

Youth handball concussion prevention strategies: a workshop-based study with experts and end users

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ABSTRACT

Sport-related concussion (SRC) is a serious injury in youth team sports, including handball. While research on the prevention of SRC has made progress over the past 5 years, prevention strategies are lacking in handball. The aim was to explore and develop strategies focusing on information, rules and training that may prevent concussion in youth handball by incorporating knowledge from experts and end users. Using a participatory methodology, experts (physiotherapy, biomechanics: n=3) and end users (players, coaches, referees, coach educators: n=7) contributed their experience and knowledge in a 2-hour online workshop. Participants were given three videos illustrating typical high-risk concussion scenarios from handball games and a youth player's accompanying fictional written scenario. In group discussions inspired by the brainwriting method, participants were asked to provide ideas for possible SRC prevention strategies related to information, rules and/or training. Data were collected on a digital whiteboard and analysed using reflexive thematic analysis. Three themes were derived: (1) 'Coaches' responsibility: raise awareness of the risk of injury and act to promote safe environments'; (2) 'Players' responsibility: safe defence and attack'; and (3) 'Improvement of personal skills'. Experts and end users found information about high-risk situations and SRC symptoms, stricter rules and safe playing strategy training for goalkeepers, attacking and defending players, respectively, may effectively reduce SRC in handball. Information and stricter rules could be delivered through education and dissemination activities, whereas safe playing strategies should be trained at regular handball practice.

INTRODUCTION

A sport-related concussion (SRC) is defined as 'a traumatic brain injury caused by a direct blow to the head, neck or body resulting in an impulsive force being transmitted to the brain that occurs in sports and exercise-related activities'.¹ The player may experience various acute and sometimes complex persistent symptoms.¹⁻⁴

SRC is particularly common in sports such as ice hockey and American football, although it frequently occurs also in other

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Sport-related concussion (SRC) is common in several youth sports, including team handball.
- ⇒ While research on the prevention of SRC has progressed over the last 5 years, prevention strategies are lacking in handball.
- ⇒ Concussion prevention strategies reported in other sports include education, rule changes, equipment and specific training.

WHAT THIS STUDY ADDS

- ⇒ Using a participatory methodology, experts (physiotherapy, biomechanics) and end users (players, coaches, referees, coach educators) contributed their knowledge to generate strategies that could potentially prevent concussion in youth handball.
- ⇒ Three themes were derived: (1) 'Coaches' responsibility: raise awareness of the risk of injury and act to promote safe environments'; (2) 'Players' responsibility: safe defence and attack'; (3) 'Improvement of personal skills'.
- ⇒ The following prevention strategies are suggested: (1) information about high-risk situations for concussion and SRC symptoms; (2) stricter rules for careless play; and (3) safe playing strategies for goalkeepers, defensive players, and attacking players, respectively, and improving neck and core strength for all players.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ The results were summarised for end users as practical advice encompassing information, rules, and training and playing strategies for dissemination within youth handball.
- ⇒ Based on the findings, an educational programme on SRC could be developed, evaluated and implemented for handball.
- ⇒ Future research may evaluate the strategies regarding implementation and effect on concussion prevention.



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team ball sports.⁵ In a cross-sectional study from Germany, including approximately 3000 athletes, 25% of soccer players reported that they had experienced a concussion.⁶ The corresponding numbers were 13% in

volleyball, 15% in basketball and 24% in handball.⁶ In a Swedish longitudinal study using injury insurance data, handball injuries to the lower limbs were most common (35–49% of total injuries independent of sex), followed by injuries to the upper limbs (26–33%) and concussion (22–28%).⁷ The impact causing a concussion in handball can either be direct, as a blow or a ball hitting the head, or indirect, if an impact occurs when a player hits the head on the floor after, for instance, a push by an opponent. Young athletes are suggested to be more susceptible to mild traumatic brain injury than adults.⁸

The detection and management of concussions have made progress in the last 10 years, and research on the prevention of SRC has increased threefold in the last 5 years.¹ No concussion prevention strategies available for handball were found in the literature. Previous research on other sports, such as American football, soccer and ice hockey, suggests preventive strategies could include education, rule changes, equipment (eg, mouthguards) and specific training.⁹

A systematic review reported that concussion education programmes improve youth coaches' knowledge about concussions and support their intentions to reduce the risk of and manage concussions among players in different sports.¹⁰ In soccer, concussion rates decreased after introducing stricter red card rules.¹¹ Rule changes have been implemented in handball to reduce impact towards the head, where the most recent changes were made to the season 2022–2023 and include a 2 min suspension for head-shooting a goalkeeper in certain situations.¹² However, the effect of this rule change on concussion rates remains to be established. The use of mouthguards and helmets/headgear has been examined in different sports.¹¹ However, a recent systematic review reports some conflicting results.⁹ In handball, mouthguards are allowed but not helmets,¹² and there are no available studies on the effects of mouthguards in handball. It is established that specific training is effective in reducing injuries to the lower and upper extremities^{13–15}; however, there are few studies on training strategies aimed at reducing concussion and/or head impact rates.⁹

Although the concussion incidence rate in handball is higher than in many other sports,⁷ which may also apply to youth players, handball-specific concussion prevention strategies are absent. It is proposed involving end users in developing prevention and treatment strategies to ensure these are context-specific and to support implementation in real-world settings.¹⁶ This study aimed to explore and develop strategies focusing on information, rules and training that could potentially prevent concussion in youth handball by incorporating knowledge from experts and end users.

METHODS

This study adheres to the Standards for Reporting Qualitative Research (<https://www.equator-network.org/reporting-guidelines/srqr/>).

Participants

Participants were purposely chosen to cover different fields of expertise that could contribute to creating potential handball-specific strategies to prevent concussions related to information, rules and training. 10 people with expertise in handball (n=7), physiotherapy (n=1) or biomechanics (n=2) participated (table 1). The end users in handball were two coaches (one goalkeeper coach), two youth players (16 years old), two referees, and one former elite player and current coach educator. Two end users worked within the Swedish handball organisation (club or national federation). The expert in physiotherapy was a senior associate professor with a research focus on sports injuries, particularly handball-related concussions, current handball coach and former player and coauthor of this paper (KJ). The two experts in biomechanics were professors in engineering with a research focus on impacts on the head.

Patient and public involvement

End users of the concussion strategies participated in the workshop and contributed their handball expertise in their respective roles (player, coach, referee, coach educator). They contributed actively to the development

Table 1 Breakout groups, facilitators and participants

Group 1	Facilitator VS	Participant 1 (female, player–field player)	Participant 2 (male, coach–goalkeeper coach)	Participant 3 (male, biomechanical engineer–PhD, research focus on prevention of head and neck injuries)	Participant 4 (female, coach educator–coach, former elite player and project manager at the Swedish Handball Federation)
Group 2	Facilitator EA	Participant 5 (female, player–goalkeeper)	Participant 6 (male, referee–youth and adult level)	Participant 7 (male, biomechanical engineer–PhD, research focus on prevention of head and neck injuries)	
Group 3	Facilitator PM	Participant 8 (male, coach–youth coach and club manager)	Participant 9 (male, referee–national and international level)	Participant 10 (female, physiotherapist–PhD, research focus on sports injuries, especially concussion, senior handball coach, former elite player)	

of the strategies and had the opportunity to provide input on the interpretation of the results. Three research team members (VS, KJ, EA) have handball experience (practice and/or research). The results outlined in this article were summarised for end users in a popular science format and will be disseminated within the Swedish handball community.

Data collection

Data were collected at a 2-hour digital workshop held over Zoom (table 1) facilitated by three authors (PM, VS, EA). Participants were given a summary of current knowledge on youth handball concussion prevention ahead of the workshop, which the researchers repeated at the beginning of the workshop to point out the aim of the current research study focusing on the development of strategies that can prevent youth handball concussions.

Participants were invited to work with handball scenarios as part of the data collection. Scenarios are stories describing actions and events that lead to a specific outcome,¹⁷ a versatile method used in research across various disciplines.¹⁸ Scenarios can be used to explore design ideas grounded in a real-world context¹⁹ and, therefore, represent a lightweight method to envision future practices.¹⁷ The authors (VS, PM, EA) selected three videos that illustrated typical high-risk concussion scenarios from professional handball games: head shot, push in the air during a jump and a

blow to the head. The authors (VS, PM, AR, EA) created fictional written scenarios to accompany each video, consisting of a story of an injured youth handball player (table 2).¹⁹ This was done to enhance participants' understanding of the situation and to appeal to their lived experiences. Using Collaboard, a website that facilitates collaborative working,²⁰ a digital whiteboard was created containing a visual framework with scenarios and video files (figure 1).

Participants were divided into three breakout groups with three to four participants each. The participants were distributed to cover a broad range of knowledge and experiences (table 1). One facilitator was assigned to each group.

The facilitation of the breakout groups was inspired by the brainwriting method, an iterative process in which participants build on each other's ideas.¹⁹ Brainwriting aims to generate unique ideas.²¹ It traditionally includes a sequence of silent writing and sharing written ideas.²¹ However, we customised the method to focus more on group discussions. Iterating through three rounds, each of the three breakout groups worked with a different scenario at the time, ultimately completing all scenarios at the end of the exercise. Participants were encouraged to discuss the scenarios and videos and provide their ideas related to the following categories: information, rules and training.

Table 2 Fictional written scenarios for each video clip, along with instructions for workshop participants

Scenario 1	<p>Anders is in the second year of a handball-profiled secondary school and is looking forward to playing elite handball as a goalkeeper. He is aware of the risks of concussion as a goalkeeper, and in one game, he takes a hard shot to the head from close range and collapses helplessly. He is forced to discontinue the game, is diagnosed with a concussion and undergoes the 'brain steps' in his rehabilitation.</p> <p>For this specific situation:</p> <ul style="list-style-type: none"> ▶ You are his coach/physiotherapist/physician and will now give him training. What principles and examples of training do you suggest? ▶ Can you change the rules to prevent Anders from being shot in the head again, and if so, how? ▶ What other measures can prevent Anders from getting another concussion?
Scenario 2	<p>Pelle is 16 years old and has played handball since childhood. He prioritises his studies but wants to continue playing handball because it is so much fun. However, in one game in Division 4, he gets a blow to his head when he jumps up to shoot, which causes him to collapse. After the initial facial pain had subsided, he experienced dizziness and nausea and discontinued the game. He does not want to risk permanent damage and, therefore, wonders whether it is worthwhile to continue playing.</p> <p>For this specific situation:</p> <ul style="list-style-type: none"> ▶ You are his coach/physiotherapist/physician and will now give him training. What principles and examples of training do you suggest? ▶ Can you change the rules to prevent Pelle from being hit in the face again, and if so, how? ▶ What other measures can be taken to prevent Pelle from getting another concussion?
Scenario 3	<p>Tova is 15 years old, right-handed, and has just played the Swedish Cup in handball. Her goal is to be selected for the first national youth team. She is now playing a league match and jumps up to take a shot from the 9-metre line when she gets a hard push in the air so that she loses body control and hits her head. She then becomes dizzy and has to seek medical care, where she is diagnosed with a concussion.</p> <p>For this specific situation:</p> <ul style="list-style-type: none"> ▶ You are her coach/physiotherapist/physician and will now give her training. What principles and examples of training do you suggest? ▶ Can you change the rules to prevent Tova from losing body control after a push, and if so, how? ▶ What other measures can be taken to prevent Tova from getting another concussion?

Workshop prevention hjärnskakning

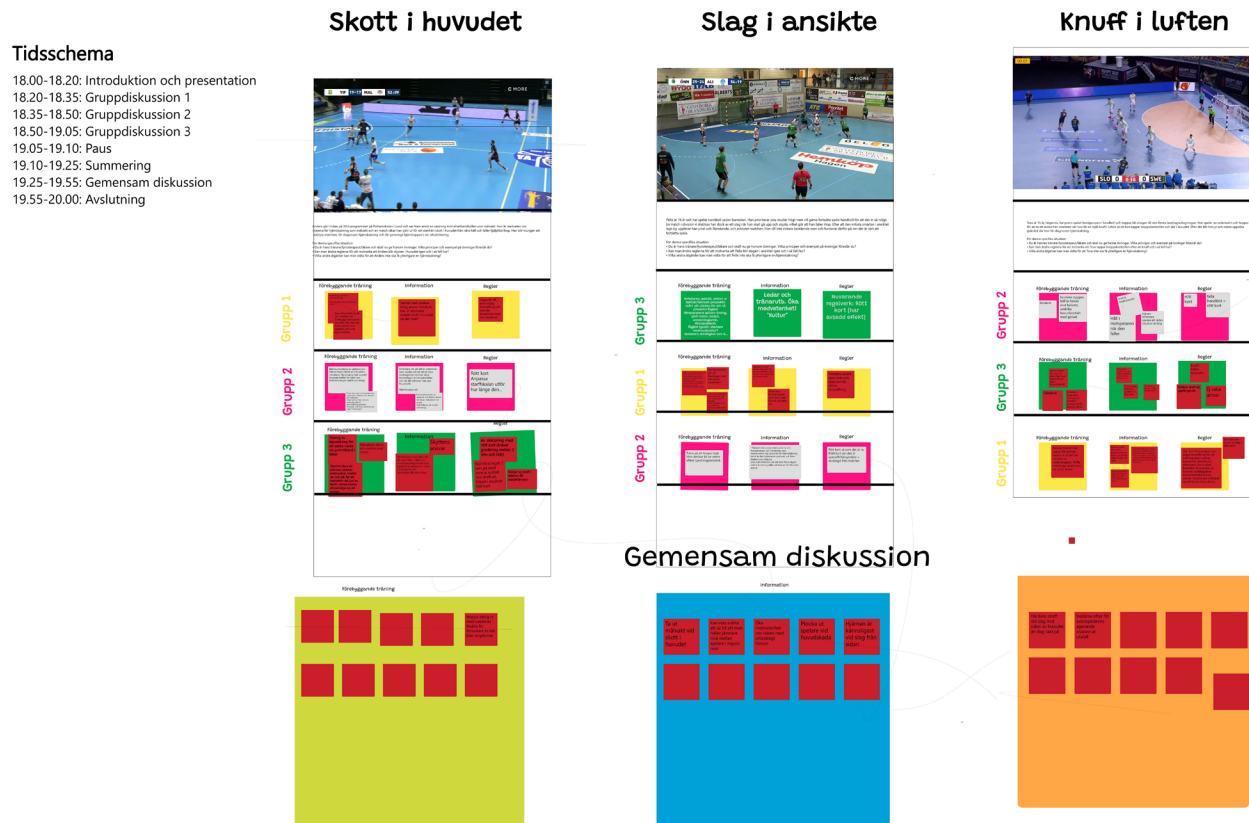


Figure 1 The layout of the Collaboard after the workshop was held, with a timeline, video clips, fictional scenarios and sticky notes (in Swedish).

Related to each video and scenario, the following questions were asked:

1. You are his/her coach/physiotherapist/physician and will now give him/her training. What principles and examples of training do you suggest?
2. Can you change the rules to prevent him/her from concussion (scenario-specific text describing the situation) again, and if so, how?
3. What other actions can be taken to prevent him/her from getting another concussion?

Ideas were collected as sticky notes on the digital whiteboard. The facilitators prompted participants to discuss each category for 15 min before moving on to the next scenario. Participants were then instructed to read the sticky notes posted by other groups, discuss and expand on them during the next round (figure 1).

After the breakout group activities, each group presented their discussion, followed by a collective discussion with all participants. The focus of this discussion was to elaborate on sticky notes that had generated different or opposing ideas. During this part of the workshop, one facilitator took notes on the digital whiteboard. All attendees saw text written in real time and could edit the notes themselves. Participants could edit the notes up to 4 days after the workshop, an opportunity none of the participants took.

Participants and facilitators collected data in the form of notes taken on the digital whiteboard. 28 unique data points were collected. Audio recordings from the Zoom workshop served as an assistive tool for the researchers to contextualise the findings further or for clarification purposes. Selected representative quotes were transcribed. Translation of data and quotes into English was aided by the online tool DeepL Translator. All authors checked the translations for accuracy.

Analysis

The data were analysed using reflexive thematic analysis.²² Reflexive thematic analysis is a widely used approach to analyse qualitative data. Due to its theoretical flexibility,²³ it is well suited to analyse creative workshops. Reflexive thematic analysis aims to generate themes, which are patterns of shared meaning across a dataset.²³ Using a deductive analytical approach based on the three areas of interest (information, rules and training), three authors (VS, PM, EA) assigned a combination of semantic and latent codes to each data point. The codes were subsequently discussed by four authors (VS, PM, AR, EA) and grouped into three distinct themes: (1) 'Coaches' responsibility: raise awareness of the risk of injury and act to promote safe environments'; (2) 'Players' responsibility: safe defence and attack'; (3) 'Improvement of

personal skills' (table 3). The derived themes and underlying codes were sent to the workshop participants for review, allowing them to express their opinions. This sense-checking process adequately represented what participants had shared throughout the workshop. All participants recognised the derived themes as an appropriate outcome of the analysis. The author (KJ), a workshop participant, checked the data and confirmed the analysis. This was done as a last step of triangulation to increase the credibility and validity of research findings.²⁴

RESULTS

Theme 1. Coaches' responsibility: raise awareness of the risk of injury and act to promote safe environments

This theme outlines the importance of risk awareness among coaches and coaches' responsibility to educate players about high-risk situations and their consequences.

The workshop participants discussed that the risk of concussions on the handball field can increase through careless defence, backward fall situations or impacts to the side of the head. It was therefore deemed important that coaches inform and make young players aware of the risks of the sport. The data reflected that 'coaches [should] inform players that such [backfall fall] the situation is dangerous' (sticky note, group 2, scenario 3) and that the coach should 'Raise awareness [through informing players] of the risk of careless defence' (sticky note, group 1, scenario 2). Therefore, the coaches' responsibility could be described as an advisory role, clearly communicating risks to the players while encouraging them to take responsibility for a safe playing style. Communicating information and regulations as a regular part of handball practice can raise awareness of risk.

We also derived that an additional responsibility and challenge to be taken on by coaches is to promote the sport safely despite different levels of skill within a team. Less skilled players can potentially contribute to injuries due to a greater risk of unsafe defensive play and a higher risk of head-shooting a goalkeeper. The participants wrote on the digital whiteboard that 'the challenge of everyone's right to participate—the importance of levelling up as different growth spurts and sport-specific development may need to be considered' (sticky note, group 3, scenario 1). This statement pinpoints player heterogeneity regarding body composition, height and body mass, in addition to skills. Therefore, coaches must reflect on and choose adequate exercises for everyone on their team while embracing an inclusive environment.

Caution after potential concussion was also brought up as important. Participants discussed that it is important to substitute players after a headshot to avoid further damage to the brain. It was shared that 'it is very hard for a 16-year-old boy to decide if he should continue playing or stop playing because of something he did not influence, but something someone else caused him' (field player). This statement highlights that players need support from coaches to make appropriate decisions. Additionally, it is

equally important to be aware that concussion may result in a variety of, and sometimes vague, symptoms that do not necessarily include the signs commonly known by the population, that is, headache, dizziness and/or nausea: 'The research is a bit undeveloped and it [the symptoms] does not have to be a headache' (sticky note, group 2, scenario 1). This further supports the need for coaches to make decisions to substitute a player after a headshot rather than leaving the choice up to the player. Raising awareness for the variety, or lack, of symptoms associated with concussion in an informative manner can contribute to appropriate decisions and likely better acceptance for replacing players, which ultimately supports safer play for all.

Theme 2. Players' responsibility: safe defence and attack

This theme outlines specific actions that defenders and attackers can take and rules that can support players' responsibilities.

During the workshop, it became clear that defenders are responsible for using an adequate technique and minimising the rotation of an attacking player when tackling. One of the groups noted that a good 'defence technique: [is to be] responsible for not tackling so that there is rotation of the lower body. Hit the upper body so that one [can easier] receive [the landing after the tackle] with the legs' (sticky note; group 1, scenario 3). This means aiming to hit the upper body but avoiding the face and neck when tackling. That way, the attacker will be supported and may maintain stability, making it possible to land on the feet and keep control of the body, making them less prone to injury.

We also derived that the attackers' responsibility is to jump in a balanced and upright position without a backwards tilted centre of mass. An unbalanced attacking player is more likely to fall and, therefore, at higher concussion risk. According to current rules, the defending player is responsible for almost all injuries caused by an attacker. The workshop participants noted that it should be in the attacker's interest not to get injured: 'If the defensive player is acting according to the rules and the attacking player is 'careless', not in control, the offensive player should be informed of his/her responsibility to be in control as well' (sticky note, group 1, scenario 3). This highlights a shared responsibility for all players as part of safe sportsmanship.

Regarding rules, everyone supported the perspective that there should be zero tolerance for shots to the head in practice and matches. In addition to individual players' responsibilities, participants proposed an even stricter rule change that may support safe playing techniques. The suggested change included harder punishment for headshots and better distinction between a 2 min penalty and a red card. 'If you come all by yourself in a fastbreak, then I think that if you shoot a goalkeeper straight in the head when you are all alone at high speed, you should be able to get a red card. I think that could be a matter of judgment just like all other things in handball are a

Table 3 Themes, selected codes and selected data from the analysis

Theme	Code	Data in English	Data in Swedish	
Coaches' responsibility: raise awareness of risk of injury and act to promote safe environments	Communicate the risk of injury	Raise awareness [through informing players] of the risk of careless defence	Öka medvetenhet [genom att informera spelare] om risken med oförsiktigt försvar	
		Coaches inform players that such [fall backwards] situation is dangerous	Tränare informera spelare att sådan [fall bakåt] situation är farlig	
		The coach should talk to the players about the consequences that [follow] when the player gets a concussion. However, it is still the player's choice, but the coach should advise. A bit difficult because there is no major research or too much responsibility is given to the coach	Tränaren bör prata med spelarna om konsekvenser som [följer] när spelaren får hjärnskakning, dock är det fortfarande spelarens val, men ledaren ska rådgiva. Lite svårt eftersom det inte finns någon större forskning eller att ledaren får för stort ansvar	
		Inform them that side impacts can cause worse effects so that they are more watchful during these encounters	Informera om att impact från sidan kan ge värre effekter så att man är mer observant vid dessa träffar	
		Vague symptoms after concussion	The research is a bit undeveloped, and it does not have to be a headache [as a symptom of concussion]	Forskningen är lite outvecklad och det behöver inte vara huvudvärk [som symptom på hjärnskakning]
Players' different skill levels increase the risk	Players' different skill levels increase the risk	The challenge of everyone's right to participate—the importance of levelling up as different growth spurts and sport-specific development may need to be taken into account	Utmaningen med allas rätt att vara med—vikten av nivåanpassning då det kan behöva tas hänsyn till olika tillväxtpurt och idrottsspecifik utveckling	
		Caution after injury	Take out goalkeeper in case of head shot	Ta ut målvakt vid skott i huvudet
			Pulling out players in case of head injury	Plocka ut spelare vid huvudskada
Players' responsibility: safe defence and attack	Sportsmanship in defence	Defence technique: Responsible for not tackling so that there is lower body rotation. Hit the upper body so that one [can easier] receive [the landing after the tackle] with the legs	Försvarsteknik: Har ansvar för att inte tackla så att det blir rotation av underkroppen. Träffa överkropp så att man [enklare] tar emot [landning efter tackling] med benen	
		If a defending player somehow creates a bad landing when the attacking player is in the air, he bears all responsibility	Om en försvarsspelare på något sätt skapar en dålig landning när anfallsspelare är i luften så bär den allt ansvar	
	Sportsmanship in attack	Striker—jump shooter—Timing and distance—avoid getting backward rotation	Anfallare—hoppskytt—Timing och avstånd—undvika att få bakåtrotation	
		If the defensive player is acting according to the rules and the attacking player is 'careless' and not in control, the offensive player should be informed of his/her responsibility to be in control as well	Om försvarsspelaren agerar helt enligt regelboken och anfallsspelaren är 'vårdslös', inte har kontroll, så bör man informera anfallsspelaren om dennes ansvar för att också ha kontroll	
	Rules	Zero tolerance in games and training [shots to the head]	Nolltolerans på match och träning [skott i huvudet]	
	Continue to work with red and blue cards for stricter punishment	Fortsätta arbeta med röda och blåa kort för större bestraffning		
	Possible stricter red card (requires gradation between 2 min [penalty] and red [card])	Ev. skärpning med rött kort (kräver gradering mellan 2 min [utvisning] och rött [kort])		
Improvement of personal skills	Safe goalkeeper strategy	Focus-training on the ball may prevent some head shots	Fokusträning på boll kanske kan förebygga vissa skott i huvudet	

Continued

Table 3 Continued

Theme	Code	Data in English	Data in Swedish
		Better technique [proactive technique] of the goalkeeper in [opponents'] attack. Have arms above instead of beside the head	Bättre teknik [proaktiv teknik] av målvakten vid [motståndares] anfall. Ha armarna ovanför huvudet istället för sidan om
	Safe defending strategy	The player's skill is more crucial	Spelarens skicklighet som är mer avgörande
		[Increase players' abilities in] Defensive player action; timing, split vision, decision making, responsibility, defensive technique	[Öka spelares förmågor i] Försvarsspelarens aktion; timing, split-vision, beslut, ansvarstagande, försvarsteknik
		Hold on to your opponent as they fall	Håll i motspelaren när den faller
	Safe attacking strategy	Better shooting accuracy by the players	Bättre prickskytte [skottsäkerhet] av spelarna
		Practice jumping high. But there may be a bigger effect [increased risk of concussion due to higher fall height]. Landing technique	Träna på att hoppa högt. Men det kan bli en större effekt [ökad risk för hjärnskakning pga högre fallhöjd]. Landningsteknik
		Timing as an attacker—distance from the defence	Timing som anfallare—avstånd till försvaret
		Curve your back, keep your chin to your chest and avoid head contact with the floor	Krumma ryggen, håll in hakan mot bröstet, undvika huvudkontakt med golvet
	Muscle strength	Alternately, be able to activate the small muscles of the neck quickly (on and off) to instinctively react to the sound of a shot at the pole and defend against impact	Växelvis klara att aktivera nackens småmuskler snabbt (av och på) för att instinktivt vid ljud av skott i stolpe kunna slå på/värja sig vid impact
		General strength (eg, core and neck) can help prevent loss of body control	Allmän styrka (ffa bål och nacke/hals) kan bidra till att inte tappa kroppskontroll
		But it is hard to know if it [neck training] can have an effect	Men svårt att veta om det [nackträning] kan ge effekt

matter of judgment' (coach educator). Thus, factors that can determine the degree of punishment are eventual disturbance (stricter punishment without disturbance), intention of the punished player (shooting aim towards the head) and harm to the exposed player.

Theme 3. Improvement of personal skills

The third theme covers improving individual skills, including playing strategies related to the goalkeeper, defending players and attacking players, respectively, and prevention training for all players as ways to prevent concussion.

Workshop participants elaborated on how to keep goalkeepers safe. They suggested 'Focus-training on the ball may prevent some headshots' (sticky note, group 1, scenario 1) and 'Better technique [proactive technique] of the goalkeeper in [an] attack. Have arms above instead of beside the head' (sticky note, group 2, scenario 1). It was discussed that safe technique for goalkeepers comprised having their hands closer to the head, preventing attacking players from shooting close to the head. Practising these strategies may support goalkeepers in improving their skills for preventing concussions.

Regarding safe defence playing, participants suggested that '[increasing players' abilities in] defensive player

action, timing, split vision, decision making, perceived responsibilities, and defensive technique' (sticky note, group 3, scenario 2) can prevent concussions caused by defenders. These aspects were raised as possible strategies to reduce the risk of causing a blind tackle, hitting an opponent's head and uncontrolled pushes in the air. Another concrete example of a player's possibility was that defenders can hold on to the opponent as they fall to limit impact: 'When the shooter jumps and obtains backwards rotation, you can as a defender grab the shirt and make sure that the fall does not get very harmful. That is incredible sportsmanship' (physiotherapist). This highlights that a common match situation which could have harmful effects on a falling player can be prevented in a simple manner by practising individual skills.

Different individual skills were identified for a safe attack. First, better 'shooting accuracy by the players' (sticky note, group 2, scenario 1) could mean avoiding goalkeeper headshots. Second, even though practising jumping high is associated with a potential risk of a higher fall, it could, at the same time, be safer as the risk of getting hit in the head by defenders is lower (sticky note, group 2, scenario 2). This highlights the importance of considering the risks and benefits of

specific techniques. Third, ‘timing and distance from the defence (players)’ (sticky note, group 3, scenario 3) are crucial parts to avoid harmful impact with defenders and promote defender safety against the attacker. As handball is a very intense sport involving extensive body contact, appropriate timing and distance may reduce the risk of injuries, including SRC. A specific fall technique to avoiding head impact when being pushed in the air as an attacking player is to curve the back and keep the chin to the chest. ‘I am a bit into that you could teach to bend the back, so you don’t hit the head, but that will mean that you also will have much more pain in the back’ (biomechanical engineer). This point was raised as a strategy that could be applied as a specific landing technique to prevent concussions.

Regarding prevention training, participants proposed that improving muscle strength in the neck and core region to achieve stability and body control could benefit players of all positions. Neck exercises should focus on strength, reaction time and activation of the small muscles that rotate the head to reduce harmful rotation. However, the possible preventive effects of strengthening neck muscles were questioned. ‘A typical concussion could be 100G. A head weighs 5 kg, so it is 500 kg that you have to hold against in a typical concussion, so it is not negligible how much you can generate with the neck muscles. But it needs to be studied’ (biomechanical engineer). The force generating a concussion in a player who gets hit in the head would be so high that the muscle strength that exercises can gain would be minor and possibly negligible.

Practical advice for end users

In line with the participatory research approach taken in this project, the results were summarised for youth coaches, players and referees in the form of practical advice (figure 2 (in English) and figure 3 (in Swedish)).

DISCUSSION

This study aimed to understand possible concussion prevention strategies in youth handball using knowledge from experts and end users. In a workshop, experts and end users discussed which information about high-risk situations and SRC symptoms, stricter rules and safe playing strategies may effectively reduce SRC in handball.

Involving end users in the development of educational programmes on concussion prevention in handball

A strength of our study lies in its participatory methodology, in which both experts (physiotherapy, biomechanics) and end users (players, coaches, referees, coach educators) contributed their experience and knowledge on SRC. Participatory and interactive methods can enhance creativity and foster dialogue in group work.²⁵ The experts and end users co-created strategies that could potentially prevent concussion in youth handball that were both research-informed and context-specific. This methodology allowed us to draw on participants’ lived experiences and create high relevance for the suggested prevention strategies.

We suggest that the strategies derived for coaches and referees could be delivered through education programmes. At the same time, players can receive

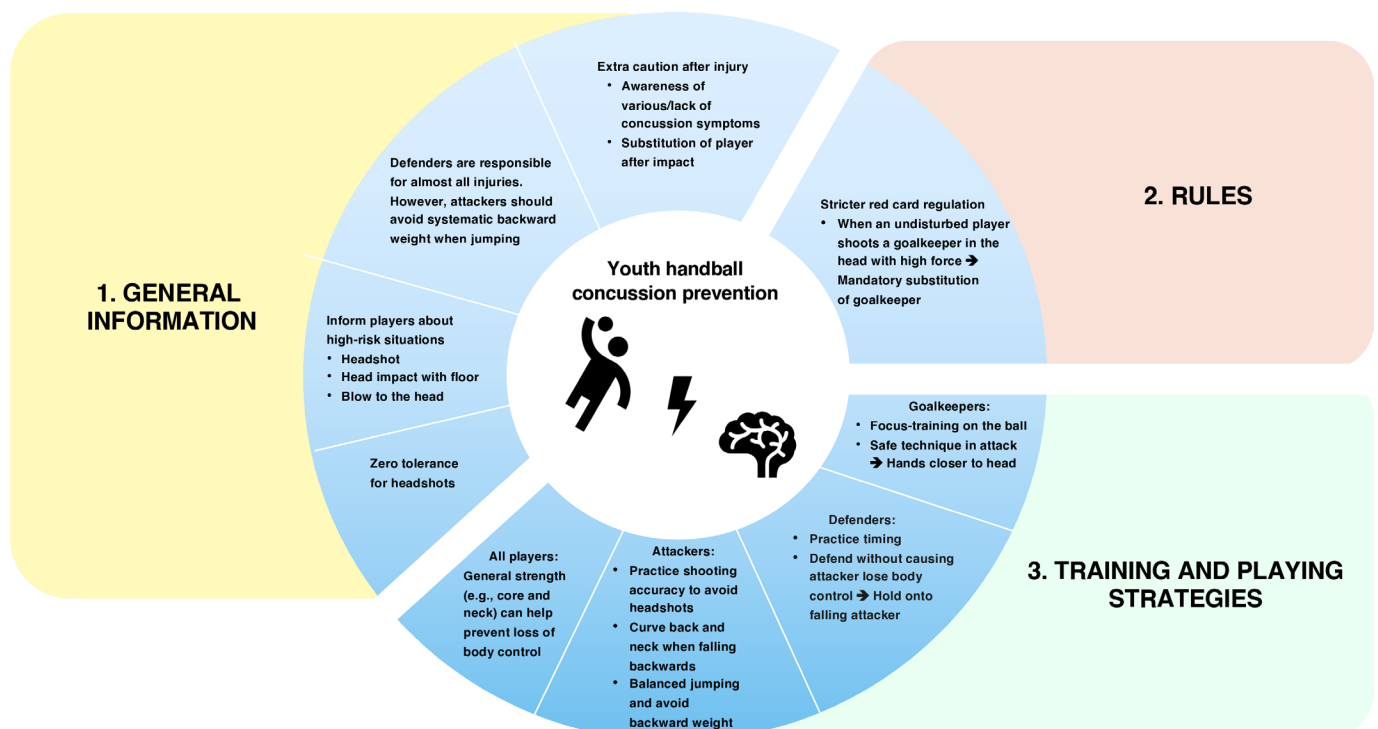


Figure 2 Results summarised for end users in the form of practical advice.

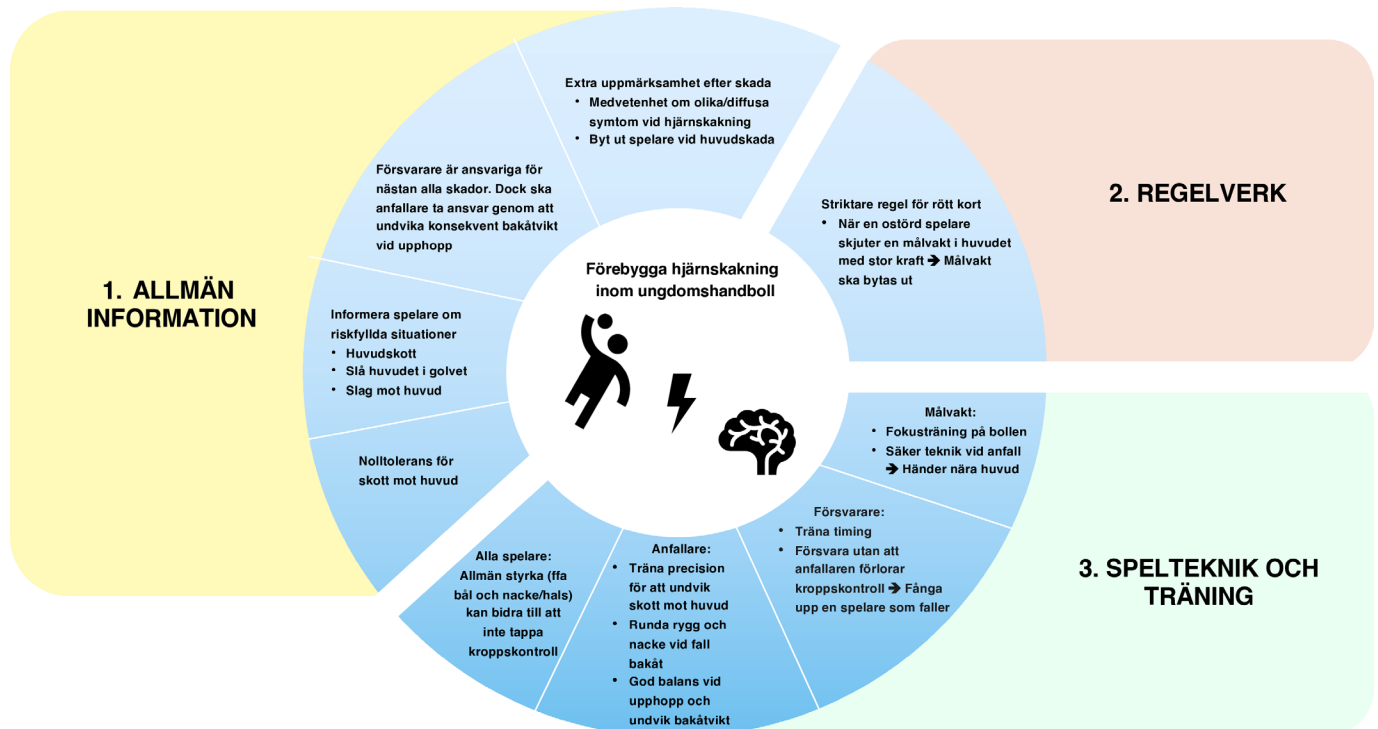


Figure 3 Results summarised for end users in the form of practical advice (in Swedish).

information through coach communication as part of regular handball practice. Educational programmes for coaches regarding SRC in other sports increased knowledge and understanding of SRC.^{26 27} It was shown that these programmes changed coaches' attitudes regarding concussion prevention²⁶ and improved self-efficacy regarding recommended actions.²⁷ Building on the participatory methodology that underpinned this research, an educational programme on SRC could be developed, evaluated and implemented in co-creation between experts and end users for handball. Although it was not discussed during the workshop, we deem such education relevant for referees.

Developing components for a successful concussion prevention programme

Based on the results from this study, an educational programme should include the components of information, rules and safe playing training to create a safe playing environment in handball that might reduce concussion and/or head impact rates.

Information about high-risk situations and SRC symptoms

One of the main findings of this research was that all handball players, coaches and referees should be informed that there should be zero tolerance for shots to the head in practice and matches. Additionally, the findings highlight the need to include information about SRC signs and symptoms in the coach education. Our findings align with existing research that calls for increased awareness of the variety, or absence, of symptoms associated with concussion to help coaches with

appropriate decisions concerning the substitution of a player after a head impact.¹ Our findings echoed that the coach should make this decision rather than leaving it to the players themselves. A player with a suspected possible SRC should not continue to play, as it is difficult to identify early SRC symptoms. We suggest that information about high-risk situations and SRC symptoms could be disseminated to other end users (players and parents/guardians) through, for example, the handball federation's and clubs' respective web pages. Our research points to raising awareness of high-risk situations and unsafe playing behaviour. Head impact with the floor, a blow to the head and a headshot are typical high-risk SRC situations that handball players should be aware of to be able to prevent them. Furthermore, defenders need to be aware that they, according to the rules, are responsible for most injuries caused to an attacker, but that attackers have a responsibility to jump in a balanced and upright position to avoid getting injured.

Stricter rules

Stricter red card regulations are needed when an undisturbed attacking player shoots a goalkeeper in the head with high force. When declaring the player 'undisturbed', the degree of punishment (2 min suspension or red card) should be determined by evaluating the intensity of the foul (dynamics) and its effect on the goalkeeper. In the case of a headshot with high dynamics, there is a high risk of sustaining SRC, and therefore, substitution of the goalkeeper should be mandatory. This way, it is not up to the young player or coach to decide whether a substitution is

necessary. The findings indicate that this rule should be particularly carefully followed for youth players, as they might be more susceptible to SRC than adults.²⁸ Stricter red card rules regarding heading duels in football have shown a reduction in SRC,¹¹ and our findings suggest that stricter rules in certain situations than those recently implemented could be tested in handball as well.

Safe playing strategy training

We suggest the following strategies as important preventive actions. For goalkeepers, two specific strategies apply: (1) increased focus on the ball allows better possibility for positioning and reaction, and (2) holding the hands close to the head increases the likelihood that the attacking player will shoot outside the head and hands. These skills could be trained by implementing specific exercises in handball practice.

For defensive players, preventive strategies to protect attacking players must be taught as part of good sportsmanship. Good timing and minimising contact that causes rotation and/or loss of body control for the attacking player are key points in safe defensive play. Catching a falling player after a push is frequently seen as a strategy in adult handball. Teaching and training to catch falling players after a push could reduce head impacts to the floor during play and should already be taught to youth players. In American youth football, fewer head impacts were observed in players of leagues where coaches had implemented an educational programme that included, for example, proper tackling technique and other playing strategies compared with leagues that had not used this programme.²⁹

Practising shooting accuracy for attackers could be part of regular training to a greater extent than today, which may reduce the risk of head-shooting goalkeepers. Improvement of falling techniques, for instance, curving the back and neck, may also be considered in practice. Although this strategy may reduce the SRC rate, it could potentially increase the risk of back injuries. Attackers are also responsible for attacking safely, that is, without backward weight, to avoid loss of body control followed by a head impact. Split vision training has been shown to reduce SRC risks in American football³⁰ but has, to our knowledge, not yet been tested to reduce blind-side tackles in handball.

Even though neck and core strength training may benefit all players, independent of position, it was questioned whether stronger muscles could prevent SRC, given the high force that generates a concussion. Therefore, only a few exercises were discussed and suggested. A recent systematic review reports few studies (n=4) on the association between neck strength and SRC incidence in different sports, with overall very low certainty of evidence according to Grading of Recommendations, Assessment, Development, and Evaluations (GRADE).⁹ Results conflict with two studies reporting that increased neck strength was associated with reduced SRC,^{31 32} but two other studies did not support this association.^{33 34}

The role of neck muscle strength on head impact characteristics, for example, linear and rotational acceleration, is also scarce, with conflicting results.⁹ The authors of the systematic review recommended further research on the role of neck muscle strength in preventing SRC.⁹

Strengths and limitations

The main contribution of this study is to provide an overview of potential strategies that can help prevent concussions in youth handball, using experience and knowledge from various fields. While similar strategies already exist in other sports, this paper is the first to investigate these issues for handball. A possible limitation is that only one workshop was held. Although participants provided and discussed several ideas and reviewed data, themes and codes, a follow-up workshop might have enabled them to rethink and grow their knowledge. However, gathering all participants for a second workshop was considered too challenging, given participation was voluntary work. Our findings should be interpreted within the obvious limitations of a small empirical study, which necessarily draws on evidence from a smaller sample. We cannot exclude the possibility that a different research team and a group of participants would generate other results, a common limitation in qualitative and participatory research. Like most qualitative and participatory projects, this study aims for the transferability of findings rather than generalisability. Nonetheless, the results of this study make a valuable contribution to developing safer handball training for youth to prevent SRC.

CONCLUSION

Using a participatory research approach, experts (physiotherapy, biomechanics) and end users (players, coaches, referees and coach educators) participated in a workshop where they contributed their experience and knowledge to generate strategies to prevent concussion in youth handball potentially. Workshop participants discussed information about high-risk situations and SRC symptoms and suggested that stricter rules and safe playing strategy training may effectively reduce SRC in youth handball. The information could be delivered through a coach (and referee) education, through coaches to players at handball practice and by dissemination through the national handball federation. Safe playing strategies should be trained at regular handball practice. Training for neck and core muscles could be beneficial. However, the possible preventive effects of strengthening neck muscles were questioned, given the knowledge of the high forces generated during a typical concussion.

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Contributors EA conceived of the study. The study was designed by EA, AR, VS and PM. AR contributed with expertise in workshop methodology, and VS, PM and EA collected data. VS, PM, AR and EA analysed and interpreted data. KJ participated in the workshop and cross-checked data analysis and interpretation. VS and PM wrote early drafts of the manuscript. EA contributed to the development of the work into a full paper including writing, reviewing and editing of manuscript drafts. AR contributed to the writing, reviewing and editing of draft versions. KJ reviewed and edited later draft versions. All authors read and approved the final version. EA is the guarantor of the study.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study is part of a larger project ('Implementing injury Prevention training Routines in TEams and Clubs in youth Team handball (I-PROTECT)'),³⁵ approved by the Swedish Ethical Review Authority (EPN 2014/713 (4 March 2015), 2020-02952 (8 June 2020) and 2022-06148-02 (6 December 2022)). No sensitive personal data were collected. The invitation to attend the workshop was sent through email and contained information about what involvement would mean, how data (such as recordings) would be stored and mandatory information required by the Swedish Ethical Review Authority, for example, participants' right to withdraw from the study at any time. All participants gave their consent to participate. The study included two persons over 15 but under 18 years, who were well informed and understood the study. From age 15 years, people can give consent to participate in a study in Sweden without informed consent also being required from parents/guardians. Data were stored in a high-secure data management platform at Lund University, Lund, Sweden, in accordance with current regulations.

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Data availability statement Data are available upon reasonable request. The data used in this study contain sensitive information about the study participants and they did not provide consent for public data sharing. The current approvals by the Swedish Ethical Review Authority (reference numbers: 2014/713, 2020-02952, 2022-06148-02) do not include data sharing. A minimal dataset could be shared by request from a qualified academic investigator to replicate the present study, provided the data transfer agrees with EU legislation on the general data protection regulation and approval by the Swedish Ethical Review Authority. Contact information: Department of Health Sciences, Faculty of Medicine, Lund University Box 117, 221 00 Lund, Sweden; contact address: DHSdataaccess@med.lu.se; principal investigator: Eva Ageberg, Department of Health Sciences, Faculty of Medicine, Lund University, PO Box 117, SE-221 00 Lund, Sweden; email: eva.ageberg@med.lu.se; Swedish Ethical Review Authority, Box 2110, 75 002 Uppsala, Sweden; phone: +46 10 475 08 00.

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