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The Influence of Anthropological Features on Ball Flight Speed in Handball

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A B S T R A C T

The purpose of this study, done on the sample of 41 students of Faculty of Kinesiologyi in Spli,t was to determinate the differences in anthropological characteristics between students who achieved above average and students who achieved under average ball flight speed after jump shoot in handball. Anthropological characteristics were defined by 16 variables, 6 of them were used for the estimation of morphological characteristics, 7 variables for evaluation of motor characteristics and one variable each for evaluation of kinetic, kinematics and technical parameters of shooting. The significant differences were determined in variables for evaluation of longitudinal dimensionality of dominant arm, explosive strength of pull-out agility, strength of the hand grip, hand flexion ability for the ball throw-out and finally, correct and sound technique of the throw-out movement.

***Key words**: handball, ball flight speed, anthropological features*

Introduction

The result of handball game is determined by outcome of terminal attacking phase – shot. Shot outcome depends on large number of factors, especially on technical factors of shot execution which include regularity and rationality of pulling movement, tactical factors such as abruption, timeliness etc. and all anthropological factors of throw executor[1,2]. Of course, shot outcome depends also on all the above mentioned factors regarding the opposing team, which means performance and anthropological features of opposing defenders and goalkeeper[3]. If we isolate the final throw and ignore outer factors that can not be influenced by the player himself, it can be stated that the outcome of the shot, besides the precision, dominantly depends on ball speed[4], that is, on all the anthropological features of the player that determine final ball movement speed in shot.

Achieved speed depends on the length and the speed of arm activity on ball, successiveness and synchronization of movements in chronological order in kinetic chain, starting from the trunk movement to shoulder and elbow joint movement, but also, it greatly depends on the speed of the final throw movement that occurs in the wrist. Wrist flexion and inversion of the wrist at the terminal pull cause the final acceleration of the ball, required direction and rotation. Due to this fact, the strength of wrist joint and forearm muscles is of great importance in handball. Therefore, in the process of training, special attention should be dedicated to the development of this ability. Starting from the importance of the ball flight speed for the success of the shot in handball[5], main goal of this paper is to determine in which anthropological features differ the examinees that achieve under average ball flight speed from those that achieve above average ball flight speed from jump shot in handball.

Basic jump shot starts with push-off from the leg opposite to the throwing arm. The push-off is performed with so called rolling, starting from the heel over foot and toes and with energetic extensor muscle activity in the jumping leg ankle joint as well as jumping leg knee and hip joint. Due to this reason, pull-off leg is slightly flexed in knee while the other leg, which is more flexed, swings in order to bring body forward and sideway outward, thus improving the pull-off power. Body posture is similar to the posture of the basic ground shot. Hand with the ball and the shoulder of the throwing arm is adducted, the opposite shoulder is put forward while trunk is upright. Pull-out phase starts with the rotation in the trunk bouncing around the vertical axis and the

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throwing arm shoulder moving forward. The arm is slightly flexed in elbow so the ball is placed sideway and high above the head, somewhat higher than the shoulders width. At the moment when the throwing shoulder passes the frontal plane, throw continues with the elbow movement and, finally, forward movement of the fist, followed by retroactive movement of the swinging leg forward and down thus improving the throw-out force. First contact of the leg with the ground in the landing phase is done with the pull-off leg.

Besides this basic jump shot, there can be various modifications that are characteristical for particular playing positions. For example, typical jump from the wing position, in addition to direction of the pull-off at around 45° which is diagonally positioned towards penalty line in order to open the shooting angle, includes typical pose of the throwing arm that is more aside, sometimes even parallel to the ground. Also, because the trunk is more rotated around axially axis, it is necessary to push forward the hip of the swinging leg. At small shooting angles, or when the approach is directed aslant towards the goal, wing players sometimes use jump-shot with the pull-off from the same leg in relation to the hand holding the ball. Backcourt players sometimes shoot using both-legs-jump from the short approach, while those pivots who lack the time for approach phase and are disturbed by the defenders, often perform the jump shot from both legs while being turned to the goal sideways or even with their back. Following mistakes are the most often: Leaning trunk backward or aside during the jump, throwing arm elbow under shoulder level, not bringing shoulder of the throwing hand backward, passivity of the swinging leg, discrepancy of kinetic chain during the shot.

Assuming the importance of the influence of anthropological features on the ball flight speed in handball, the aim of this research is to determine in which anthropological features differ students who achieved above average and students who achieved under average ball flight speed after jump shoot.

Materials and Methods

Subjects

Research was conducted on the sample of 41 students attending first year of Faculty of Kinesiology in Split that were not handball players, ages 18–19. All of the examinees had finished seven-week handball course.

Variables sample

Prediction anthropological space is defined by 16 variables, 6 variables for the estimation of morphological features, 7 for the estimation of motor abilities and one variable for each of the following parameters: kinetic, kinematical and technical shooting parameters.

Morphological characteristics of the dominant arm are defined by 6 variables: arm length, forearm length and hand length for the estimation of longitudinal arm dimensionality, while hand width, hand joint diameter and elbow diameter are used for the estimation of transversal hand dimensionality.

Motor capabilities are defined by 6 variables of special importance for success in handball[6]: 20 m sprint for the estimation of power speed (20M), side-steps for the evaluation of lateral agility (SSA), »Japan« test for the evaluation of vertical agility (JAP), two-handed 1 kg »medicine« ball throw from lying position for the evaluation of explosive throwing power (MBT), knuckles for the evaluation of relative repetitive arms and shoulders strength (KNC), hand taping for the evaluation of hand movement frequency speed (TAP) and long jump from without approach for the evaluation of explosive power during take-off (JWA).

Kinetic features are defined with squeeze strength of dominant arm measured by digital dynamometer »Takei«. Examinees performed three maximal contractions with sufficient pauses and the maximal value was chosen as the measured result.

Kinematical parameter that was measured was the pitch length of the handball ball thrown from the hand joint with all the other joints fixed. Dimensions and weight of the ball were in accordance with the standard handball rules for seniors and according to approval of IHF. Examinees were throwing the ball from the sit-down position with the angle of 90° between forearm and the upper arm. Both, forearm and the upper arm were fixed behind upper surface of the Swedish chest and only the hand was free and above the chest level. Metric features of this test variant had been previously determined by Čavar et al. (2007)[7].

Motor knowledge quality**,** that is technical correctness of jump-shot, was estimated by 6 independent handball experts (experts that have PhD, master's degree or have graduated in the field of handball). Evaluators were diagonally positioned towards the performer in order to have as good view to the shot performance as possible. Examinees were performing jump-shot three times and the evaluation experts graded the best performance on the scale 1–10.

Criterion variable that corresponds to ball flight speed was measured with a radar laser gun Speedster Radar Gun manufactured by American company Bushnell. From the distance of 9 meters away from the goal, after the jump-shot and by using handball ball number 3 (weight 450 g, circumference 58 cm, pressure 0.5 bar) examinees were aiming at a linen target (50 cm x 50 cm) placed within goalpost. Each examinee performed described test for three times and a statistical mean value was calculated in order to obtain ball flight speed for particular examinee.

Statistical analysis

Data processing included calculation of basic descriptive and distributional statistical parameters such as arithmetic mean ($\overline{X}$), standard deviation (SIG), minimal and maximal result values (MIN, MAX), coefficient of skewness (SKE), distribution kurtosis (KUR). Distribu-

tion normality test was conducted by Kolmogorov-Smirnov test on the significance level $p<0.01$.

Differences in anthropological characteristics between students who achieved above average and students who achieved under average ball flight speed after jump shoot were determined by univariate variance analysis. Therefore, students were separated into two groups, those who achieved the ball flight speed higher than the average speed of all students and those who achieved under average ball flight speed.

Results

Table 1 shows descriptive statistics results. It is evident that all variables have normal distribution and that they can be used in further multivariate data processing. Only the ball throw length variable is on the margin of normal distribution since the results have a tendency towards lower values and because the distribution is quite stretched.

When comparing morphological descriptors of this sample and the results obtained by previous research on top handball players[6], it is evident that top players have more emphasised dimensionality, which is logical and understandable. For example, average hand length for top handball players in Croatia is 22.22 cm, while average hand length for students is 20.30 cm.

Comparing the results of our motor tests with the results of other researchers obtained for the student samples[8,9], it can be stated that motor efficiency is on the expected average level for male population in Croatia.

Table 2 shows the results of the univariate analysis of variance. It is well-known that ball speed, besides on player's anthropological features, depends on length of the ball trajectory, the quantity of engaged musculature as well on the speed and synchronisation of contraction and relaxation of the muscles involved in the ball throwing movement. Regarding the variables of morphological space, statistically significant differences were determined for all longitudinal measures, while no transversal dimensionality measure was found statistically significant in relation to ball speed. Students who have above average length measures of dominant hand achieve significantly higher ball speed after jump shot throw because longer arm provides bigger amplitude of the throwing movement as well as the longer period in which the end of kinetic chain influences the ball, which implies higher ball acceleration.

TABLE 1
BASIC DESCRIPTIVE AND DISTRIBUTIONAL STATISTICAL PARAMETERS (N=41)

Variables	$\bar{X}$	Min	Max	Sig	Ske	Kur	Max d
Morphology							
Arm length (cm)	81.34	74.80	90.20	4.16	0.45	–0.40	0.12
Forearm length (cm)	27.73	24.50	39.10	2.41	2.88	12.13	0.19
Wrist diameter (cm)	5.79	5.30	6.60	0.30	0.61	0.31	0.12
Hand width (cm)	8.41	7.50	9.30	0.44	0.03	–0.95	0.12
Hand length (cm)	20.30	17.35	22.30	1.14	–0.22	–0.03	0.08
Elbow diameter (cm)	7.21	6.40	8.40	0.41	0.80	1.37	0.17
Motorical performance							
20M (sec)	3.30	2.97	3.78	0.20	0.66	0.17	0.12
SSA (sec)	7.64	6.35	10.09	0.74	1.02	1.83	0.15
JAP (sec)	13.63	12.20	15.50	0.79	0.29	–0.13	0.08
KNC (reps)	9.50	2.00	19.00	3.49	0.24	0.28	0.10
TAP (reps)	42.45	37.00	46.00	2.47	–0.41	–0.52	0.16
JWA (cm)	259.79	224.00	295.00	16.97	–0.06	–0.31	0.12
MBT (m)	13.61	11.50	17.43	1.37	0.82	0.18	0.13
Dynamometry							
Dominant arm squeeze (kg)	49.38	37.80	67.27	7.60	0.63	–0.20	0.10
Motorical knowledge							
Technique evaluation grade	5.63	1.83	9.33	1.31	0.05	1.56	0.08
Kinematical – throw length							
Hand joint throw (m)	3.60	2.21	7.13	1.04	2.13	5.37	0.19
Criterium ball speed							
Jump shoot ball speed (km/h)	70.60	59.50	84.00	6.06	0.20	–0.42	0.08

20M – 20 m sprint, SSA – side step agility, JAP – japan, KNC – knuckles, TAP – hand taping, JWA – long jump without approach, MBT – medicine ball throw

TABLE 2
RESULTS OF THE UNIVARIATE ANALYSIS OF VARIANCE

Variable	$\overline{X}$ better (N=19)	$\overline{X}$ inferior (N=22)	F	p-level
Morphology				
Arm length (cm)	83.30	79.64	9.59	0.00**
Forearm length (cm)	28.69	26.90	6.40	0.02*
Wrist diameter (cm)	5.87	5.72	2.61	0.11
Hand width (cm)	8.51	8.32	1.85	0.18
Hand length (cm)	20.67	19.98	4.04	0.05*
Elbow diameter (cm)	7.31	7.13	2.07	0.16
Motorical performance				
20M (sec)	3.26	3.34	1.69	0.20
SSA (sec)	7.37	7.87	5.05	0.03*
JAP (sec)	13.42	13.84	3.03	0.09
KNC (reps)	9.00	9.86	0.61	0.44
TAP (reps)	41.84	43.00	2.25	0.14
JWA (cm)	264.26	255.64	2.69	0.11
Dynamometry				
Dominant arm squeeze (kg)	52.05	47.09	4.61	0.04*
Motorical knowledge				
Technique evaluation grade	6.25	5.15	8.28	0.01*
Kinematical – throw lenght				
Hand joint throw (m)	3.68	3.21	5.10	0.03*

*p>0.001, **p>0.05, 20M – 20 m sprint, SSA – side step agility, JAP – japan, KNC – knuckles, TAP – hand taping, JWA – long jump without approach, MBT – medicine ball throw

Discussion

From the physical aspect, ball speed during throw-out depends on transmitted force impulse,

$$\div\vec{\tau} \mid \frac{1}{m_{ball}} \int_{t1}^{t2} \vec{F}(t)dt$$

where stands for the increase in ball speed from the beginning of swing t1 until throw-out moment t2, and m_{lball} is mass of the ball.

Therefore, player who longer affects the ball with the force will transmit more kinetic energy to the ball. Since the following equation can be written for kinetic energy (E_k),

$$E_k \mid \frac{m_{ball}v^2}{2} \mid \vec{F} \rfloor \vec{s}$$

which means that it is equal to scalar multiplication of force affecting the ball and the path that it is travelling on (while held in the hand), it is obvious that longer ball path during swing can be achieved by players with longer arms i.e. players that can perform bigger amplitude of the throw-out movement.

At the same time, besides arm and forearm lengths, hand length is very important because, in order to ease ball manipulation, a player does not hold ball firmly and low on the palm, yet it is held on distal ends of the metacarpal bones. Based on the basic biomechanical laws, bigger hand length increases lever length, i.e. the last clevis of the throw-out kinematic chain, and that is an important component of the efficient throw finalisation[10].

By observing motorical space variables, it can be noticed that statistically significant differences occur in variables for estimation of lateral agility and explosive strength in throw-out. Explosive throw-out strength, which was, in this case represented by throwing a 1 kg »medicine» ball while using both hands from the laying down position, is one of the motor characteristics that largely defines situational efficiency of a player in handball. It is defined as a capability of fast excitation and contraction of motor units needed for suppressing absolute or relative load, i.e. efficient force generation in as small time unit as possible during one isotonic contraction aimed towards acceleration of an instrument or a body.

Explosive pull strength is necessary for efficient shooting, especially for backcourt players that shoot from longer distance, but it also indirectly participates in other kinesiological structures of handball game such as, for example, when a defense player steps out and encounters closely with an attacker. Significance of the explosive pull-out strength measured by this test and its influence on ball flight speed is understandable and expected because kinesiological structure and biomechanical principles of the throw-out movement execution are highly correlated with the structure of the criterium test[2,10]. Corre-

lation can be detected in the fact that both of these cases activate the same arm and shoulder area muscle groups, especially m. deltoideus and m. triceps brachi.

Statistically significant difference, between students achieving under-average and above-average ball flight speed achieved from the jump-shot, can be noticed in side-step variable that is aimed towards estimation of lateral agility. Agility is ability of quick establishing, execution and change of movement direction in limited space. This ability is important for final ball speed because it ensures higher initial acceleration of the whole body on a short path.

Hand grip strength is also statistically significant in differentiating students regarding the achieved ball speed which is logical and understandable. Firm hand grip is not only important for firm holding of the ball with distal ends of the metacarpal bones, but it also provides fast hand flexion in the terminal phase of the throw-out which gives final ball acceleration and provides kinematic efficiency of the throw-out. Considering previously explained hand length importance on ball speed, it can be assumed that distinguishable hand longitudinal dimensionality contributes also to the hand grip strength because examinees with longer hand, due to biomechanical reasons, need to produce proportionally shorter affecting path to the instrument than the students with shorter hand. Also, longer tendons contribute to more efficient grip[11]. In fact, examinees with longer hand have to extend hand less in initial grip of the instrument and therefore they have better initial base for forearm muscles contraction. Motor knowledge of the jump-shot execution significantly determines differences in ball speed because only technically sound, rational, harmonious and precise throw-out movement provides efficient transfer of the body to the ball. Time-spatial synchronisation, timeliness and successiveness of the various muscle groups and joints inclusion in kinetic chain as well as optimal relations and angles between levers are necessary premises for maximal generation of force impulse in throw-out movement. Therefore, the speed of distal end of kinematic chain in the moment of throw-out, besides on the lever lengths responsible for achieving as longer trajectory as possible, greatly depends on technical characteristics of the throw-out movement, i.e. it depends on motor knowledge quality because it ensures that motor and morphological components are optimally utilised. Also at the level of statistical significance, ball flight length when thrown from the wrist differentiates students in relation to the achieved ball flight speed from the jump-shot which is understandable because basic mechanical laws tell us that speed and path are proportional. Ball flight length in this test dominantly depends on quick and explosive wrist flexion capability that is primary correlated to the forearm muscles strength[11]. Strength of these muscles is also dominant for the final phase of the throw-out movement in jump-shot when the energetic hand flexion transfers impulse to the ball.

When sublimating the results of this research, it is possible to define an anthropological model that ensures high ball speed during throw-out in jump shot. It is primarily based on emphasized longitudinal dimensionality of dominant arm skeleton which, by using the longer levels, provides larger throw-out movement amplitude and longer influence of muscle force on a ball, larger strength of front trunk, shoulder area and especially throwing forearm muscles[12]. This model also depends on the information component relating to technique sound, rational and precise structure of the throw-out movement.

Conclusion

Results obtained by this research direct attention to important parameters that condition ball speed in jump shot. Out of morphological parameters we can outline long levers of the shooting arm, especially of the hand whereas explosive throw-out strength and strength of the forearm muscles of dominant arm, providing the firm ball grip stand out of motor parameters. Previously mentioned anthropological characteristics are expressed only in combination with technically correct execution of the throw-out movement. Research results show that, during the selection of players, especially for back positions, advantage should be given to the players with bigger longitudinal dimensionality and significant explosive strength that is similar to previous research[14]. Also, in training process, special attention should be paid to explosive pull-out strength, strength of the forearm muscles and agility. However, attention should be focused on training's informational component, i.e. learning and improving the motor knowledge especially the one of the correct technique of the throw-out movement.

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UTJECAJ ANTROPOLOŠKIH ZNAČAJKI NA BRZINU LETA LOPTE U RUKOMETU

S A Ž E T A K

Cilj ovog rada, provedenog na uzorku od 41 studenta Kineziološkog fakulteta u Splitu, bio je utvrditi u kojim se antropološkim značajkama razlikuju ispitanici koji postižu ispodprosječnu od onih koji postižu iznadprosječnu brzinu leta lopte kod skok-šuta u rukometu. Antropološke značajke definirane su sa 16 varijabli, od čega 6 varijabli za procjenu morfoloških značajki, 7 za procjenu motoričkih sposobnosti te po jednom varijablom za procjenu kinetičkih, kinematičkih i tehničkih parametara šutiranja. Statistički značajne razlike utvrđene su u varijablama za procjenu longitudinalne dimenzionalnosti dominantne ruke, motoričkim sposobnostima eksplozivne snage tipa izbačaja i agilnosti, jakosti stiska šake, sposobnosti brze fleksije šake u cilju izbačaja lopte te pravilnoj tehnici izbačajnog pokreta.