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EFFECT OF TRAINING ON THE KINEMATICS AND PERFORMANCE IN OVERARM THROWING IN EXPERIENCED FEMALE HANDBALL PLAYERS.

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The purpose of this study was to compare the effect of different training programs upon the kinematics and performance in overarm throwing in experienced female handball players. No significant change in ball velocity (p=0.25) was found after the different training programs. However, the changes that occurred in ball velocity were probably caused by the changes in maximal internal shoulder rotation after the training period as indicated by the positive correlation. However, more studies that examine the kinematics in overarm throwing before and after training have to be conducted before it can be stated with more accuracy that it is maximal internal shoulder rotation velocity, which is responsible for the changes in throwing performance (velocity).

KEY WORDS: ball velocity, coordination, team handball

INTRODUCTION: Maximal throwing velocity in overarm throwing is of major importance in many team sports like baseball, cricket, netball and handball. A lot of studies examined the effect of different types of training with the goal to enhance throwing velocity (van den Tillaar 2004). Most of the time throwing velocity was just measured before and after a training period and concluded if training was successful or not. However, what exactly changes after training with the throw was often not known. Some studies tried to explain it by testing the subjects on bench press or other strength tests to show increased strength in some muscle groups (e.g. Edwards van Muijen et al., 1991). However, it is not known if and how these possible strength changes help to increase the throwing velocity. Where does the difference in throwing velocity come from? Is the increase of throwing velocity the result of strength of the distal joints or of the proximal joints or both? To understand more about the possible changes caused by the training programs, kinematics would give more information about what exactly changes.
Several studies have examined the kinematics in overarm throwing in different sports (e.g. in javelin: Mero et al., 1994; baseball: Matsuo et al., 2001; water polo: Feltner & Taylor, 1997). Van den Tillaar and Ettema (2004, 2007) showed that the internal shoulder rotation and elbow extension were of major importance for the throwing performance (velocity) since they showed a significant correlation with release velocity. However, to our knowledge no study has examined the differences in kinematics due to training. The gained knowledge about the changes in the kinematics could help trainers to develop more detailed training plans that can help the athletes to increase their throwing performance.
Therefore the aim of this study was to compare the kinematics before and after training in a so-called penalty-throwing situation of experienced female handball players. It was hypothesised that the changes in ball velocity were caused by the changes in kinematics of the major contributors: internal shoulder rotation and the elbow extension.

METHODS: Twenty experienced female handball players (playing in the second-fourth division of the Norwegian national competition) volunteered for this study (mean age: 19.9 ± 2.1 years, mass: 67.3 ± 7.5 kg, height: 1.69 ± 0.03 m, training experience: 11 ± 1.5 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. Pre- and post-tests were performed on maximal throwing velocity with weight adjusted javelin balls

(circumference 0.3m; regular handball mass 0.360kg). The instruction was to throw as fast as possible aiming at a 0.5m by 0.5m-square target at 1.65m height. The subjects threw until three hits were performed for each ball. Only throws that resulted in target hits were considered for further analysis. After the test the subjects were matched on throwing velocity and allocated to the strength, variable and control groups, accordingly. All groups performed an assigned training program alongside with their normal handball training three times per week for a period of 8 weeks. The training forms were matched for total training load, i.e. impulse generated on the ball or pulley device (Ettema et al., 2008). This meant that the control group threw 84 times per training with a regular ball (0.36 kg). The variable training group threw each session 50 times with overweight balls (0.432 kg) and 36 times with underweight balls (0.288 kg). The last group trained each session 3 sets of 6 reps at 85 % of 1 RM, consisting of a throwing movement on a pulley device.

Throwing velocity, 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: malleolus 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) Ball: half a hemisphere of the javelin ball was covered with reflective tape to identify the center of the ball. Computation of velocity of the different distal endpoints of segments and joints and the ball was done using a five point differential filter (van den Tillaar and Ettema, 2003; 2004). The subjects had approximately 1-minute rest between each throw.

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.

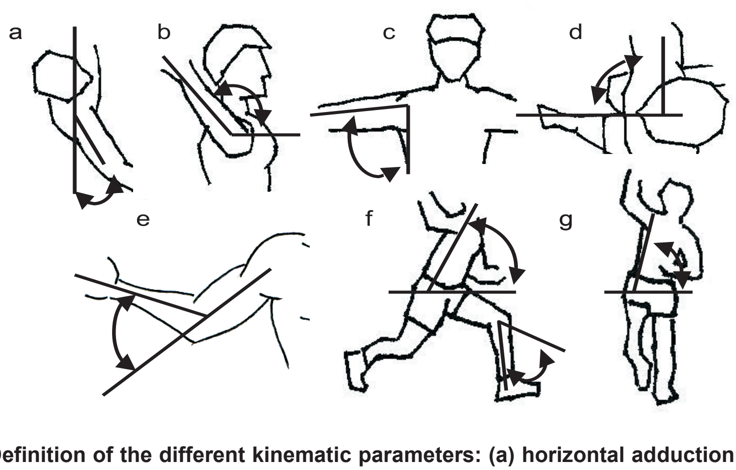

Figure 1: Definition of the different kinematic parameters: (a) horizontal adduction shoulder (b) internal shoulder rotation (c) shoulder abduction (d) pelvis and upper torso rotation (e) elbow flexion (f) trunk tilt forwards and knee flexion (g) trunk tilt sideways.

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 van den Tillaar and Ettema (2007). 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.

One-way ANOVA for repeated measures was used and a significance level of 0.05 was used to identify differences. Pearson correlation was used to locate intra individual relationships between maximal ball velocity and the maximal velocity of the joint movements, maximal joint angles, joint angles at ball release, and the timing of these variables.

RESULTS: During the progression of the study, nine subjects withdrew because of injure (5 subjects) or not being able to attend sufficient training sessions (4 subjects). Since the main aim was to investigate the kinematics and performance changes the three groups were taken together.
No significant increase (p=0.25) in throwing velocity was found after the intervention period, since four subjects did not increase their throwing velocity (table 1). However, significant differences (p<0.05) were found for maximal linear velocity of distal endpoints of segments of the arm and the forearm and the timing of the occurrences for the forearm and trunk (table 1). Also significant differences occurred for knee angle at ball release and the maximal trunk tilt sideways angle after the training period (table 3). No other significant differences were found for the maximal angular joint velocities, angles and their timing (table 2 and 3).

Table 1
Maximal linear velocity of distal endpoints of segments during the throw and their timing before ball release

	Max velocity (m/sec)		Timing max velocity (s)	
Variable	**Pre test**	**Post test**	**Pre test**	**Post test**
Ball velocity	18.0±1.7	18.5±1.5	0±0	0±0
Forearm	11.8±0.9	12.3±0.6*	-0.012±0.006	-0.009±0.008*
Arm	9.1±1.0	9.7±0.8*	-0.059±0.009	-0.059±0.014
Trunk	4.4±0.8	4.8±1.1	-0.046±0.025	-0.030±0.022*
Lower extremity	2.8±0.5	2.6±0.3	-0.135±0.039	-0.135±0.024

* indicates a significant difference between throws at pre and post-test

Table 2
Maximal angular velocity of the different joints during the throw and their timing before ball release

	Max velocity (rad/sec)		Timing max velocity (s)	
Variable	**pre test**	**post test**	**pre test**	**post test**
Pelvis rot.	10.5±2.5	9.6±1.9	0.110±0.027	0.105±0.025
Shoulder hor. add.	4.2±2.2	4.6±1.6	0.091±0.038	0.081±0.040
Upper torso rot.	17.0±3.4	18.3±3.4	0.065±0.029	0.053±0.028
Knee ext.	6.1±2.1	7.0±1.9	0.039±0.026	0.028±0.028
Trunk tilt	6.3±1.8	6.7±1.4	0.023±0.014	0.019±0.013
Trunk tilt sideways	5.3±2.0	5.3±1.8	0.024±0.029	0.019±0.026
Shoulder abduction	7.5±2.4	8.8±2.0	0.072±0.051	0.081±0.037
Elbow ext.	21.1±4.8	21.8±3.0	0.007±0.006	0.004±0.005
Int. Shoulder rot.	25.1±9.1	31.5±22.0	0±0	0±0

Table 3
Angles at T0, max. angles (^{o}) during the throw and the timing before ball release (s)

	Angle at T_0		Max angle		Timing max angle	
Variable	**pre test**	**post test**	**pre test**	**post test**	**pre test**	**post test**
Knee angle	36±14	27±16*	62±14	59±14	0.153±0.033	0.151±0.029
Pelvis angle	71±13	72±12	171±4	173±4	0.398±0.128	0.389±0.089
Upper torso angle	53±14	50±14	190±7	196±6	0.296±0.066	0.283±0.060
Trunk tilt sideways	61±12	63±9	87±8	92±8*	0.358±0.113	0.306±0.085
Trunk tilt	62±8	64±11	87±5	86±4	0.322±0.088	0.314±0.181
Shoulder hor. add.	2±8	3±8	-14±9	-13±8	0.274±0.168	0.306±0.207
Shoulder abduction	79±13	79±10	85±11	85±9	0.110±0.105	0.100±0.086
Int. shoulder rot.	93±15	99±13	136±17	136±19	0.167±0.059	0.182±0.088
Elbow angle	60±12	66±14	102±10	105±13	0.073±0.035	0.060±0.011

* indicates a significant difference between throws at pre and post-test

Only significant correlations were found between the change of maximal ball velocity with the change of the maximal angle of the trunk tilt sideways (r=.84), maximal angular velocity of the internal shoulder rotation (r=.75). Also change in ball velocity correlated negatively with the maximal trunk tilt forwards velocity (r=-.70). No other significant correlations were found.

DISCUSSION: No increased performance (ball velocity) was found after the training period. However, the maximal linear velocity of the endpoints of the forearm and arm increased after the training period indicating that the training can increase throwing performance. The reason that the ball velocity did not increase could be due to the ineffective use of the wrist and finger flexions that were not studied in this study. Also the use of different training regimes could influence the total ball velocity. However, in every group there was at least one subject that did decrease her performance. A weakness of the study is that there were only a few subjects that conducted the whole study. This was the result of a few dropouts (around three in each group), which made it impossible to study feasible differences in kinematics due to the different training regimes.
It was hypothesized that the change in performance was caused by the change in maximal velocity of the elbow extension and the internal shoulder rotation. Only a significant positive correlation with the internal shoulder rotation was found indicating the important contribution of this movement in overarm throwing. This was in line with the earlier results of van den Tillaar and Ettema (2004, 2007) in male handball players. Due to the low number of subjects in the current study and the use of different training regimes no clear statement can be given. We suggest that future studies with more subjects should focus upon training the internal shoulder rotation to enhance throwing performance and that kinematics are measured to gain more knowledge about the actually changed differences in technique due to training.

CONCLUSION: Despite non-significant in the present study, possible changes in ball velocity after different types of training are probably caused by the changes in maximal angular velocity of the internal shoulder rotation as indicated by the positive correlation. However, studies with more subjects involved in training the internal shoulder rotation should be conducted before it is possible to come to a general statement about the technique changes (kinematics) due to training.

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