A COMPARISON OF KINEMATICS BETWEEN ELITE HANDBALL PLAYERS WITH AND WITHOUT SHOULDER PAIN AFTER A FUNCTIONAL FATIGUE PROTOCOL

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Shoulder pain are common in team handball, and players often continue playing despite pain. The aim of the study was to investigate whether a functional fatigue protocol(FFP) affects throwing kinematics, and whether this effect was different between players with and without shoulder pain. Thirty female players performed maximal standing throws before and after a FFP, while joint kinematics were measured with eight cameras (Vicon T40, Oxford, UK). The main findings were that fatigue affected throwing velocity positively. Some kinematic parameters in both groups were affected, but the effect on kinematics was not the same in both groups, especially timing of the maximal shoulder extension and minimal internal shoulder rotations seems to change differently between the groups after a FFP. No previous studies have investigated, whether functional fatigue influences throwing kinematic differently at team handball players who are playing with or without shoulder pain.
KEYWORDS: Throwing kinematics, Team Handball, Overhead athletes, fatigue protocol, shoulder pain, risk factors

INTRODUCTION: Team handball is a worldwide popular sport. However, sadly 44-75% of all the athletes have a history of shoulder pain (Myklebust et al., 2013). Several studies have reported incidents of shoulder injuries in elite handball players between 9-58% (Moller et al., 2012, Myklebust et al., 2013). It is reported that regular handball regimes may cause many overload shoulder injuries and that players often continue playing handball despite experiencing pain (Clarsen et al., 2013, Moller et al., 2017). Fatigue and pain affect the function of the muscles around the shoulder (Almeida et al., 2013, Plummer and Oliver, 2017, Bencke J JM, 2016). A painful arch often creates new patterns in the kinematics, which may worsen an already existing pathological situation in the shoulder (Tripp et al., 2004, Kibler and Sciascia, 2010). Prior studies have suggested reasons for how pain occurs, but none have investigated the kinematics of throwing as a possible risk factor for shoulder injury, where a non-optimal or incorrect throwing technique is anticipated to increase stress on the structures in the shoulder (Trakis et al., 2008, Byram et al., 2010, Borsa et al., 2008, Laudner et al., 2006). To the best of our knowledge, no studies have investigated what the effect of fatigue is on throwing kinematics and if there is a different effect of fatigue upon upper body kinematics between elite handball players playing with pain and players playing without pain. It was hypothesized that after the FFP the group playing with pain would be affected more by fatigue compared with the group playing without pain.

METHODS: Thirty female elite handball players (age 21.2±2.8 yrs., height 1.74±0.06 m, body mass 70.5±8.0 kg), 15 players with shoulder pain(WP) and 15 players with no shoulder pain (NP) recruited from the top three best leagues in Denmark and the best in Sweden. Participants were excluded if they had missed a match within the last six weeks due to pain in the shoulder and/or if they reported pain, which was associated with a traumatic event or shoulder surgery. The presence of shoulder pain was established by the Oslo Sports Trauma Research Center (OSTRC) questionnaire (Clarsen et al. 2013;Jorgensen et al.,2016). A functional Fatigue Protocol (FFP) was used to simulate a fatigue situation like training and matches. The FFP included six rounds of 10 throws: five throws of 75-85% and five with maximal power (90-100%). Ratings of perceived exertion (RPE) were assessed before every 10th throw with Borg CR-10 (Chen et al., 2002). 3D kinematics was measured with 8 infrared cameras (Nexus 2.9, Vicon Motions Systems Ltd., Oxford, UK) and recorded with a frequency of 200Hz. Twenty-three markers were placed over anatomical landmarks on the pelvis, thorax, scapula and arm in accordance with the recommendations by the International Society of Biomechanics (Wu et al., 2005, Plummer and Oliver, 2017). Joint angles of the following joints: wrist, elbow, shoulder, trunk and pelvis were calculated using custom made scripts in Matlab© and Bodybuilder (Vicon Motion Systems Ltd). Max angles and angular velocity together with their timing were calculated for each throw. A 2 repeated measures ANOVA was used compare the effect of fatigue upon throwing velocity and kinematics. Means and SD were calculated for all data, and P-values of ≤0.05 were considered statistically significant.

RESULTS:

The RPE increased significantly from 2.2±1.5 to 6.3±1.9 during the FFP. Throwing velocity also increased from pre to post test (69.7±5.3 vs 71.0±5.8 km/h) ($p=0.036$; $\eta^2=0.15$), but no group effect was found ($p=0.87$, $\eta^2=0.01$). Throw start is estimated by the initiation of the rotation of the pelvis and ends 0.2 milliseconds after ball release. A significant group effect was found for shoulder extension at ball release, timing of maximal shoulder extension and timing maximal internal rotation(MIR) ($p\leq0.039$, $\eta^2\geq0.15$) (table 1). No significant interaction effect was found, but MIR almost reached significance level ($p=0.051$, $\eta^2=0.14$). The MIR angle decreased only significantly in the P-group. At ball release shoulder flexion angle decreased in both groups but was larger after the FFP for the P-group than the NP-group. Timing of maximal shoulder extension and internal rotation occurred much earlier before and later after ball release in the P-group compared with the NP-group (Table 1).

Table 1: Main ± SD joint angles and timing of both groups at pre and post test.

Variable	Pain group		No pain group	
Maximal (°)	**pre**	**post**	**pre**	**post**
Shoulder extension	25.8±12.6	38.0±35.3	28.7±13.3	28.0±10.6
External rotation	158.6±10.6*	162.1±10.5	156.5±13.1	157.6±12.0
Internal rotation	22.3±13.0*	16.5±14.2	21.8±14.5	21.5±13.7
Pelvis rotation	-79.7±8.2	-83.7±11.7	-80.3±12.8*	-86.7±14.2
Trunk rotation	-98.3±9.6*	-104.3±10.5	-97.8±11.5*	-102.0±10.6
At ball release				
Shoulder flexion	-19.2±9.0*	-17.3±9.3†	-12.6±10.5*	-9.2±6.5†
Shoulder abduction	89.3±11.3	88.5±12.9	86.0±10.7	84.4±10.7
Internal rotation	131.5±16.8	135.4±19.1	125.3±13.6	127.8±13.0
Pelvis rotation	18.8±7.5	18.8±7.3	17.0±10.1	18.9±9.8
Trunk rotation	19.6±8.6	19.2±9.5	18.5±9.1	18.6±9.4
Timing maximal angle (s)				
Shoulder extension	-0.252±0.081†	-0.272±0.113	-0.183±0.056†	-0.198±0.784
Internal rotation	0.036±0.010†	0.033±0.012	0.029±0.072*†	0.027±0.061

* indicates a significant change from pre-to post test on a p<0.05 level.
† indicates a significant difference between the groups on a p<0.05 level.

The FFP had a significant effect upon maximal angular pelvis and trunk rotation and elbow extension ($p\leq0.033$, $\eta^2\geq0.16$). Post hoc comparison revealed that the maximal angular velocities of these movements only significantly increased in the NP-group (Table 2). Only a significant group effect ($p=0.031$, $\eta^2=0.17$) was found for timing of minimal internal rotation velocity (stopping the arm during follow through phase). The P-group increased the occurrence of minimal internal velocity after the FFP, while the NP-group did not change this (Table 2).

Table 2: Main ± SD angular velocities of different joint of both groups at pre and post test.

Variable	Pain group		No pain group	
Maximal (°/s)	**pre**	**post**	**pre**	**post**
Pelvis rotation	523±70	556±127	519±55*	573±64
Trunk rotation	389±108	433±144	426±115	450±102
Shoulder flexion	463±115	551±305	499±118	508±106

External rotation	806±280	822±321	847±237*	933±280
Elbow extension	1348±160	1346±142	1349±140*	1409±167
Wrist flexion	1008±233	1054±277	883±243	882±256
Internal rotation	1736±461	1687±479	1950±674	1981±585
Min internal rotation	-1504±306	-1411±601	-1246±449	-1264±405
Timing (s)				
Pelvis rotation	-0.102±0.027	-0,109±0.028	-0.111±0.020	-0.110±0.021
Trunk rotation	-0.016±0.017	-0.017±0.017	-0.021±0.010	-0.017±0.009
Shoulder flexion	-0.058±0.021	-0.084±0.073	-0.071±0.053	-0.062±0.042
External rotation	-0.166±0.041	-0.158±0.059	-0.136±0.063	-0.137±0.081
Elbow extension	-0.007±0.007	-0.007±0.008	-0.011±0.007	-0.012±0.006
Wrist flexion	0	0	0	0
internal rotation	0	0	0	0
Min internal rotation	0.086±0.009*	0.090±0.007†	0.082±0.009	0.081±0.008†

* indicates a significant change from pre-to post test on a p<0.05 level.
† indicates a significant difference between the groups on a p<0.05 level.

DISCUSSION: The main findings were that fatigue affected throwing velocity positively with an increased velocity. Both groups were affected on kinematics parameters, but they were influenced differently. Especially, the timing of the maximal shoulder extension and minimal internal shoulder rotations seems to change differently between the groups after the FFP. The increase of ball velocity was not to expect. The purpose of the FFP was to simulate throwing fatigue compared to training/ match, in which the handball player never fully fatigued in their throwing ability. The main kinematic differences between the players with P and NP, are the time of occurrence of the maximal shoulder extension and minimal shoulder rotation. The pain group positioned the shoulder joint earlier in peak angles of the maximal shoulder extension and minimal shoulder rotation and after all release. The earlier occurrence of the maximal shoulder extension could be a mechanism of adaptation to avoid pain because this joint angle indicates the transition from the cocking phase to the ball acceleration phase. A longer ball acceleration phase may allow lower peak acceleration around the different joints, and thus, lower force-induced stress to passive joint tissues, without compromising throwing velocity. In other words, this may be a way of reducing the pain-causing stresses in the anterior and inferior parts of the shoulder joint capsule, as well as to the medial collateral ligament of the elbow. Furthermore, different shoulder flexion at ball release between the groups were observed after the FFP. The different position of shoulder flexion at ball release may be an adaption to avoid pain and create less stress on the glenohumeral joint. This position may influence the time the players have in the deceleration phase and follow-through, which also was found by the later minimal angular shoulder rotation during this phase(Table 2). That would require a longer period of eccentric muscle contraction of the posteriorly placed muscles in the pain group compared to the no pain group. However, kinetic calculations must be conducted to confirm this, which was not possible in the present study. Furthermore, the no pain group showed some increases in maximal angular velocities of elbow extension and external shoulder rotation, which are some of the main contributors to the throwing velocity (van den Tillaar and Ettema, 2007). This could explain the increase in throwing velocity in this group. These adaptations did not occur so much in the pain group, thereby they had to compensate with other kinematic changes. Limitations do exist. Individualized throwing technique and pain have an impact on muscle strength, joint stability, field position and other specific requirements of their sport (Laudner et al., 2013). Because the P-group consisted of athletes with different types of shoulder pain, these adaptations varied, so different solutions occurred in the changed motor patterns, which reflected in very few differences between the P and No-group in kinematics and muscle activity.

CONCLUSION: This study identified that fatigue influenced throwing performance and kinematics, while the adaptations were differently between the P- and NP-group indicating that pain could result in different adaptations. Future studies should include muscle activation measurement to investigate what the effect of fatigue had on the muscles to get more information about the adaptations when playing with pain in handball.

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