value of the ball velocity ($Y$) was calculated using the following equation:

$$Y = 0.018 X_1 + 0.733 X_2 + 0.039 X_3 - 0.332 X_4 + 0.006 X_5 - 2.854$$

where: $X_1$ - maximal angular velocity (MSD), $X_2$ - range of fingers, $X_3$ - average power (CMJ), $X_4$ - shoulder width, $X_5$ - isometric muscle strength of trunk flexors
Dynamic conditions were part. Subjects performed runs of the Arm-Leg Station. Speed diagnostics (MSD), and 500 deg/s, isotonic, 90 cm. During the vertical swing, maximal height of the extremity and trunk were measured (IBM PC).

Coefficient of variance were examined using a correlation matrix and a multiple regression analysis. Data were recalculated using statistical methods (e.g., the contribution to the Multiple Discriminant Analysis (MDA) and anthropometric (A)).

Most important throwing criterion is the length of hand strength of trunk flexors, and average mechanical value of the ball velocity:

\[ 0.006 X_5 - 2.854 \]

The ball velocity criterion, however, is not significantly correlated with the ball velocity in measured throws. All these factors determine the grip quality, which allows the ball to be caught, held, and manipulated easily. The influence of these factors on throwing velocity is significantly less than motor abilities. The basic somatic features (body height, body...
mass) seem to be more important to the selection of players to specific positions in
the game than to general selection for the sport, although it statement still needs
verification (Maia et al. 1991).

CONCLUSIONS

These results suggest that:
1. The most important throwing velocity determinant is the motor abilities level (if
the technique of motion is not taken into the consideration).
2. Among analyzed motor parameters the strength of trunk flexors (abdominal
muscles) and maximal arm (shoulder joint) angular velocity have a decisive effect
on ball velocity in handball.

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KINEMATIC ANALYSIS

RESULTS

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INTRODUCTION

The purpose of the present study was to analyze the mechanical parameters
of shooting. It doesn't deny the importance of the sport in the game, but it
only assumes that all these factors are significant in the reduction of throwing
speed should be assured by their interactive movements. The youngster's feeling
of shooting performance. The study was conducted in a separate room which is the reason why
Shooting is the first technique. The youngster's feeling of shooting performance.
The process is very important. It must be conducted by the youngster and the theory that
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METHODS

Eighteen four-year-old players were involved in the study. The subjects' mean
mass was 50.82 (+/-6.39) kg. Two different balls were used: one was a standard size ball (613 gr weight) and the other was a smaller, adapted-size-ball (600 gr weight).