MECHANISMS OF INJURIES IN HANDBALL

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Handball is a typical throwing sport, as well as a dynamic contact sport, characterised by repetitive joint motions and large forces acting on the shoulder and elbow, frequent contact and collisions between opponents, high tempo, rapid changes of movement and jumps with hard landings. Even though there are specific rules and regulations to make the sport safe and fair, players are vulnerable to both acute and overuse injuries. Injury surveillance studies from the most recent Summer Olympic Games have reported that handball is among the sports with the highest injury rate[1,2], and this is supported by several one-season cohort studies from the national level[3–6]. The injury rate and injury pattern among handball players are well-described previously in this journal, but the question still remains: *why and how do injuries occur?* This paper provides a brief review of injury mechanisms and describes three typical high-risk situations in handball:

- throwing,
- player contact and
- landing.

WHY IS IT IMPORTANT TO UNDERSTAND THE INJURY MECHANISMS?

A complete understanding of injury causation requires knowledge about the complex interaction between internal (related to the individual) and external (related to the environment) risk factors[7]. Internal risk factors include, for example, age, gender, previous injuries, physical fitness and psychological factors, while external risk factors include rules, regulations, equipment and floor/turf type. The sum of these risk factors and the interaction between them can contribute towards making the athlete susceptible to injury, while an inciting event is necessary to cause an injury. In epidemiological studies on sport injuries, the inciting event is usually termed the 'injury mechanism'. To fully understand the injury mechanism, this should include a description of the specific playing situation, opponent-player interaction, the athlete's behaviour and movements, and ideally also a detailed description of motion and loads affecting the relevant anatomical structures[8].

CIRCUMSTANCES OF INJURIES IN HANDBALL

It is well-documented that the injury incidence in handball is significantly higher during match play than in training, which can probably be explained by more intense

play, more aggressive behaviour and more contact between players[3–6]. During matches, more injuries occur while attacking than defending, which means that most injuries occur when the team is in possession with ball control on the opponent's court half. It appears that the risk of time-loss injury (i.e. injuries leading to absence from training and competition of at least 1 day) is equally distributed over the entire course of the match[9]. However, it is suggested that the injury rate changes according to the player position within the team[3–5]. The playing formation on the court consists of seven players in four different player positions:

- 3 back players,
- 2 wing players,
- 1 line player,
- 1 goalkeeper.

It is suggested that the back and wing players are more injury prone, which is probably not surprising as these positions involve a wide range of different manoeuvres e.g. frequent throws, jumps and falls, rapid changes of direction and inappropriate contact with opponents.

Over the past few years, handball has developed into an even more dynamic and powerful contact sport, and to prevent injuries among the players, the mechanisms that play a part in the occurrence of injuries must be identified[10]. To understand these mechanisms, knowledge about the essential biomechanics of the throwing motion, typical player contact situations and different landing techniques is needed.

THROWING

A professional handball player probably plays on average 20 hours per week, including training and match play, and it is suggested that a player performs at least 48,000 throws each season[11]. There is no doubt that handball players impose high demands on the dominant upper extremity, and a large number of elite players suffer from shoulder or elbow pain[12]. Studies suggest that repetitive stress on the dominant arm is responsible for physiological and pathological changes in soft tissue and bony restraints around the shoulder and elbow[13]. However, these findings are not necessarily symptomatic.

The speed, force and precision of a throw will vary according to the type of throw and throwing approach. Most of the throws in handball are overarm throws performed while jumping. A typical overarm throw can be described as a motion consisting of three main phases:

1. Wind-up/arm cocking phase.
2. Arm acceleration phase.
3. Deceleration phase[14,15].

Wind-up/arm cocking phase

The wind-up/arm cocking phase is the first phase of a throw. The objective of this phase is to put the thrower in a good starting position. The player moves the upper extremity and ball backwards (the arm is cocked back in the wind-up), while the hip starts moving forward. The throwing shoulder externally rotates and abducts, and the farther back the arm rotates, the greater range it has to rotate forwards generating velocity.

Large eccentric loads are produced around the shoulder and elbow joint in order to terminate arm cocking and initiate arm acceleration, and this situation is assumed to be related to shoulder and elbow overuse injuries[15].

Arm acceleration phase

The arm acceleration phase is the explosive portion of the throw between the time of maximum shoulder external rotation and the instant of ball release. During this phase, the trunk flexes forward from its extended position. The throwing shoulder remains abducted, while the shoulder internal rotators contract concentrically to help produce a maximal internal rotation velocity, which occurs near the time of ball release. In addition, the throwing elbow extends until almost full extension is reached.

Deceleration phase

The arm deceleration phase is the short time from ball release to maximum shoulder internal rotation. During this phase, the arm also adducts horizontally across the trunk in order to decelerate. The high compressive forces produced at the shoulder and elbow near the time of ball release, along with the deceleration loads, is another part of the throw that is assumed to be related to shoulder and elbow overuse problems[15].

During all three phases of the throw, maintaining scapula stabilisation and humeral head control (i.e. proper humeral head position within the glenoid fossa) are important to prevent excessive humeral translation. However, this can be challenging due to the rapid changes of motion and large forces and torques produced at the shoulder and elbow during throwing. In addition, individual factors e.g. abnormal range of motion, scapular dyskinesis and rotator cuff weakness will make scapula stabilisation and humeral head control even more difficult. Therefore, in order to prevent excessive humeral translation and shoulder overuse problems among handball players, risk factors need to be rectified.

PLAYER CONTACT

Handball is a contact sport, which means that a certain amount of contact between players is allowed and is a part of the game. It therefore comes as no surprise that epidemiological studies report that the majority of all acute injuries occur in contact situations, mainly with an opponent. While players from one team attack, i.e. move forward on the court in order to threaten the opponent goal (at high speed), their opponents will defend, i.e. try to stop the attacking players with appropriate technique and tactics. Even if athletes are well trained for the attacking and defending phases of the game, inappropriate contact between players does occur, such as inappropriate timing of contact, as well as accidental contact (collisions) and contact due to foul play, perhaps intentionally. Video analyses of injuries from the 1992 Barcelona Olympic Games showed that inappropriate player contact was observed at the time of injury in most of the cases, contributing directly or indirectly to the injury[16]. Injuries can be caused by a direct blow to the body, e.g. during collisions between players, or by being pushed or held by an opponent, which may put the player off balance and indirectly cause the injury.

A typical situation is collision during a forward move by the attacking player towards the defensive line, which represents a basic and necessary move of all back and wing players to develop the attack. When an attacking player receives the ball while moving forward and at the same time has to initiate shooting, he may have minimal time to prepare himself for a subsequent contact with a defending player, who will usually be moving at high speed towards the attacking player in order to stop him. Even though this type of contact is being repeated numerous times during training and match, the situation may cause an injury when the attacking player is not mentally and physically prepared for the contact e.g. due to fatigue. The most severe injuries are assumed to occur during a counterattack (attack that starts by winning the ball), where the attacking player is running for a fast break, facing his own goal in order to receive the ball, and then collides with an opponent he is not aware of.

A contemporary view in handball is that 'defence is the best attack', forcing coaches to focus on the defending phase of the game and increasing the extent of game obstruction. This may potentially lead to a higher number of injuries, as inappropriate contact situations also occur during basic manoeuvres performed by the defending player such as obstruction, screening, blocking and stealing the ball.

Obstruction represents a fast move toward the attacking player, with the intention to stop his action. The defending player usually tries to grab the attacking player around the waist and with the other hand, block his shooting arm near

the elbow. In this situation, inappropriate player contact may occur due to bad timing of movements or foul play.

The screen is the most important technical manoeuvre performed by a defending player, where he tries to interfere with the attacking player's moves by timely positioning his body in the line of the attacking player's movements. In this case, the defending player often illegally uses his shoulder, elbow or knee.

Illegal blocking of the ball by a defending player, who uses his leg instead of his arm, can also cause injury to the attacking player. In addition, when the attacking player jumps forward through the defensive line with the arm and ball raised high, the defending player may by intention or mistake grab the attacking player's shooting arm from behind when trying to steal the ball. This situation can cause a fall backward for the attacking player, and indirectly contribute to an injury. It should also be mentioned that if it is not possible to prevent the attacking player from shooting, the intention of the defending player is to limit the shooting angle as much as possible. This is usually achieved by pushing the attacking player (mainly wing players) toward the sideline. In addition, the opponents' goalkeeper often jumps toward the attacking player with the same intention, and it is well known that injuries also occur in contact between the attacking player and the opponents' goalkeeper. To this end, increasing player awareness and responsibility for fair play is important to reduce the risk of contact injuries.

Finally, it should be mentioned that contact injuries also have been described as injuries caused by contact with the ball[6,17]. These injuries are often in the hand/finger in young players and are most likely related to limited player skills or technique that is not yet fully developed.

LANDING

Injuries also occur in contact with the floor/ground during landing situations[6,17], which make the sport more attractive for the audience than any other manoeuvres during match play. Landing is an essential part of the game and can be divided into two different groups:

1. Landing as a part of the shooting technique.
2. Landing as a part of falling after losing balance due to game obstruction (defending play).

Falls due to game obstruction, such as illegal pushing and pulling by a defending player, are not under the attacking player's control and the landing is most often unpredictable. In contrast, landing as a part of the shooting technique is a complex and highly effective way of throwing the ball to the opponents' goal and this approach is mainly performed by wing and line players. Shooting the ball during a 'flight' with a subsequent landing to the floor is first of all used to bring the body into a better shooting position, as well as to achieve a better shooting angle and higher ball speed after throwing. This approach is also used by players to decrease the distance to the opponents' goalkeeper and avoid interference of an opponent player. Shooting during a 'flight' can start from either a standing position or running movement, which both represent actions and body impacts that can be associated with an increased risk of injury. Shooting the ball during a 'flight' that starts from a running movement is technically a very demanding manoeuvre and the most difficult way of throwing the ball. Due to high speed, the player will have a longer 'flight' phase, thus the landing becomes more complex. Therefore, the players need a high level of skills, flexibility and experiences to perform this type of landing without inappropriate consequences.

There are mainly two different landing techniques in handball: landing with and without body rotation.

Landing with body rotation is most commonly used by line and wing players as this allows them to decrease and absorb landing forces. The body rotation is mainly performed over the throwing shoulder, which can be anteriorly or posteriorly positioned. Landing with body rotation is mainly used when shooting from the 6-metre line or while performing a 7-metre penalty shoot.

Landing without body rotation is often called 'landing with a dive'. During this type of landing, the player can either slide on the ground or stop immediately after initial contact. In addition to the two basic landing techniques we have described, we can see other types of landing, which represent a combination of these.

Video analyses from the 1992 Olympics showed that inappropriate player contact contributed directly or indirectly to most injuries

It is well known that injuries also occur from landing on one leg after a jump shot. This situation has been well-investigated and described in the literature, as it is one of the two most frequent scenarios leading to ligament injury to the knee and ankle. In the following section, we will describe the mechanisms of ACL injury and lateral ankle sprain in more detail.

ONE-LEG LANDING AND SIDE-STEP CUTTING

Injuries that occur without player contact are called non-contact injuries. However, video analyses have shown that the injured player is usually in close proximity to an opponent, and most often, there is some form of perturbation or contact prior to the time of injury that may influence the player's behaviour and movements, contributing to the injury situation[18]. It is well documented that two of the most frequent specific injury types among handball players (particularly in females), ACL injuries and lateral ankle sprains, are defined as non-contact injuries. They occur mainly during one-leg landing from a jump shot and during side-step cutting. One-leg landing from a jump shot is exactly that: landing on one leg after the player has jumped up to shoot the ball, while a side-step cutting manoeuvre (also called a plant and cut situation) is a high-speed evasive technique in which the player tries to get past an opponent by changing direction sideways.

Based on systematic video analyses of real ACL injuries, knee motion appeared to be the same in both manoeuvres[18]. A consistent pattern with a forceful valgus collapse from a position with the knee close to full extension combined with slight internal rotation of the tibia was observed. Biomechanical studies support that tibia internal rotation and knee valgus in combination with knee joint compression is an important component of the ACL injury mechanism. A proposed hypothesis is that the ACL tears within approximately 40 ms after initial contact and that knee abduction loading and lateral compression generate tibia internal rotation and anterior tibia translation due to the joint surface geometry and possible quadriceps drawer[19].

Lateral ankle sprains have also been investigated biomechanically during one-leg landing and side-step cutting. Kinematic and kinetic calculations have shown that these manoeuvres can produce loads that are sufficient to rupture the lateral ligaments shortly after initial contact, due to sudden increase in inversion and internal rotation combined with either dorsi- or plantarflexion[20,21].

SUMMARY

This brief overview of injury mechanisms and high-risk situations in handball emphasises that acute injuries first and foremost occur in player contact and landing situations. Handball is a contact sport; opponent contact is a normal part of the game. However, inappropriate contact and collisions between players contribute towards the large number of acute injuries. It is reasonable to believe that emphasising fair play and strict implementation of the rules is essential to avoid careless tackles and collisions. Landings are another frequent high-risk situation in handball leading to injury. Landing as a part of falling after losing balance due to game obstruction is frequently cited among handball players. ACL tear and lateral ankle sprain represent the exception; these are usually non-contact injuries mainly occurring during one-leg landing from a jump shot or side-step cutting. With today's knowledge, these injuries can be significantly reduced by implementing a structural warm-up programme aimed to improve running, landing and cutting techniques, as well as neuromuscular control, balance and strength. It is suggested that repetitive stress on the dominant arm during throwing is the most common cause of overuse injuries in handball and a large number of elite players suffer from shoulder or elbow pain. Better conditioning and training programmes are needed to prevent these injuries.

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most injuries occur when the team is in possession with ball control on the opponent's court half

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