A COMPARISON OF PERFORMANCE AND KINEMATICS IN THROWING WITH THE DOMINANT AND NON-DOMINANT ARM IN HANDBALL PLAYERS.

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The purpose of this study was to compare the differences in throwing performance and kinematics between throwing with the dominant and non-dominant arm in experienced handball players. Significant differences in throwing performance (accuracy and ball velocity) were found between the dominant and non-dominant arm. Maximal velocity of most joint movements was significantly different between the arms. However, timing of these maximal velocities did not change. The main cause of the decreased ball velocity was probably the decreased range of motion of the internal rotation of the shoulder. The lower ball velocity was compensated by the increased ball release height, which was caused by increased shoulder abduction and trunk tilt sideways angle at ball release.

KEY WORDS: accuracy, ball velocity, coordination

INTRODUCTION: Overarm throwing is of major importance in many team sports like baseball, cricket, netball and handball. In most of the sports only with the dominant arm is thrown. However, in Team handball sometimes the non-dominant arm is used in the game. Much research has been done on the performance and kinematics in overarm throwing with the dominant arm in different sports (e.g. Matsuo et al., 2001; Feltner & taylor, 1997; Mero et al., 1994). However, only a few studies reported the kinematics of throws with the non-dominant arm (Hoshikawa and Toyoshima, 1976; Hore et al. 1996) Hoshikawa and Toyoshima (1976) only the contribution of the different body segments was studied. Hore et al. 1996 studied the accuracy and kinematics when throwing with a tennis ball while the trunk was fixed. They showed that the accuracy was less when throwing with the non-dominant arm and concluded that the timing of the onset of the finger extension caused this. In their study, no attention was made to throwing velocity of the ball and movements of the different joints. Due to the fixed trunk the throwing movements were restricted and seemed to be unnatural for experienced throwers who also use trunk rotations when throwing.
Therefore the aim of this study is to compare the performances (accuracy and velocity) and kinematics of throws with the dominant (Dom) and non-dominant arm (Non-dom) in a so-called penalty-throwing situation of experienced handball players.
The analysis consists of angles, maximal angular velocities of the different joint movements and their timing during the throw

METHOD: Eleven experienced male handball players (top and first division of the Norwegian national competition) volunteered for this study (mean age: 22.9 ± 3.5 years, weight: 85.8 ± 11.75 kg., height: 1.84 ± 0.05 m., training experience: 13 ± 3.3 years).
After a general warm-up of 15 minutes, the subjects performed a standing throw with holding the front foot on the floor during throwing, also called a penalty throw. The subjects were instructed to throw with a regular ball (0.46 kg.) randomly seven times with each arm as fast as possible and try to hit the target (0.5 by 0.5 m square target at 1.65 m height located in the middle of a handball goal) from seven meters' distance (van den Tillaar and Ettema, 2003; 2004). The subjects had approximately 1-minute rest between each throw.
Velocity of the different segments and joints was measured using a 3D motion capture system (Qualysis, Sävedalen, Sweden, six cameras, 240 Hz) that measured the position of the reflective markers (2.6 cm diameter) on the following anatomical landmarks: a) Ankle: maleolus of the front leg, b) Knee: lateral epycondyle of the front leg, c) Hip: trochanter major on both sides, d) Shoulder: lateral tip of the acromion on the both sides, e) Elbow: lateral

epicondyle of the throwing arm, f) Wrist: radial styloid process and ulnar styloid process of the throwing arm, g) Hand: os metacarpal III, and h) Ball: on top of the ball.
Computation of velocity of the different joints and the ball was done using a five point differential filter. The moment of release was derived from the change in distance between the wrist and the ball. At the moment the ball leaves the hand the distance between the wrist marker and the ball marker increases abruptly and dramatically.

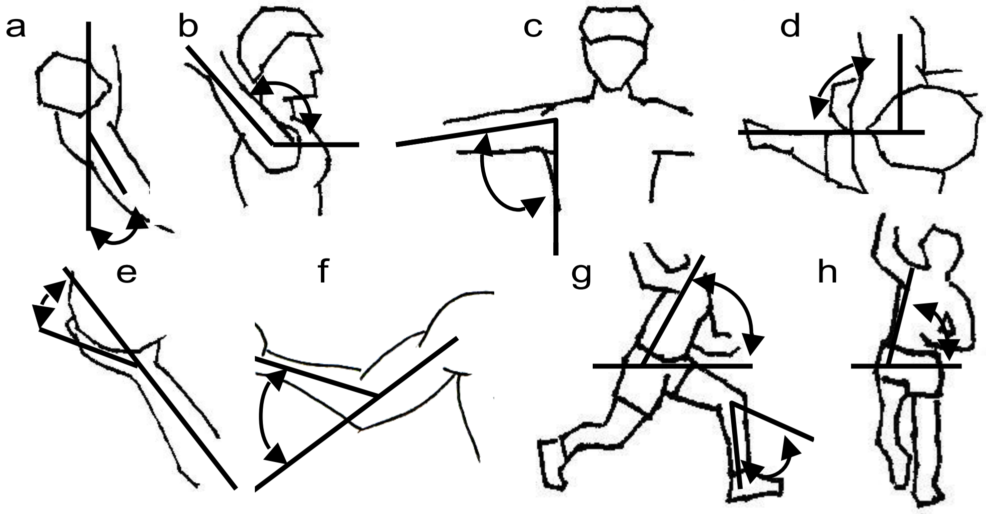

Figure 1: Definition of the different kinematic parameters: (a) horizontal adduction shoulder (b) internal rotation shoulder (c) shoulder abduction (d) pelvis and upper torso rotation (e) wrist flexion (f) elbow flexion (g) trunk tilt forwards and knee flexion (h) trunk tilt sideways.

The angles and angular movement velocities of the different joints were derived from relative positions between the different markers according to the same methods used as Feltner and Dapena, 1989, and Stodden et al. 2005. The maximal angle, maximal angular velocity, their timing and angle at ball release of the following movements displayed in figure 1 were calculated. Timing was measured as time before ball release.
Throwing accuracy was measured with a video camera standing at a distance of 12 meters from the goal. Mean radial error (MRE), bivariate variable error (BVE) and centroid error (CE) as described by van den Tillaar and Ettema (2003) were used as a measurement of accuracy (fig. 2). Mean radial error was measured as the average of absolute distance to the center of the target.
To assess differences between the maximal velocities, angles and timing of the joint movements oneway ANOVA for repeated measures was used and a significace level of 0.05 was used to identify differences.

RESULTS: As expected, the subjects threw significantly more accurate ($p<0.01$) i.e. less MRE, BVE and CE when throwing with the dominant arm (fig. 2) than with the non-dominant arm. All subjects threw significantly faster with the dominant arm (table 1). Also the maximal velocity of most of the joint movements was significantly higher ($p<0.05$) when throwing with the dominant arm (table 1). Maximal internal rotation velocity was reached after ball release. Therefore the angular velocity of the internal rotation of the shoulder at ball release was used in further analysis. Timing of the maximal velocity did not differ much; only a significant difference in timing for the max velocity shoulder abduction was found (table 1). Most joint movements showed a decreased range of motion, measured by the maximal angle and angle at t0 when throwing with the non-dominant arm (table 2).

The onset of the forward movement of the ball (also called the ball acceleration phase) was also significantly different: 0.145±0.031 (Dom) vs. 0.178±0.034 (Non-dom). Most of the significant differences in timing of the maximal angle of the joint movents occured before the ball acceleration except for the internal rotation angle of the shoulder (table 2).

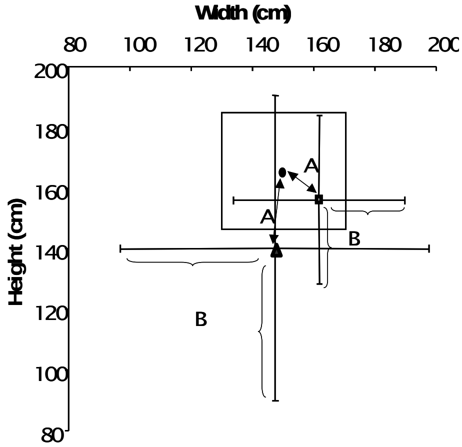

Figure 2: Accuracy measured as the averaged Subjects' Centroid Error (A) and bivariete variable error (B) in throws with the dominant (□) and non-dominant arm (▲). Midpoint of target (●)

Table 1 Maximal velocity (radsec^{-1}) during the throw and their timing before ball release (sec). * indicates a significant difference between throws with dominant and non-dominant arm

	Max velocity		Timing max velocity	
Variable	**Dom.**	**Non-dom**	**Dom.**	**Non-dom**
Pelvis rot.	9.1±2.2	6.9±2.0*	-0.112±0.023	-0.117±0.033
Shoulder hor. add.	2.9±0.8	2.7±0.5	-0.107±0.034	-0.102±0.048
Upper torso rot.	14.9±2.0	13.2±2.8*	-0.053±0.014	-0.053±0.012
Knee ext.	5.0±1.9	5.3±3.9	-0.044±0.031	-0.074±0.064
Wrist flexion	8.8±3.1	11.0±3.7	-0.037±0.022	-0.065±0.045
Trunk tilt	4.9±1.0	4.0±1.1*	-0.037±0.025	-0.048±0.018
Trunkt tilt sideways	4.1±0.4	3.4±1.1	-0.035±0.041	-0.062±0.060
Shoulder abd.	9.0±2.5	7.1±2.8*	-0.014±0.019	-0.058±0.047*
Elbow ext.	24.8±5.0	21.5±2.8*	-0.017±0.018	-0.010±0.010
Int. Rot. Shoulder	44.6±17.3	21.3±12.7*	0±0	0±0
Ball velocity	21.5±1.6ms-1	16.1±2.2ms-1*	0±0	0±0

Table 2 Angles at T0, max. angles (o) during the throw and the timing before ball release (sec) * indicates a significant difference between throws with dominant and non-dominant arm

	Angle at T0		Max angle		Timing max angle	
Variable	**Dom.**	**Non-dom**	**Dom.**	**Non-dom**	**Dom.**	**Non-dom**
Knee angle	43±18	39±16	64±17	63±20	-0.128±0.037	-0.185±0.083
Pelvis angle	81±9	92±15*	152±10	157±13	-0.270±0.068	-0.299±0.067*
Upper torso angle	62±9	66±14	183±13	169±10*	-0.241±0.019	-0.289±0.051*
Trunkt tilt sideways	67±5	73±8*	88±8	81±6*	-0.266±0.050	-0.298±0.104
Trunk tilt	57±6	57±7	84±4	84±3	-0.229±0.076	-0.297±0.164
Shoulder hor. add.	3±4	13±9*	-8±4	-3±9	-0.249±0.060	-0.391±0.126*
Shoulder abd.	86±9	99±8*	86±9	100±9*	0±0.001	-0.004±0.011
Int. Rot. shoulder	59±11	69±10*	129±10	115±11*	-0.065±0.016	-0.114±0.029*
Elbow angle	53±13	61±17	102±7	115±12*	-0.102±0.099	-0.104±0.038
Wrist angle	2±5	4±3	11±2	11±3	-0.145±0.043	-0.182±0.079

DISCUSSION: The signifncant difference in accuracy between the throws was probably caused by the inexperience of the subjects to throw with the non-dominant arm as indicated by the increased variability, i.e. increased MRE and BVE when throwing with the non-dominant arm. A possible reason for the decreased accuracy, suggested by Hore et al. (1996) was the increased variability of joint movements of the non-dominant arm. In the current study no significant difference in variability was found for any of the variables ($p \geq 0.18$). However, Hore et al. (1996) concluded that the major cause of the deceased variability was the increased variability of the distal joint, i.e. in the timing of onsett of the finger extension. This was not measured in the current study.

The ball trajectory after ball release is fixed and determined by release velocity and gravity (minimal effect of air resistance), Thus, the placement on the target in height is known right after ball release. The only variables that can influence this are the throwing height, throwing angle and throwing velocity. Since the throwing velocity was significantly slower between the two throws (table 1), the release height and and throwing angle had to compensate for the loss of velocity. This was shown by the significantly increased release when throwing with the non-dominant arm (1.90±0.11 vs. 1.82±0.12: Dom). This was caused by the increased shoulder abduction angle and trunkt tilt sideways angle at ball release (table 2). The throwing angle was also increased by meanings of the significant increase in internal rotation angle of the shoulder at ball release.
The significantly lower ball velocity when throwing with the non-dominant arm is probably caused by the significant decrease in range of motion of the internal rotation movement of the shoulder (table 2). This caused a significant decrease in angular velocity of the internal rotation movement of the shoulder (table 1). Since the internal rotation of the shoulder together with the extension of the elbow are two major contributors to the maximal ball velocity (van den Tillaar & Ettema, 2004), a decrease in these variables would result in a decrease in the maximal ball velocity (table 1).
Even when the forwarded movement of the ball began earlier, most of the timing of the maximal velocities of the different joints were at the same time before ball release (table 1), indicating the same movement patterning between the throws with both arms.

CONCLUSION: The significant differences in throwing performance between throwing with the dominant and non-dominant arm were generally caused by the decreased maximal velocities of the major joint movements and especially by the decreased range of motion of the internal rotation movement of the shoulder.

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