


Cocreating injury prevention training for youth team handball: bridging theory and practice

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ABSTRACT

Although it is advocated that end-users are engaged in developing evidence-based injury prevention training to enhance the implementation, this rarely happens. The 'Implementing injury Prevention training Routines in TEams and Clubs in youth Team handball (I-PROTECT)' uses an ecological participatory design incorporating the perspectives of multiple stakeholders throughout the project. Within the I-PROTECT project, the current study aimed to describe the development of holistic injury prevention training specifically for youth handball players through using knowledge from both end-users (coaches and players) and researchers/handball experts. Employing action evaluation within participatory action research, the cyclical development process included three phases: research team preparation, handball expert-based preparation and end-user evaluation to develop injury prevention training incorporating both physical and psychological perspectives. To grow the knowledge of the interdisciplinary research team, rethinking was conducted within and between phases based on participants' contributions. Researchers and end-users cocreated examples of handball-specific exercises, including injury prevention physical principles (movement technique for upper and lower extremities, respectively, and muscle strength) combined with psychological aspects (increase end-user motivation, task focus and body awareness) to integrate into warm-up and skills training within handball practice. A cyclical development process that engaged researchers/handball experts and end-users to cocreate evidence-based, theory-informed and context-specific injury prevention training specifically for youth handball players generated a first pilot version of exercises including physical principles combined with psychological aspects to be integrated within handball practice.

INTRODUCTION

Although highly effective in reducing musculoskeletal injuries in youth team ball sports under controlled conditions, evidence-based injury prevention training has had limited public health impact because it is not widely or properly implemented or sustained in real-world sports settings.^{1 2} Not engaging

Key messages

What is already known?

- Evidence-based injury prevention training is highly effective in reducing musculoskeletal injuries in youth team ball sports under controlled conditions but has had limited public health impact because it is not widely or properly implemented or sustained in real-world sports settings.
- The lack of engaging end-users at the individual (athlete and coach) and organisational (administration) levels to plan, develop and implement injury prevention training is an important contributor to insufficient implementation.
- There are no injury prevention programmes available for youth handball players that target both upper and lower limbs or include psychological aspects of injury prevention

What are the new findings?

- This study engaged end-users and researchers/handball experts in participatory action research to cocreate holistic injury prevention training specifically for youth handball players.
- A cyclical development process was used, including three phases: research team preparation, handball expert-based preparation, and end-user evaluation, along with continuous rethinking and growing knowledge within an interdisciplinary research team.
- A pilot programme was generated, encompassing examples of handball-specific exercises including physical principles of injury prevention (movement technique upper and lower extremities, respectively, and muscle strength) combined with psychological aspects (increase end-user motivation, task focus and body awareness) to integrate in handball practice warm-up and skills training.
- Further studies may reveal if injury prevention training cocreated in a cyclical development process involving researchers and end-users helps make such training a regular part of handball practice.

end-users at the individual and organisational levels to plan, develop and implement injury prevention training (or any other health

promotion intervention) is an important contributor to insufficient implementation.³⁻⁵ Collaborating with end-users provides insights into the implementation context,^{2,6,7} helps identify and overcome implementation barriers (eg, lack of motivation and context-specificity,⁸⁻¹² and creates end-user ownership in an inclusive way with all voices heard.¹³ Moreover, social or behavioural theories can inform intervention development to improve programme adherence.¹⁴

Although youth handball players are vulnerable to lower and upper extremity injuries,^{15,16} available injury prevention interventions target either lower^{17,18} or upper¹⁹ limbs. Furthermore, it is recommended that injury prevention training combine physical and psychological interventions,²⁰ as psychological training also reduces the risk of injury.²¹ To our knowledge, there are no injury prevention programmes available for youth handball players that target both upper and lower limbs or include psychological aspects of injury.

In this context, the 'Implementing injury Prevention training Routines in TEams and Clubs in youth Team handball (I-PROTECT)' project was initiated through dialogue between end-users and researchers in 2015 with the overall goal to make injury prevention training part of regular handball practice in youth handball through a series of studies. While available injury prevention training for handball players commonly has a researcher-perspective focusing on evidence-based content and poorly described end-user involvement,¹⁷⁻¹⁹ I-PROTECT has an ecological participatory design incorporating the perspectives of multiple stakeholders (health beneficiaries, programme deliverers, policymakers) throughout the project.^{7,22} The first I-PROTECT study identified the facilitators among stakeholders at multiple levels that could help embed injury prevention training in regular training routines.⁷ The findings suggested that context-specific injury prevention training, incorporating both physical and psychological aspects, and accompanied by a context-specific implementation strategy should be developed in collaboration with stakeholders.⁷ End-users wanted to know and understand why and how injury prevention training works. They wanted a set of age-relevant, fun, varied and handball-specific exercises to integrate within handball practice. Psychological aspects of injury prevention can include coach communication, behaviour change, and providing feedback and creating a positive and accepting training environment. End-users also emphasised the importance of strong club leadership and support from the district and national handball federations, for example, by including injury prevention training in the coach education.⁷ Based on the first I-PROTECT study results, the next steps included developing the I-PROTECT model, an end-user-driven implementable intervention featuring evidence-based, theory-informed and context-specific injury prevention training, and an associated implementation strategy, as described in a recent planning paper.²²

This study aimed to describe the development of an injury prevention training programme specifically for youth handball players, incorporating knowledge from coaches, players and researchers/handball experts.

MATERIAL AND METHODS

Action research as theory and practice

The I-PROTECT project is methodologically framed by the principles of action research, which 'brings together action and reflection, theory and practice, in the pursuit of practical solutions to issues of pressing concern'.¹³ In contrast to other forms of applied research, action research implies 'pragmatic cocreation of knowing with, not on *about*, people'¹³ in a cyclical developmental process, where researchers and stakeholders collaborate in a common project. In this study, the cyclical development process corresponded to the research team's knowledge progress informed by input from stakeholders at different stages towards the outcome, that is, a first program version. Given that action research is a broad methodology with various research practices, the I-PROTECT project is further defined as a participatory action research (PAR) practice in which action evaluation (AE) is used as a specific PAR method. In AE, stakeholders are asked to define what goals they have, why these goals are important, and *how* they should be achieved before evaluating the goal-related activities in practice.²³

Stakeholder engagement can be monitored on a 5-point rating scale, where very low (1) indicates that researchers make all decisions, moderate (3) that stakeholders contribute to decision-making, but researchers make the final decision, and very high (5) that stakeholders are involved in all decision-making.²⁴ The current study is high (4) on this scale. The I-PROTECT project was initiated during a dialogue between researchers and end-users, in which end-users expressed that they wanted to use injury prevention training but needed help to do so. Therefore, our first I-PROTECT study explored the end-users' needs and showed that they wanted to understand the importance, benefit and principles of injury prevention training (why) and have a set of handball-specific exercises (what) to integrate within handball training (how and when).⁷ Hence, in this study, key stakeholder representatives in the planning group underlined that they wanted researchers/handball experts to initiate the development of exercises. End-users would then test and evaluate exercises in practice in line with AE. Results from each phase were presented to key stakeholders in the planning group to enable discussions and agree on how to proceed to the next phase.

Guiding process

The starting point of this study was the results from the first I-PROTECT study in which end-users' needs were identified.⁷ We then: (1) identified and synthesised research evidence and clinical experience; (2) consulted relevant experts and (3) engaged end-users to ensure their needs, capacity and values were considered. These

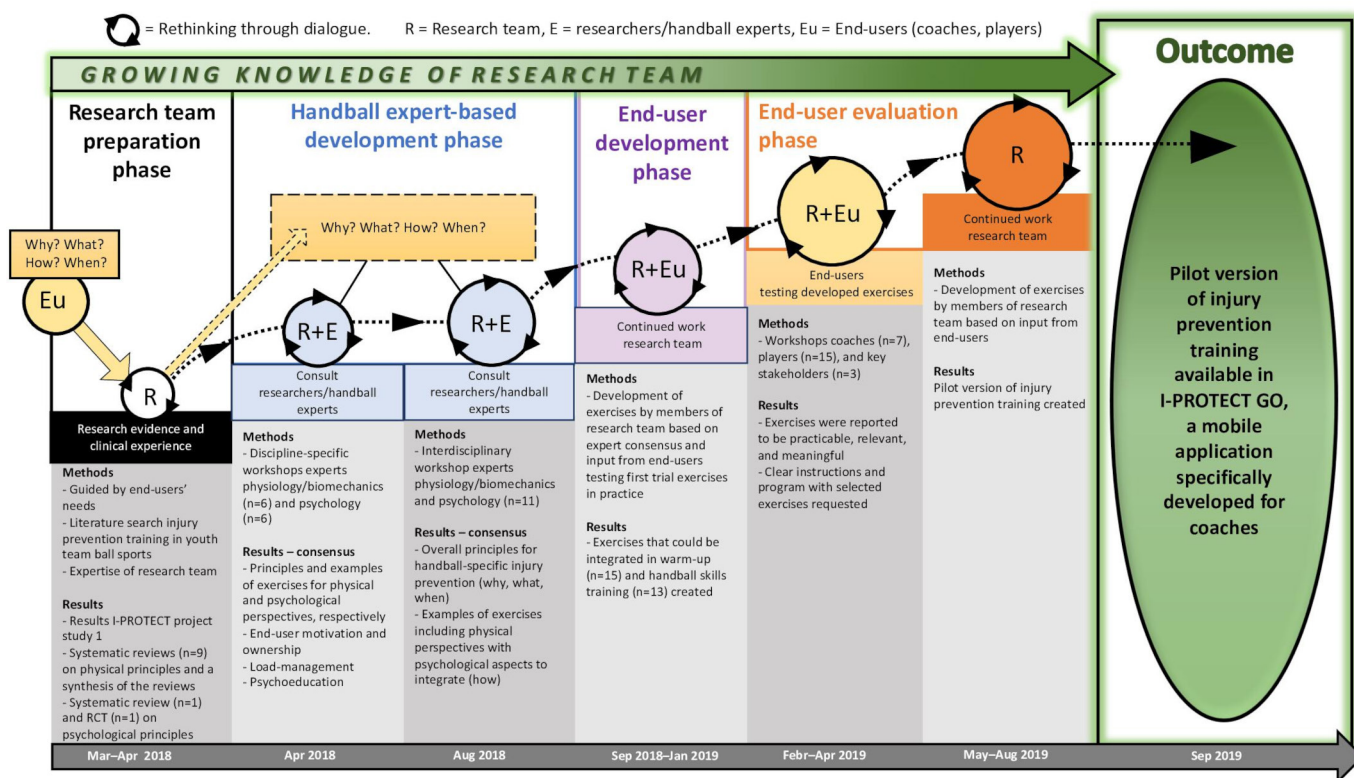


Figure 1 Development of pilot version of injury prevention training for youth handball players available in I-PROTECT GO, a mobile application specifically developed for coaches. The starting point was end-users' needs identified in our first I-PROTECT project study.⁷ I-PROTECT, Implementing injury Prevention training Routines in TEams and Clubs in youth Team handball.

align with the three first steps of the generalisable six-step intervention development process.⁶

Employing PAR and the guiding process, the current study included three phases: research team preparation, handball expert-based preparation, and end-user development and evaluation to develop the first draft of an injury prevention training programme. To grow the research team's knowledge, rethinking was conducted within and between phases based on participants' contributions (figure 1).

Research team preparation phase

Systematic reviews and randomised controlled trials (RCTs) published in the peer-reviewed literature in the past 5 years were reviewed to identify physical and psychological principles of effective injury prevention training. Literature was also reviewed to identify key challenges to implementing injury prevention interventions in community youth team ball sports. The collective knowledge and experience of the research team of theory, evidence and practice, including end-users' needs identified in our first I-PROTECT study,⁷ was also employed.

Handball expert-based development phase

Experts with relevant knowledge within the research field and/or implementation context living within reasonable travel distance from Sweden were identified and contacted by members of the research team (EA and SB). Sixteen

experts were invited, and five declined to participate due to lack of time. The 11 experts (8 PhD, 2 MSc and 1 BSc degree) had research and/or clinical knowledge in sports medicine or sport psychology, and all handball knowledge (player, coach and/or coach instructor) and/or knowledge in physical/psychological development in youth.

Three structured 1 day face-to-face workshops—two discipline-specific (sports medicine and sport psychology, respectively) and one final interdisciplinary—were held to develop injury prevention training specifically for Swedish youth handball players. One expert participated in both discipline-specific workshops as she had knowledge of both physical and psychological aspects of handball. Two experts (one in sports medicine, one in sport psychology) could not attend the interdisciplinary face-to-face workshop but gave feedback on the results. The experts were provided with the outcome of the research team preparation phase and a summary of the results from the first I-PROTECT study,⁷ before the workshops via an Open Science Framework (Centre for Open Science, USA) homepage.

The workshops aimed to identify and reach consensus on principles and propose examples of exercises of injury prevention training for youth handball players. The experts were asked to consider the following key aspects from stakeholders' perspective, identified in the first I-PROTECT study⁷: to know and understand the importance, benefits, and principles of injury prevention training (why); be given



examples of exercises that are age-relevant, fun, varied and handball-specific (what); and exercises that could be integrated in handball practice (how, when). Nominal group technique^{25 26} was used in the workshops including²⁷: (1) Introduction and explanation (ie, study background and specific aim); (2) Silent (individual) ideas generation; (3) Sharing ideas without debate; (4) Group discussion and (5) Consensus. Sharing ideas and group discussion were first done in small groups (two or three participants), then in the whole group. Consensus discussion was performed in the whole group. Workshop participants documented their results. Handballs were used, and the proposed exercises were practised in small groups and the whole group. Research team members circulated between the groups to answer questions and/or reinforce the task(s) and goal of the workshop and ensure that the key aspects from the stakeholders' perspective were considered. When needed, the research team ensured progress by emphasising the frame of the task. Research team members (EA and SB) planned, facilitated, and synthesised the results from each workshop. The experts reviewed and provided feedback on each synthesis, and then all agreed on a final version. The results from the workshops were discussed with the key stakeholders before the research team developed the exercises into a first programme draft.

End-user development and evaluation phase

The initial end-user acceptability of the first programme draft was evaluated in structured workshops with youth handball coaches (programme deliverers) and players (programme participants and beneficiaries). Coaches and players were recruited from the youth teams in the two community handball clubs participating in the I-PROTECT project. Eight coaches (all males) and 15 players (15–17 years, 8 females) volunteered to participate. Members of the research team (EA, SB and JL) led and facilitated the workshops, and a representative (n=3) from each of the two clubs and the regional handball federation (responsible for club/federation operation) participated in the workshops. The workshops started with an introductory didactic session to provide participants with information about the I-PROTECT project, current research evidence and results from study 1,⁷ and a summary from the researchers/handball expert workshops. Participants were given examples of exercises intended to be integrated into handball practice (warm-up and handball skills training) and practised the exercises. To evaluate acceptability,²⁸ coaches were asked if exercises were practicable (ie, easy/difficult to put into practice), relevant, and/or meaningful. They scored individually as a yes/no answer together with any comments on a sheet. In addition, discussions with coaches and players were continuously facilitated (after each exercise, warm-up exercises, and handball exercises, respectively), and the received feedback was summarised to ensure mutual understanding. Finally, in group discussions with coaches and players, respectively, they were asked their perceptions about usability,²⁸ to ensure their

perspectives and suggested revisions were considered. These group discussions aimed to get feedback from coaches and players and agree on exercises that were easy to understand and use, efficient, acceptable, appealing and valuable. Research team members developed the exercises into a second programme draft based on feedback from coaches and players.

Reflexivity

Given the asymmetrical power relationship between experts and practitioners, particularly when youth are involved, we anticipated that the youth might hesitate to express their actual experiences (eg, if an exercise felt uncomfortable) or opinions (eg, if they did not enjoy the programme). Therefore, we engaged in continuous dialogue with participants following the PAR methodology. The interdisciplinary research team represented different expert fields (both theory and practice), that is, sports medicine (EA), sport psychology (SB) and handball (JL) and adopted continuous reflection to reinforce rethinking and growing knowledge (figure 1), as reported in previous PAR studies.²⁹ The joint reflective knowledge process sometimes required thoroughly discussing the meanings of different key concepts and interpreting results to reach a common understanding. These discussions resulted in a more complex and pragmatic understanding than would be possible from a single discipline approach. The research team indicated and emphasised that all participants (coaches, players, researchers/handball experts) were experts within their field(s) to encourage and optimise input, creativity and feedback.

RESULTS

The main results are provided in figure 1.

Research team preparation phase

Nine systematic reviews, including physical principles, along with one systematic review and one RCT on psychological principles of effective injury prevention training in youth team ball sports, were identified. Literature on key challenges to implementing injury prevention interventions in team ball sports, that is, lack of time and interest, lack of programme variation, low priority, lack of context-specific training, lack of support, was also identified. The research team's experience included knowledge of existing injury prevention training programmes for team sports, particularly handball (Fittoplay.org and a Swedish knee control programme), expertise in implementation science and behaviour change, and knowledge of the implementation context from our first I-PROTECT study. The literature identified is provided in online supplemental appendix 1.

Handball expert-based development phase

Discipline-specific workshops

The sports medicine experts agreed on physical principles and examples of exercises, and to increase player/

coach motivation and ownership (online supplemental appendix 2). Generally, exercises were to be integrated into handball practice. Some exercises (eg, throwing) could be performed before training when waiting to access the courts, and muscle strength exercises could be integrated into either warm-up (all ages) or strength training (older players). The sport psychology experts agreed that the main aspect should be reducing stress levels with focus areas for the individual, team, and organisation. Generally, sport psychology exercises and perspectives were outlined (online supplemental appendix 3).

In both workshops, experts agreed on the following overall guidance/principles to increase motivation and end-user (player, coach) ownership of exercises: age-relevant (younger 13–14 years, older 15–17 years); sport-specific and meaningful; fun, varied, challenging and progressions of difficulty; player-attractive and coach-attractive (packaging); injury prevention and performance-enhancing; and use role models to demonstrate exercises (eg, films as in fittoplay.org). The existing guidelines employed by handball coaches in Sweden, that is, use of a ball, perceived fun, and high activity were thought to help integrate the training within the regular practice.

After summarising the results, the research team and experts agreed that the organisational perspective, load-management (physical and psychological perspectives), and packaging would be developed in future project work.

Interdisciplinary workshop

A consensus was reached about the overall principles on *why* handball-specific injury prevention is important (reduce injury, enhance performance, fun, more players available), what components to include in exercises (handball-specific, meaningful, fun, skill development, the external focus of attention, cooperation, competition, mindfulness and task focus, throwing and also jumping with/on the non-dominant side for symmetry), and when to perform (prewarm up, start-up, warm-up, handball skills training, fitness training (all ages) and strength (15–17 years)). It was also agreed that the proposed exercises were relevant for males and females. Thus, no gender-specific exercises were suggested. Specifically, examples of exercises including a holistic view were developed from four physical perspectives (movement technique lower extremities, movement technique upper extremities, muscle strength, and all-round training for physical fitness) and three psychological perspectives (decrease stress and increase task focus, increase motivation through applying self-determination theory (SDT), and external focus of attention) (table 1, online supplemental appendix 4). At the end of the workshop, it was agreed that further work was needed to develop handball-specific injury preventive strength exercises and sport psychology exercises.

Continued work in the research team

Based on the results from the expert consensus and subsequent discussion with key stakeholders, research team members (JL, EA, SB) continued to develop exercises to integrate within warm-up and handball skills training. A team member (JL), who is also a coach, tested trial exercises with players to receive their input and to evaluate, from a coaching perspective, whether exercises were feasible to perform at handball practice (figure 1). Handball-specific exercises were developed to target lower extremities, upper extremities, and muscle strength, respectively, with integrated psychological aspects (increase end-user motivation, task focus and body awareness) (table 2). Muscle strength exercises targeted the core, although several exercises also targeted leg and shoulder strength. Based on our clinical experience, grip/wrist strength training was added and integrated into relevant exercises to enhance performance and ensure handball-specific exercises. General aspects of injury prevention, that is, balance, coordination, posture and/or flexibility, were included in several exercises.

End-user development and evaluation phase

Workshops with coaches and players

Feedback from coaches and players (see table 2) aligned with autonomy (eg, meaningful exercises), perceived competence (eg, progression of difficulty), and relatedness (eg, pairwise exercises) (table 2). All coaches reported that the exercises were, in principle, practical (ie, able to put into practice), relevant and meaningful to incorporate in warm-up and handball skills training. Some coaches perceived that three exercises were not relevant or too difficult to put into practice for younger players. Coaches requested clear instructions (why and how) for each exercise and examples of correct/incorrect movement techniques. They requested a programme including selected exercises instead of a bank of exercises to choose from. They also wanted the exercises available on a digital platform. Players perceived the exercises as fun, relevant, and handball-specific and indicated that clear instructions (why and how), as well as pair and group exercises, enhanced motivation for uptake. Two physical fitness exercises (obstacle course and dance) were discussed as an optional warm-up, and coaches and players believed both could work for all ages. However, these exercises were not prioritised at this stage of programme development.

Continued work in the research team

Research team members (JL, EA, SB) continued developing the exercises based on coach and player feedback, for example, include clear instructions for exercises (why, how, movement technique and feedback) and provide an example programme (table 2). This generated a pilot version of exercises including physical principles and psychological aspects to be integrated into handball practice (figure 1, table 3). Information Technology

Table 1 Consensus from the interdisciplinary workshop with experts in sports medicine and sport psychology including four physical perspectives and psychological aspects to integrate

What		Why		How		When
Main focus	Goal/Purpose	Rationale	Principles(s)	Type of exercises	Psychological aspects to integrate	Warm-up/drill training/strength
Movement technique LE	Improve landing technique during jumping, landing, and cutting	<ul style="list-style-type: none"> Acute injuries to LE are common during cutting and landing with hip-knee-foot not aligned, landing on one leg, and/or with wide cutting technique Specific exercises reduce LE injuries by approx. 40%.^{38,39} 	<ul style="list-style-type: none"> Hip-knee-foot alignment Landing on both legs not one leg (back and line players) Soft and controlled landings Narrow cutting technique 	Jumping, cutting, landing	Decrease stress and increase task focus <i>Be present and mindful when performing exercises</i>	Warm-up and/or skills training
Movement technique UE	Increase posterior shoulder strength to unload front muscles	<ul style="list-style-type: none"> Overuse shoulder problems are common, and risk factors include reduced internal rotation motion and external rotation weakness Specific exercises reduce shoulder problems by approx. 30%.⁴⁰⁻⁴² 	<ul style="list-style-type: none"> Train posterior part of shoulder, especially external rotators No “vacation” for shoulder No shooting if shoulder is not ready Weight training 15–17 years 1 Front 2 Back exercises (strength) 	<ul style="list-style-type: none"> Throwing exercises for posterior part of shoulder. Weight training for posterior part of shoulder (older players 15 to 17 years) 	Eg, focus on breathing during each exercise, focus on the working muscles, relax other muscles, such as face muscles	Before warm-up, during warm-up, skills training, strength
Muscle strength	Strengthen muscles of the core, legs, and shoulder and emphasise correct movement performance	Muscle strength enhances efficiency of movement and athletic performance, and reduces injury risk. ^{43,44}	<ul style="list-style-type: none"> Promote and improve fine motor ball skills and muscle strength, mass, coordination, and control Emphasise correct movement performance 	<ul style="list-style-type: none"> Functional exercises during handball practice. Strength exercises for older players (15 to 17 years) 	<ul style="list-style-type: none"> External focus instructions <i>Mastery oriented motivational climate</i> Coaches create an open and non-judgmental environment, for example, by providing positive and constructive feedback Apply SDT, that is, create perceived autonomy, competence, and relatedness 	Functional tasks integrated in warm-up, and/or in strength training
All-round training for physical fitness	Enhance/improve balance, coordination, functional movement, flexibility, and aerobic capacity	Multifaceted training programmes focused on, for example, strength, endurance, balance and agility reduce injury incidence in youth. ^{39,43,45}	<ul style="list-style-type: none"> Use of ball, perceived fun, and high activity (ie, guidelines included in the coach education in Sweden) 	<ul style="list-style-type: none"> Obstacle course Warm-up dance 		Warm-up

LE, lower extremity; SDT, self-determination theory; UE, upper extremity.

Table 2 Examples of handball-specific injury prevention exercises (n=26) including physical principles and integrated psychological aspects developed by research team based on the results from expert consensus and subsequent discussion with key stakeholders, and feedback from coaches (n=7) and players (n=15) from workshops

Main body part (exercises, n)	Example of exercises	Included physical principles	Integrated psychological aspects	Feedback from coaches and players
Exercises integrated within warm-up				
Lower extremities (n=3)	Run with foot plant*; Forward lunge then lift back leg (as if to jump)†; Double-leg squats with partner in plank position	Hip-knee-foot alignment, soft and controlled landings, leg muscle strength	Pairwise‡, peer-feedback§ mindful muscle activation¶	Coaches <i>Positive feedback</i> ▲ exercises generally practicable, relevant, and meaningful** ▲ high activity in group exercise** <i>Feedback for improvement</i> ▲ clear instructions re. Why (purpose and relevance to handball) and how§ instructions re. correct and incorrect movement techniques
Upper extremities (n=6)	Shoulder external rotation*; Drop and catch ball**††; Shoulder press*	Muscle strength posterior part of shoulder, grip	Pairwise‡, peer-feedback§, mindful muscle activation¶	▲ instructions re. feedback§ ▲ video of exercises§ ▲ age-related (eg, smaller balls in grip exercises)§
Core (n=4)	Plank with arm wrestling and ball; Single-leg balance with ball; Slow-motion rotations–man-to-man†	Muscle strength core, shoulders, legs, and grip	Pairwise‡, competition‡, mindful muscle activation¶	▲ progression of difficulty§ ▲ exercises in digital platform§ ▲ programme with selected exercises rather than choosing from a bank of exercises§
Exercises integrated within handball skills training				
Lower extremities (n=6)	Jumping and cutting exercises with catch and throw	Landing on both feet, hip-knee-foot alignment, soft and controlled landings, narrow cutting technique, leg muscle strength	Pairwise‡, peer-feedback§, competition†	▲ rather than choosing from a bank of exercises§
Upper extremities (n=3)	Backwards throw*; Throw behind back; Overhead-throw	Muscle strength posterior part of shoulder, wrist	Pairwise‡, peer-feedback§	Players <i>Positive feedback</i> ▲ exercises fun, relevant, handball-specific, new and varying** ▲ clear instructions re. why and how** ▲ pairwise and group exercises fun† ▲ individual feedback important§ <i>Feedback for improvement</i> ▲ avoid too many new exercises at the same time§
Core (n=2)	Core side to side with catch and throw; Core sit-up with catch and throw	Core muscle strength, wrist	Pairwise‡, peer-feedback§	
Integrated strength (n=2)	Strength exercises coupled with specific handball skills practice, that is, shoulder – throwing; core – defence; jumping and landing – feint and cutting movements	Muscle strength core, shoulders and legs	Group exercise, players choose exercises from circuit program**	

Balance, coordination, posture and flexibility included in most exercises and are not specifically detailed in physical principles

*Exercises from Fit to play (fitto play.org).

†Coach reported as difficult to put into practice for younger players

‡Relatedness (ie, aspect aligned with self-determination theory).

§Perceived competence (ie, aspect aligned with self-determination theory).

¶Task focus and body awareness.

**Autonomy (ie, aspect aligned with self-determination theory).

††n=3 coaches reported not relevant for younger players (gripping the ball difficult).

Table 3 Pilot version of injury prevention training including exercises integrated within warm-up and handball skills training, respectively

Exercises integrated within warm-up (n=6)

Exercise description	Included physical principles	Integrated psychological aspects
Plank with arm wrestling and ball. 2 levels of difficulty (online supplemental file 5)	Core and grip muscle strength	Pairwise, competition
Single-leg standing balance with ball	Leg and grip muscle strength	Pairwise, competition
Run with foot plant*	Hip-knee-foot alignment, soft and controlled landings, leg strength	Mindful muscle activation, peer-feedback (optional)
Bow and arrow with resistance band*	Muscle strength posterior part of shoulder	Pairwise
Shoulder external rotation (upper arm close to body) with resistance band	Muscle strength posterior part of shoulder	Pairwise
Squat with partner. 2 levels of difficulty	Leg and core muscle strength, hip-knee-foot alignment	Pairwise

Exercises integrated within handball skills training (n=8)

Exercise description	Included physical principles	Integrated psychological aspects
Backwards throw*	Muscle strength posterior part of shoulder, wrist	Pairwise, peer-feedback
Throw behind back	Muscle strength posterior part of shoulder, wrist	Pairwise, peer-feedback
Overhead-throw	Muscle strength posterior part of shoulder, wrist	Pairwise, peer-feedback
Integrated strength in technical skills training	Muscle strength exercises coupled with specific handball skills practice, that is, shoulder—throwing; core—defence; jumping and landing—feint and cutting movements	Group exercise in which players choose exercises from circuit programme
Slow-motion feint with elevated arm. 3 levels of difficulty (online supplemental file 6)	Leg and core muscle strength	Pairwise, mindful muscle activation
Jumping and cutting exercise with elevated arm and ball in hand. 3 levels of difficulty	Landing on both feet, hip-knee-foot alignment, soft and controlled landings, narrow cutting technique, leg muscle strength	Mindful muscle activation
Jumping and cutting exercise with catch and throw (catch ball after landing)	Landing on both feet, hip-knee-foot alignment, soft and controlled landings, narrow cutting technique, leg muscle strength	Pairwise, mindful muscle activation
Jumping and cutting exercise with catch and throw (catch ball when jumping, before landing) (online supplemental file 7)	Landing on both feet, hip-knee-foot alignment, soft and controlled landings, narrow cutting technique, leg muscle strength	Pairwise, mindful muscle activation

The exercises were developed by the research team based on feedback from coaches and players (table 2) and were made available for coaches in a mobile application, I-PROTECT GO, specifically developed for the present study.

Examples of exercises are provided in online supplemental file 8, along with videos of exercises provided in online supplemental files 5–7.

*Exercises from Fit to play (fittoplay.org).

I-PROTECT, Implementing injury Prevention training ROutines in TEams and Clubs in youth Team handball.

consultants were appointed to produce a mobile application prototype, called I-PROTECT GO, including this pilot version of the programme.

DISCUSSION

In this study, researchers/handball experts and end-users cocreated holistic injury prevention training specifically for youth handball players. A cyclical development process including multiple phases, rethinking and growing knowledge generated a first pilot version

encompassing examples of exercises informed by physical principles combined with psychological aspects to integrate into warm-up and skills training within handball practice.

In most previous work, researchers and/or clinicians developed injury prevention programmes to evaluate efficacy in controlled trials^{30–33}, with little or no end-user engagement. In this study, we cocreated injury prevention training by applying PAR and using a cyclical development process including

dialogue between researchers and stakeholders, and continuous collective reflection and rethinking to grow knowledge within an interdisciplinary research team. This process aimed to facilitate sustained and high-fidelity delivery and practice of injury prevention training. PAR is particularly appropriate for this as it involves stakeholders throughout the research process. As a result, they see the practical value of the outcome as it reflects their perspectives.

The literature search identified several systematic reviews, including physical perspectives of injury prevention within team ball sports, but few studies on psychological perspectives. This was expected as psychological interventions are rare in this context.²¹ Knowledge of the implementation context is important to facilitate the adoption and sustained use of evidence-based injury prevention training.³⁴ Therefore, results from our first I-PROTECT study were crucial in this programme development phase as these identified facilitators among stakeholders at multiple levels, which could help injury prevention training become part of regular training routines.⁷ These results,⁷ and the identified research evidence, were discussed within the planning group and underpinned subsequent phases.

To avoid an overly complex task initially, research team members decided to start with discipline-specific workshops with the researchers/handball experts. This enabled participants to interact and develop knowledge within their intellectual comfort zone before generating more multifaceted knowledge in the subsequent interdisciplinary workshop. Although the experts agreed on overarching physical and psychological principles and proposed examples of exercises, it was challenging to develop handball-specific exercises incorporating both physical and psychological principles that could be integrated into different parts of handball practice. In contrast to our holistic approach, existing injury prevention training (eg, Fit to play, FIFA 11+, Knee Control) appears to be less complex with a focus on physical aspects only (mainly lower extremity) and is typically part of, or an optional, warm-up. After consensus from the interdisciplinary workshop, research team members continued to develop handball-specific injury preventive exercises focusing on physical perspectives incorporating psychological aspects integrated within warm-up and handball skills training that the end-users tested and evaluated.

Few previous studies have involved end-users in programme development. In one study, end-users provided feedback on a programme developed by a research team,⁶ and in another study, end-users identified critical elements to include in an injury risk reduction program.³⁵ We started our study with end-users' needs, and coaches and players tested and evaluated exercises during development. Feedback from coaches and players was generally well aligned with SDT (ie, autonomy, perceived competence, and relatedness) (table 2), a framework for understanding factors that promote motivation,³⁶ that the experts agreed should be applied in the

exercises. Coaches and players also generally perceived the exercises as meaningful, handball-specific, varied and fun, suggesting that the exercises addressed the key needs of stakeholders.⁷ Sport-specific and fun exercises have been identified as facilitators by others,⁸⁻¹¹ as well as exercises that may enhance performance,¹¹ while lack of motivation, enjoyment, engagement, sport-specificity and variations are frequently identified barriers to uptake of injury prevention training.⁸⁻¹² Feedback for improvements included having clear instructions about why (purpose and relevance to handball) and how (correct/incorrect movement technique, video of exercises) and the progression of exercises for variation. End-users also requested a typical programme, not just a bank of exercises, via a digital tool to support self-management, adoption, and uptake. After the end-user workshops, research team members developed the first version of injury prevention training, which was then evaluated by coaches and players.³⁷

The main strength of this study is that PAR was applied, where coaches, players, and researchers/handball experts collaborated to cocreate the programme based on interdisciplinary research evidence and end-users' perspectives. The cyclical development process enabled the research team to rethink and grow knowledge through dialogue with researchers/handball experts, end-users, and key stakeholders. To our knowledge, our pilot version of injury prevention training is the first programme that includes a holistic approach. Moreover, we incorporated injury preventive principles into handball-specific exercises for regular handball practice. Another strength is the interdisciplinary composition of the research team, where all researchers contributed with valuable disciplinary expertise and relevant practice-based experience. Although an interdisciplinary approach is valuable, it is not without challenges. Increased understanding of another discipline area and merging perspectives into higher levels of learning and knowledge required extra time for reflection and rethinking. Replacing discipline-specific workshops with interdisciplinary workshops was considered too complex and difficult but could have diminished paradigm-specific starting points. There are also other limitations to acknowledge. Although the feedback from coaches and players is likely representative of other teams, the generalisability of the findings may be compromised due to the two participating clubs being active in the same city. Because youth handball is voluntary work for coaches and undertaken during the spare time for players, end-users had limited time to participate despite their high interest in participating in the study. The collaborative and reflective process used in our study was time-consuming. Further studies could explore more efficient ways to cocreate an evidence-based, theory-informed and context-specific injury prevention training programme. Finally, we cannot

exclude the possibility that a different research team and a group of end-users would generate other results. Nonetheless, the outcomes of this study make a valuable contribution to developing safer handball training for youth.

CONCLUSION

A cyclical development process that engaged coaches, players and researchers/handball experts to cocreate evidence-based, theory-informed and context-specific injury prevention training for youth handball players, generated a first pilot version of exercises including physical principles combined with psychological aspects to be integrated within handball practice. The pilot version was made available in a mobile application (I-PROTECT GO), specifically developed within the I-PROTECT project, for coaches to test and evaluate with their teams. A need to further develop injury preventive strength exercises and sport psychology exercises was identified.

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Appendix 1.

Identified literature including physical¹⁻⁹ and psychological principles¹⁰⁻¹¹ of effective injury prevention training in youth team ball sports, key challenges to implementing injury prevention interventions in team ball sports^{12,13}, and knowledge of the implementation context from our first I-PROTECT study¹⁴.

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Appendix 2. Consensus on principles and examples of exercises from workshop with sports medicine experts.

Principle	Example of exercises
All-round training for physical fitness	Balance, coordination, functional tasks, flexibility exercises, aerobic training
Movement technique lower extremities	Hip-knee-foot alignment during jumping/cutting/landing tasks
Movement technique upper extremities	Throw backwards, sideways to train external rotation and unload front muscles of shoulder
Muscle strength	Shoulders, legs, core
Self-control/choice (players)*	Players pick exercises they like from a bank of exercises
	Players pick the type of feedback they like and when they need it
	Players pick the equipment they like to use in practice
	Increased understanding of why to enhance positive expectancies
External focus of attention	Provide visual and verbal instructions and feedback to activate external focus of attention/implicit learning
Sport specificity/challenge	Pressure elements, e.g., "you have 10 seconds for..."
Load-management	Education about healthy loading and importance of rest

*Self-determination theory (SDT)

Appendix 3. Consensus on aspect, perspectives and suggested focus areas from the workshop with sport psychology experts.

Aspect	Perspective	Focus areas	
Stress levels are important antecedents of youth athletic injury. Increased levels of stress are associated with attentional disruption and increased muscle tension	Individual	Self-reflection and self-awareness among players and coaches. For example, “ <i>How do I feel today?</i> ”, “ <i>What makes me feel focused?</i> ”, “ <i>What makes me feel stressed?</i> ”	
		Interpersonal knowledge	
		Arousal regulation	
			Mindfulness training
			Psychoeducation (the importance of rest and recovery)
			Motivation and goalsetting
		Team	Open and supportive communication
			Social support and feedback
			Supportive motivational climate
		Organization	Involve the different organizational levels (club, regional and national organizations)
			Create conditions for long and sustainable careers – clarify educational responsibility

Appendix 4. Examples of exercises within in each physical perspective and examples of psychological aspects to integrate from interdisciplinary workshop.

Main focus	Example of exercises	Exercise description	Examples of variation and/or progression	Examples of psychological aspects to integrate
Movement technique LE	<p>Basic exercise: Three-step and jump shot in pairs or groups</p> <p>Execution: Player(s) performs a jump shot, another player observes landing (on one or two legs, and HKF-A) and gives feedback</p>	<ul style="list-style-type: none"> • Visual and written information for coaches and players to learn about correct movement technique • External focus instructions for coaches to choose from • Information for coaches to learn how to improve players' feelings of autonomy, competence, and relatedness within a given exercise/practice situation 	<ul style="list-style-type: none"> • Without ball • PL1 throws ball to PL2 during jump shot • While jumping, PL1 gets and catches ball from PL2 • PL1 makes another vertical jump after first approach, gets and catches ball from PL2 in second jump • 3 players: PL1 leads exercise, PL2 and PL3 execute. PL2 and PL3 stand with back to PL1. PL1 gives signal left or right, PL2 and PL3 both jump 180-degree rotation and land correctly (feedback by PL1). PL1 throws ball to the PL that lands correctly, or either PL2 or PL3 if both players land correctly, who approaches the goal. Vary exercise by letting player who does not get the ball act as defence against player with ball 	<p>Feedback: Athletes switch roles between practicing and observing, where the observer gives feedback to the one who practices. Underline positive feedback, on what is working and why (avoid feedback on what is wrong) and focus on the intended movement effect (external focus of attention).</p> <p>Competition: Competition element on movement technique. For example, a goal (performance) only counts when the athlete has landed with good movement technique. A coach can include a gaming element where he/she gives duo's the assignment to score within a certain time limit.</p> <p>External focus of attention: The player is instructed to focus on ball, defence, and goal. The observer focuses on and provides feedback on landing technique.</p>

Movement technique UE	<ul style="list-style-type: none"> • Throw backwards, sideways to train back muscles, external rotators and unload front muscles • External rotation with ball: drop-and-catch • External rotation with ball or rubber band: pair exercise • Weight training (15–17 years): Sitting pull-down; “pully” machine; Sitting rowing 	<p>Before warm-up (while waiting in the hallway), during warm-up</p> <p>During warm-up and/or integrated in skill training</p> <p>At the gym</p>		<p><i>Players:</i> Be present and mindful when performing exercises</p> <p><i>Coaches:</i> Create an open and non-judgmental environment. Build security and autonomy in the group using circulating leadership</p>
Muscle strength			<p>Applies to all exercises:</p> <ul style="list-style-type: none"> • Harder, more, accuracy • Rubber band • Medicine ball/heavy handball • Train with others in a coordinated fashion • Higher/harder throws • Precisions in passes in shots • Faster, more balls 	<ul style="list-style-type: none"> • Meaningful, more fun than physical exercise alone • Fun, skill development • Competition • Cooperation
Core	Inner core with throw	Player lies on back with bent knees and feet lifted off the floor. Activate inner core muscles by pressing lower back into the ground throughout the exercise. While pressing the back down, pass the ball to partner who is in a standing position	<ul style="list-style-type: none"> • Straight legs (feet still lifted off the floor), longer passes or precision • Add wrist training, by throwing with wrist only (not elbow) • Pass with rotation: Player sits down on the floor with legs bent, (think as if sitting inside a clock, with legs at 10 o'clock and shooting arm in a 	

			raised position). From here, rotate upper body towards the floor (approx. 3 o'clock), and pass the ball to partner. Then opposite direction	
	Slow-motion movement – defence training without ball	Train core muscles needed during defence. Slow-motion to emphasize focus on rotation technique in exercise.	Change speed of movement (both from the defence and the attacker)	
<i>Shoulder</i>	Activate scapula (education purpose)	Depress shoulders and retract shoulder blades		
	Throw for posterior part of shoulder 1. Backwards 2. Overhead 3. Behind back	Focus on activating posterior part of shoulder while throwing	Progression: increase distance between players (= longer throw)	
<i>Legs</i>	Slow-motion movement – cutting technique	Handball-specific cutting movements (side-hops) in slow-motion. Emphasize strength, balance, and correct body movement/position	Progression: push (by partner), resistance band around pelvis (partner pulls in different directions), or longer steps	<ul style="list-style-type: none"> • Understanding of the movement • Slowing the movement down to facilitate task focus and mindful muscle activation
All-round training for physical fitness	Warm-up dance Incorporate typical handball movements in dance (players in circle), e.g., <ul style="list-style-type: none"> • Side-cutting movements • Squats with ball over the head • Parallel jumps left/right • Jumps on one leg left/right • The dragon • Tackling shoulder to shoulder on one foot • Roof pass on one foot 	A team can choose a song and change song during a season	<ul style="list-style-type: none"> • Obstacle course 	Check-in before start

LE=lower extremity; UE=upper extremity; PL=player; HKF-A=Hip-knee-foot alignment

Supplemental online material

Supplementary material. Examples of exercises from the pilot version of injury prevention training (Table 3 in paper) developed by the research team based on the results from workshops with experts and end-users. Exercises are handball-specific, integrated within handball practice, and include injury prevention physical principles with integrated psychological aspects. Each exercise includes written instructions and video clip to meet key aspects (why, what, how, and when) emphasized by end-users’.

Exercise	How to execute	Why?	Keep in mind	Video clip
Plank with arm wrestling and ball	<ul style="list-style-type: none"> • Kneeling with straight back • One forearm on the floor, ball in other hand • Press ball in different directions, like “arm-wrestling” • Tip: Use sweater or equivalent under knees 	<ul style="list-style-type: none"> • Core and shoulder muscle strength • Upper body balance and stability • Grip strength • Increase motivation (competition, pairwise) 	<ul style="list-style-type: none"> • Hips parallel to the floor • Knees shoulder-width apart for better balance • Activate core muscles • Avoid shrugging shoulder 	Supplemental online material 5 “Plank with arm wrestling and ball”
Slow-motion feint with elevated arm	<ul style="list-style-type: none"> • Perform a feint in slow motion with elevated arm and ball in hand • After taking three steps, jump and land softly on both feet 	<ul style="list-style-type: none"> • Body awareness and control • Mindful muscle activation • Leg and core muscle strength 	<ul style="list-style-type: none"> • Slow movement • Hip-knee-foot alignment • Core activation 	Supplemental online material 6 “Slow-motion feint with elevated arm”
Jumping, cutting, throwing, and landing	<ul style="list-style-type: none"> • Player 1 moves backwards and passes ball to player 2 • Players 2 takes a three-step feint, jumps, and lands controlled and softly on both feet while catching the ball, then passes the ball back • Change roles and direction 	<ul style="list-style-type: none"> • Practice landing on both feet • Improve balance during jump and landing • Reduce risk of ankle and knee injuries • Increase motivation (pairwise) 	<ul style="list-style-type: none"> • Controlled and soft landing • Arm in elevated position (should approx. 90 degrees abduction) 	Supplemental online material 7 “Jumping, cutting, throwing, and landing”