KINEMATICS OF THE UPWARD JUMPING THROW IN HANDBALL - COMPERISON OF PLAYERS WITH DIFFERENT LEVEL OF PERFORMANCE

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The purpose of this study was to compare the kinematics and the ball velocity of the upward jumping throw in handball of three groups with different level of performance. Significant differences between the groups were founded for the ball velocity, the segment velocity of the finger and wrist, the angle range of the shoulder flexion and extension and the maximal angular velocity of the shoulder flexion, extension and internal rotation, the elbow flexion and the ulnar deviation of the wrist. Therefore the main caused of an increased ball velocity seems to be an increasing of the angular velocity of the shoulder, especially the shoulder flexion, the elbow extension and the ulnar deviation of the wrist.

KEY WORDS: kinematics, handball, performance level, ball velocity.

INTRODUCTION: Team handball can be viewed as a coordinated and synchronised system of interrelated behaviours. One of these behaviours is the shot on goal. For bringing a shot to a successful end it needs both, maximum of ball velocity and precision as well as having the surprise effect on defence player and goal keeper on ones side. The question of the relationship between kinematics and ball velocity at the handball throw has been tried to be answered in quite a few researches. Van den Tillar and Ettema (2004) pointed out, that 67% of ball velocity at ball release was explained by the summation effects from the velocity of elbow extension and internal rotation of the shoulder. Jöris et al. (1985) showed that a high ball velocity depends on an optimal proximal to distal sequence; Fradet et al. (2004) relativised this thesis because of different results measuring French handball players. That there are differences which depend on the performance level of the players could be shown by Müller (1980). But are there also differences in the angles and angular velocities depending on the performance level of the players especially for the upward jumping throw which is the most prominent throw in the game?
The study at hand points out the differences in kinematics (segment velocities and their timing, ball velocity, angles and angular velocities) of the upward jumping throw in handball of three groups (Austrian top level, Regional top level and Junior team players) with different level of performance.

METHOD: Fifteen male handball players with different performance level (Austrian top level: age: 24.2 ± 2.5 years, weight: 89.9 ± 10.2 kg, height: 188.2 ± 8.2 m, training experience: 13.6 ± 1.9 years; Regional top level: age: 26.6 ± 6.8 years, weight: 83.0 ± 5.7 kg, height: 185.0 ± 2.5 m, training experience: 10.0 ± 2.4 years; Junior team: age: 16.6 ± 0.5 years, weight: 75.0 ± 9.9 kg, height: 185.2 ± 6.8 m, training experience: 5.0 ± 0.0 years) recruited for this study.
After a handball-typical (included passing and throwing) warm-up of 20 minutes, the subjects performed a vertical jump throw (difference between droping and landing should be not more than one meter), which is typical for backcourt-players in handball. The subjects were instructed to shot with a handball to an eight meter away target (0.5 × 0.5 m, 1.75m height) with a maximum of ball velocity and precision. The subsequent evaluation used only those throws (the first ten throws) that met the above criteria, whose deviation from the centre of the target in the x and y directions were less than 0.5 m (measured with a 120Hz camera and SIMI-Motion), and for which all data were recorded without failure.
Kinematics were measured using a 3D motion capturing system (VICON-system with eight cameras, 250 fps) that calculated the positions of 38 passive markers which were positioned on the front (located approximately over the temple) and back head (horizontal plane of the

front head markers), shoulder (acromio-clavicular joint), upper arm, elbow (lateral epicondyle approximating elbow joint axis), lower arm, wrist bar thumb and pinkie side, finger (head of the second metatarsal), pelvis front (directly over the anterior superior iliac spines) and back (sacroiliac joint) side, tight wand, knee (lateral epicondyle approximating knee joint axis), tibia wand, ankle (lateral malleolus), toe (over the second metatarsal head) and heel (same hight above the plantar surface of the foot as the toe marker) right and left side and C7 (7^{th} cervical vertebrae), T10 (10^{th} thoracic vertebrae), clavicle and sternum. To measure the ball velocity the ball were marked with three separate passive markers.
Having filtered the row-data with a quintic spline filter (based on Woltering) we used a three dimensional model refering to Kadaba et al. 1990 to calculate the joint positions and angles. The centre of two markers which were placed on opposite sides of the ball, was calculated to measure the ball velocity (centre of the ball). For comparability between the individual measurements, all throws were time-normed over the ball release point (last contact between finger and ball). The beginning of the motion was established consequently at the point of time 400 ms before and the endpoint of the motion was set exactly 100 ms after the ball release point.

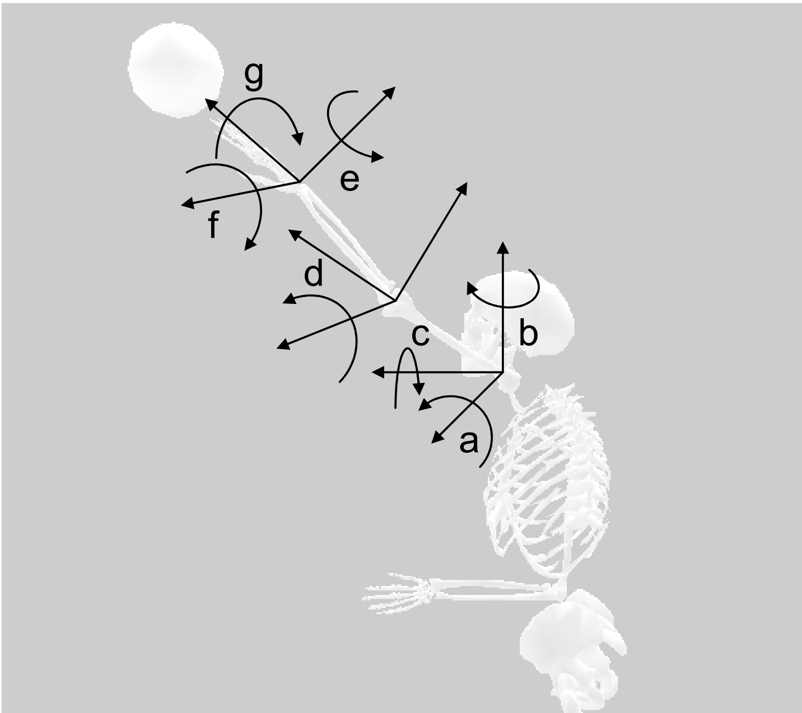

Figure 1: Definition of the calculated upper body angles: (a) shoulder flexion, (b) shoulder abduction, (c) internal rotation of the shoulder, (d) elbow flexion, (e) wrist ulnar deviation, (f) wrist extension, (g) internal rotation of the wrist

To calculate the angles and angular velocities we used Euler angles (comparing the relative orientations of the two segments), therefore each rotation causes the axis for the subsequent rotation to be shifted. These axes were defined as local axis for every segment (see figure 1). All segment angles are defined in the interval -180 to 180 degrees.
To calculate differences between the maximal segment velocities, their timing, the ball velocity, angles and angular velocities One-Way ANOVA were used. To show the significance a level of 0.05 (significant *) and 0.01 (high significant **) was used.

RESULTS: As expected there are high significant ($p = 0.001$ **) differences between the three groups (Austrian top level, Regional top level and Junior team) concerning maximal ball velocity and segment velocity of the finger ($p = 0.000$ **) as well as wrist ($p = 0.004$ **). But for all other segment velocities no significant differences could be identified. Figure 2 the mean values (and SD) of the maximal velocities of every subject of the three groups.

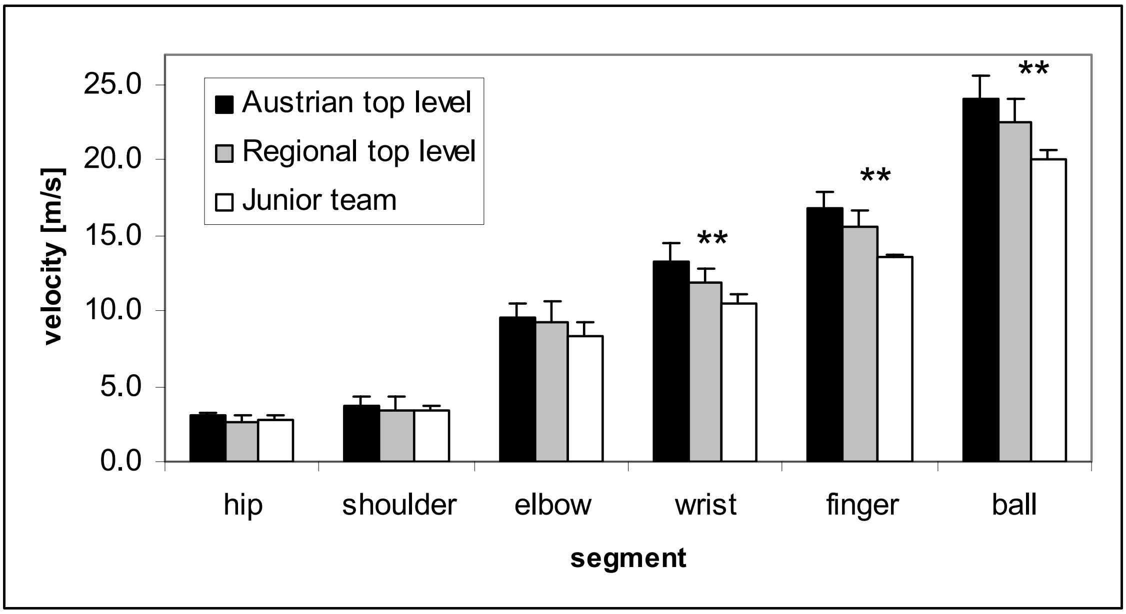

Figure 2: Maximal velocity of different segments (hip, shoulder, elbow, wrist, finger) and the ball during the throw (** indicates a high significant difference between the three groups)

Besides the differences of the maximal velocities between the groups, figure 2 also shows an increase of segment velocities from proximal to distal independent of the performance level. But the point of time where each segment reaches its maximum is different depending on the performance level of the subjects. The relative temporal sequencing of maximal segment velocity differences significant between the groups for finger-wrist (p = 0.024 *) and shoulder-hip (p = 0.021 *)

Table 1: Angle ranges (max-min) during the throw (* indicates a significant, ** a high significant difference between the three (1st column) groups ore two (2nd or 3rd column) groups)

	Angle ranges (mean values ± SD)		
Variable	**Austrian top level**	**Local top level**	**Junior team**
Shoulder flexion **	111 ± 5 --- * ---	96 ± 8	93 ± 8
Shoulder abduction **	105 ± 28	80 ± 12	61 ± 10
Int. rot. Shoulder	166 ± 42	149 ± 21	157 ± 22
Elbow flexion	66 ± 15	71 ± 11	80 ± 8
Wrist ulnar deviation	46 ± 15	41 ± 13	32 ± 4
Wrist extension	47 ± 13	48 ± 15	47 ± 9
Int. rot. Wrist	58 ± 17	60 ± 6	59 ± 23

Table 1 shows, that there are similar angle ranges for all groups for the internal shoulder rotation, the elbow flexion and the ulnar deviation, extension and internal rotation of the wrist. Differences between the groups could be identified only for the shoulder flexion (p = 0.003 **) and abduction (p = 0.008 **).
In opposite to these results there are also significant differences (see table 2) between the groups for the maximal angular velocities for the internal shoulder rotation (p = 0.010 **) and elbow flexion (p = 0.025 *).

Table 2: Maximal angular velocities (rad/s) during the throw (* indicates a significant, ** a high significant difference between the three (1st column) groups ore two (2nd or 3rd column) groups)

	angular velocity (mean values ± SD)		
Variable	**Austrian top level**	**Local top level**	**Junior team**
Shoulder flexion **	23.0 ± 2.7 --- *	--- 15.7 ± 1.9	14.3 ± 1.6
Shoulder abduction *	- 55.3 ± 36.3	- 25.3 ± 16.6	- 15.7 ± 3.0
Int. rot. Shoulder **	97.9 ± 16.3 - *	--- 71.7 ± 12.9	67.8 ± 12.0
Elbow flexion *	- 27.2 ± 2.2	- 25.9 ± 2.7	- 22.0 ± 3.1
Wrist ulnar deviation *	- 27.6 ± 10.1	- 20.4 ± 5.0	- 13.7 ± 4.5
Wrist extension	- 24.4 ± 3.2	- 26.1 ± 7.3	- 22.4 ± 5.0
Int. rot. Wrist	- 43.7 ± 16.7	- 58.8 ± 25.8	- 34.4 ± 30.1

DISCUSSION: As already shown by van den Tillar and Ettema (2004) a high ball velocity at release depends on a high angular velocity of the elbow flexion and internal shoulder rotation. Due to the fact that the maximal ball velocity is also caused by a maximal angular velocity of the shoulder flexion and abduction, an optimal coordination of the shoulder movement seems to be the most important cause of a higher ball velocity of top level players in opposite to more inefficient players.
The different maximal angular velocity of the ulnar wrist deviation, depending on the performance level, is another important result of this study (similar results shown by Wagner, 2005). This ulnar deviation of the wrist causes a higher ball rotation velocity which will, next to sure, have a positive effect on the flight quality of the ball and therefore on the velocity of the ball reaching the goal. The ulnar deviation of the wrist probably causes also a better proximal to distal sequence from wrist to the tip of the finger and therefore a higher ball velocity. This effect should be researched in a following study.

CONCLUSION: The significant differences of the ball velocity between three groups of different performance level were generally caused by a higher angular velocity of the shoulder flexion, the internal shoulder rotation, the elbow flexion and the ulnar deviation of the wrist.

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