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Implementation science to reduce the prevalence and burden of MSK disorders following sport and exercise-related injury

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A B S T R A C T

Although safety in sports and physical activity is an important prerequisite for continuing participation and maintenance of a healthy, physically active lifestyle, to date little effort has been placed upon moving evidence into preventive practice. Amongst researchers it is still often assumed that a program will disseminate itself after proven to be effective. Recently, however, there has been an increased recognition of the importance of theory-driven approaches to enhance implementation research. This manuscript aims to provide guidance for sports and physical activity injury researchers and practitioners to perform implementation research and practice. First, we will discuss the differences between research questions across the research spectrum and explain the 'drop' in effect when moving controlled evidence to a practical context. We will discuss two ways of increasing real-world effectiveness of preventive programs, i.e. through targeting the users' behaviour or through revising the intervention. Finally, we will present various implementation frameworks and tools that can guide the reader in their own efforts towards implementation practice and research.

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Introduction

Safety in sports and physical activity is an important prerequisite for continuing participation, as well as for maintenance of a healthy, physically active lifestyle. For this reason, prevention, reduction, and control of sports injuries are important goals for clinicians and researchers, as well as for society as a whole [1]. In 1992, Van Mechelen et al. [2] postulated that measures to prevent sports injuries do not stand by themselves; they form part of what they called the 'sequence of prevention'. Over the past decades the sequence of prevention has been widely adopted in sports injury research, and arguably is the most extensively used theoretical framework in sports injury prevention. There is no doubt that its use in sports injury research has led to a wide array of preventive measures for various injuries within different sports. However, over the past years debate has arisen about the preventive effect of such measures in a real-life sports setting [1,3–5]. As stated by Finch, only research outcomes that are adopted, implemented and sustained by athletes, coaches, other intermediaries and sporting bodies will at the end of the day prevent injuries [3]. For this reason, Finch introduced the TRIPP framework [3] as an expansion of the initial sequence of prevention [2] (Table 1). The TRIPP framework aims at a better understanding of the implementation context for injury prevention and stresses the importance of understanding both behavioural inputs and outputs in relation to sports injury prevention.

In line with the TRIPP framework, there has been an increased recognition of the importance of theory-driven approaches to enhance implementation research. In a literature review, Tabak et al. identified more than 60 published implementation and dissemination theories, models and frameworks [6]. Next, Nilsen et al. [7] organised these theoretical approaches into three overarching aims: (1) describing and/or guiding the process of translating research into practice (process models); (2) understanding and/or explaining what influences implementation outcomes [determinant frameworks, classic theories (i.e. Theory of Diffusion of Rogers), implementation theories]; and (3) evaluating implementation (evaluation frameworks for process evaluations). One example of a process model developed specifically from the context of sports and physical activity injury prevention, is the Knowledge Transfer Scheme (KTS) [8]. The KTS provides an approach for practice and research to engage jointly in the development of an evidence-based product to be implemented in practice (Fig. 1).

Although the notion has landed that implementation research can bridge important gaps between knowledge on efficacy and effectiveness on the one hand and sports injury prevention in practice on the other [1,5,9], amongst researchers it is still often assumed that a program will disseminate itself after proven to be effective. A sequential progression from efficacy to widespread implementation is assumed. If even possible, this progression is not easy [10]. In fact, it has been shown that it takes 17 years to translate evidence into practice [11]. This process can be facilitated with proper understanding, approaches, and research towards implementation. For this, one needs to consider that the design of implementation research is inherently different to efficacy and effectiveness studies, both which are still the standard within our field. Also, implementation is often considered later in the research process by which efficacious programs often fail in a real-world sports context due to a mismatch between the contexts of evidence and the end-users [11].

Consequently, to facilitate broad scale implementation of effective preventive strategies, in this manuscript we aim to provide guidance for sports and physical activity injury researchers and

Table 1
Comparison of the various steps in the Translating Research into Injury Prevention Practice (TRIPP) framework [3] and the Sequence of Prevention [2].

Step	Sequence of Prevention [2]	TRIPP [3]
1	Establish extent of the problem	Injury surveillance
2	Establish aetiology and mechanisms of injury	Establish aetiology and mechanisms of injury
3	Introduce preventive measures	Develop preventive measures
4	Assess preventive effectiveness by repeating step 1	"Ideal conditions"/Scientific evaluation
5		Describe the intervention context to inform implementation strategies
6		**Evaluate effectiveness of preventive measures in the implementation context**

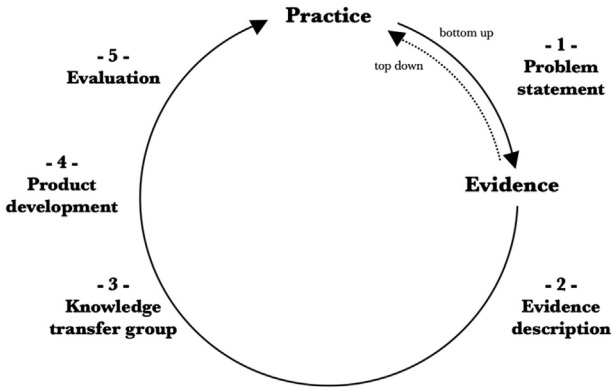

Fig. 1. Five-step Knowledge Transfer Scheme. Reprinted with permission from Verhagen et al. [8].

practitioners to perform implementation research and practice. First, we will discuss the differences between research questions across the research spectrum and explain the 'drop' in effect when moving controlled evidence to a practical context. We will discuss two ways of increasing real-world effectiveness of preventive programs, i.e. through targeting the users' behaviour or through revising the intervention. Finally, we will present various implementation frameworks and tools that can guide the reader in their own efforts towards implementation practice and research.

Difference in research questions

The research cycle from problem to real world solution

Both the sequence of prevention and the TRIPP framework can be regarded as simplified reiterations of the seven-step research cycle proposed by Tugwell et al. [12] (Fig. 2). This cycle states that factual prevention of disease results from a sequence of seven translational steps, ranging in content from fundamental to practical. The first step is identifying the burden of disease and the seventh is evaluating a program that provides, through implementation, health benefits in the real world. When one substitutes 'disease' with 'sports and exercise related injury', knowledge gaps arise in this translational research cycle. Klügl et al. [13] identified a total of 11,859 available publications on sports injury prevention. They concluded there is an abundance of knowledge on the incidence and burden of injury (1354 publications) and a vast knowledge base on injury aetiology (2558 publications). However, where it concerns subsequent steps that move beyond the problem description, evidence becomes scarce. Only 460 publications describe the efficacy of preventive efforts, and only 162 focus on the implementation of this knowledge in the field. This decline in the availability of evidence as one progresses through the research cycle is, however, only logical. After all, there is a chronological hierarchy in research questions; efficacy questions being on the fundamental side, effectiveness questions in the middle, and implementation questions on the practical end of the translational research spectrum [13,14]. Effectiveness questions can only be asked when efficacious evidence is available. Even so, implementation can only proceed upon evidence of effectiveness. In regard to advancing sports and exercise injury prevention in practice, given the relative wealth of effectiveness evidence, one might consider not to conduct yet another effectiveness study but instead to focus on implementation.

Different research questions, different levels of evidence

As mentioned, there exists a hierarchy in research questions; efficacy questions being on the fundamental side, effectiveness questions in the middle, and implementation questions on the

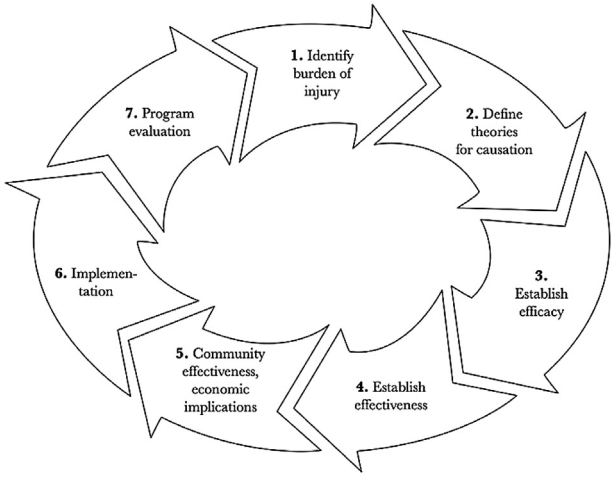

Fig. 2. The research cycle that describes 7 consecutive steps on the research pathway from identification of the burden of injury towards evaluating the implementation of a program that provides health benefits in the real world (e.g. a prevention program for ankle sprains). Adapted from Tugwell et al. [12].

practical end of the translational research spectrum [14]. Each of these questions addresses a different step towards the solution of the injury problem and provides evidence with its own strengths and limitations.

Efficacy is defined as the capacity of an intervention to produce an effect. In relation to sports injury prevention, it is the preventive capacity of a method in expert hands and under ideal circumstances. Efficacy questions may establish whether a conceptual preventive idea works and reduces injury risk factors and injury incidence under relatively controlled 'laboratory' conditions, e.g. does an eight-week neuromuscular training program lead to a decreased centre of pressure in athletes with a history of acute lateral ankle ligament injury?

Effectiveness questions move towards the practical end of the spectrum and establish whether efficacious measures are able to retain their preventive capacities in real-life situations, e.g. what is the effect of a knee neuromuscular training program embedded in regular warm-up on the incidence of acute anterior cruciate ligament injury in female soccer players? The goal of effectiveness studies is to determine the extent to which an intervention actually prevents injuries, when delivered as it would be used in real-world sporting practice. This implies an evaluation in a more practical environment and less control over how the intervention is conducted and complied with. It is important to understand that implementation questions cannot be solved in effectiveness studies. In effectiveness studies, one is interested in the effect of an intervention on a specific outcome. In order to achieve this goal, the intervention is disseminated and evaluated under relatively controlled conditions, which may include strategies such as, follow-up calls, incentives for participation, or supervised preventive training. Moreover, external validity is low as participants are a selected sample of the entire population of interest. Mostly only highly motivated participants (i.e. early adopters according to Rogers Diffusion of Innovations theory) are included in effectiveness trials. In short, the context in which effectiveness trials are undertaken differs greatly from real-life. Consequently, any conclusions regarding implementation that are derived from effectiveness studies only apply to the study protocol, of which the actual intervention is only a single part.

Implementation questions, in contrast to efficacy and effectiveness questions, are concerned with the uptake of an intervention in a real-life situation, including its compliance, fidelity, sustainability, need for adoption and outcomes [10], e.g. what are barriers and facilitators in relation to compliance and adherence to an eight-week neuromuscular training program that has been proven effective for the prevention of acute lateral ankle ligament injury, when delivered interactively through mobile

media? Such questions can only be properly answered when there is an effective intervention available. Therefore, the focus does not need to be on establishing the preventive effect of the intervention again. Implementation outcomes revolve around proper uptake, use and sustainability of intervention messages and components.

Loss of effect

With this order of research questions, the value and significance of research outcomes also changes. Where efficacy questions have a high internal validity (i.e. the extent to which a piece of evidence supports a claim about cause and effect within the context of a particular study) due to the controlled nature of research, these outcomes have a relatively low external validity (i.e. the extent to which the results of a study can be generalized to other contexts). This is in contrast to implementation questions, for which answers lead to a high external validity against lower internal validity. In line with this shift in focus, one should also expect a drop in expected effects (Fig. 3). Where in controlled efficacy studies the researcher is in control of any confounding variables, in implementation studies one needs to expect many disrupting factors that may dilute the most beneficial efficacious effect. This reduction in effect needs to be considered and, moreover, accepted when moving evidence into practice.

This hypothetical reduced effectiveness can also be quantified with simple statistics. Imagine the road from efficacy to real-world effectiveness to be a Boolean function of subsequent steps: we have an efficacious intervention AND this intervention needs to reach the users AND users need to adhere to the intervention. This turns into a basic function of A x B x C. Table 2 outlines this pathway for various scenarios based on an efficacious intervention that is able to reduce 60% of injuries under controlled conditions. With limited reach and poor user adoption, the actual effectiveness in the community is quickly reduced to only a fraction of the initial efficacy. The question then becomes, how to increase the community effectiveness? Should we invest in a better implementation plan and change the users, knowingly losing some effect as we move to a practical context; i.e. voltage drop [15]. Or, is it better to invest in an adaptation of the intervention approach to better accommodate users, i.e. program drift [15]. Likely the best approach requires a mix of both, but with current context-free evidence we would argue the easiest approach would be to adapt the form of intervention programs, whilst keeping the working mechanisms in place, to better align to the practical context.

Change the users or the program?

Changing athletes' behaviour

The implementation of preventive measures implies a change or modification of behaviour of the athlete and, in most cases, that of others involved in the athlete's care and close context, such as

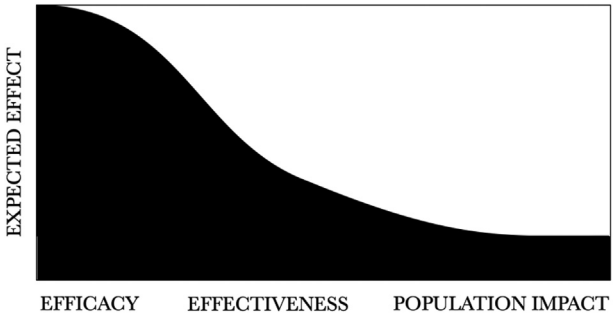

Fig. 3. Illustration of expected drop in effect when moving evidence from (clinical) controlled efficacy research to uncontrolled real-world impact.

Table 2
The hypothetical pathway of different scenarios from efficacy to real-world 'community' effectiveness.

	Efficacy	Coverage (reach)	Athlete adherence	Community effectiveness	% efficacy achieved in community
Under current conditions	60%	10%	25%	1,5%	2,5%
Targeted implementation plan	60%	50% ↑	35% ↑	~10%	~15%
Improved athlete compliance through better alignment in context	40% ↓	80% ↑	75% ↑↑	~25%	~63% ↑↑

coaches. When introducing preventive measures and when evaluating the effect of such measures, it is therefore necessary to have knowledge of the determinants of such preventive behaviours. Many models are used to explain preventive behaviour, in which behaviour is considered a planned or controlled (re)action. The most commonly used Social Cognitive Models are the Health Belief Model [16], the Theory of Planned Behavior [17], the Protection Motivation Theory [18], and the Health Locus of Control [19]. In general, these models include three sets of determinants that drive behaviour: (1) knowledge and attitude, (2) social influence and (3) barriers and self-efficacy.

Attitude

Attitude refers to the knowledge and beliefs of an individual concerning the specific consequences of a certain form of behaviour. In other words, it is the weighing of all consequences of the performance of the behaviour, as seen by the individual. Health is only seen as one of the considerations and is often an unimportant one. When health is part of attitude one may suppose that healthy motivation is a combination of the perceived severity of the health risk, one's perceived susceptibility to the health risk, and the effectiveness of preventive behaviour.

Social influence

Social influence is the influence by others, either directly by what others expect, or indirectly by what others do (i.e. modelling). Social influence is often underestimated as a determinant of behaviour. It can lead to behaviour that conflicts with previous attitudes. Importantly, most sports situations are social situations where this becomes salient to behaviour.

Self-efficacy

Self-efficacy is the individuals' perception of their ability to perform the behaviour. It involves an estimation of ability, considering possible internal (e.g. insufficient skill, knowledge, endurance) or external barriers (e.g. resistance form others, time and money not available, etc.

Social cognitive models

Social cognitive models could be applicable in injury prevention research, and have been shown to be useful in explaining injury protection behaviour [20,21] and sports injury rehabilitation behaviour [22]. It is these determinants that should be accounted for when trying to prevent sports injuries [1,22,23]. Identification of these determinants does not necessarily demand quantitative approaches. In fact, qualitative and mixed-method approaches might produce more insightful results. Recently, a number of studies employing such methods to understand and explain end-user perspectives have been published in sports medicine literature in relation to e.g. concussion education [24], overuse injuries [25], and risk communication in snowmobiling [26].

It is not always about user behaviour

The aforementioned TRIPP Framework [3] has gained well-deserved momentum within the field of injury prevention because two additional steps were proposed after establishing intervention effectiveness. These additional steps prescribe first to look at the context of an effective intervention to inform implementation strategies. Hereafter, the true effectiveness of preventive measures should be

established within the ascertained context. In essence, the TRIPP framework argues for translation of an effective intervention towards a practical context and re-evaluation of its effectiveness within this context.

However, given the chronological order of intervention development and evaluation, interventions have seldom been developed from a practical application viewpoint. Interventions developed solely to maximize health gain or risk reduction may not necessarily be the best interventions to be applied in everyday practice [27]. The resulting conclusion that low adoption and intervention uptake warrants further efforts to increase implementation is, therefore, not always warranted. It may well be that the well-intended intervention, which was designed to be efficacious, was just not useable in practice (i.e. program failure).

Green and Kreuter have previously encapsulated this translational shortcoming in the 'Lenses of Health', by which it was explained that professionals have a higher interest in objective (quantifiable) health indicators (e.g. range of motion, strength, flexibility), whereas athletes are more interested in subjective health indicators (e.g. pain, return to function, return to performance) (Fig. 4) [28]. Implementation approaches like the TRIPP framework [3] expect that effective preventive measures will be adopted in practice if the determinants and influences of sports safety behaviours are understood and transformed into implementation strategies. In a sense, such an approach attempts to translate objective research outcomes into the subjective expectations of the end-user; e.g. we may try to convince an athlete who has clinically rehabilitated from an ankle sprain that a further home-based eight-week neuromuscular training protocol, consisting of three 30-min training sessions per week, will reduce his or her future ankle sprain recurrence risk. The outcome will be a very efficacious intervention, but with very low compliance [29,30]. We clearly need to think differently about intervention development when successful implementation is the final goal.

Intervention development and implementation strategies

The development of preventive programs from a research theory-driven standpoint has been described in detail in previous frameworks [2,31,32]. The overall idea is to prevent an injury from occurring by taking away or reducing the impact of known risk factors and injury mechanisms. In this approach, initially, the injury and its aetiology are considered from a reductionist viewpoint [11]. Especially when one starts to think about implementation of preventive measures, this reductionist view falls short as the real world (sports) context starts to affect an intervention. This has to be taken into account already when developing interventions to make sure preventive solutions align to the barriers and demands of the end-users [27].

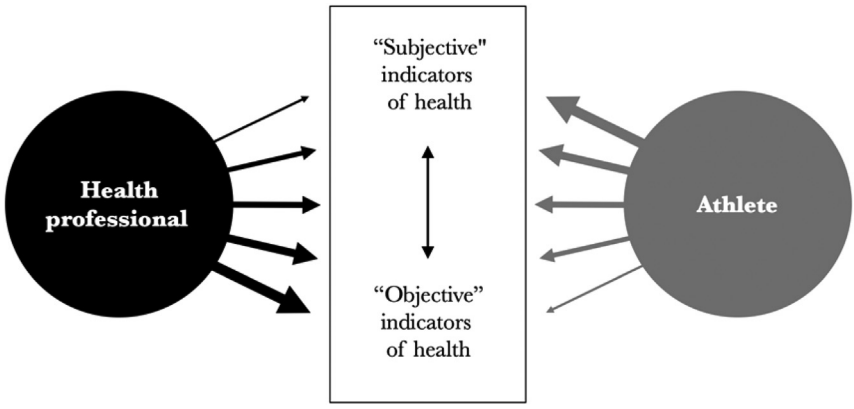

Fig. 4. The lenses of health. Adapted from Green and Kreuter [28].

Intervention development

For implementation efforts, one very promising framework in constructing acceptable and evidence-based intervention programs is the Intervention Mapping protocol (IM) [27,33]. IM captures the process of the development of a health promotion program in a series of six consecutive steps (Fig. 5). IM maps the path from recognition of a need or problem to the identification of a behavioural solution and provides the tools to do so in a multidisciplinary manner. The strength of IM lies therein that the end-users and others involved with the intervention program are part of the development process.

While originally designed for health promotion programs, IM can easily be used for injury prevention programs as well. Following the protocol, before a start is made with the actual development of the intervention program, the health problem needs to be assessed. This should include related behaviours, environmental conditions, and their associated determinants for the at-risk populations. This initial problem definition encompasses two components: (A) a scientific, epidemiological, behavioural, and social perspective of an at-risk group or community and its problems; and (B) an effort to "get to know," or begin to understand, the character of the community, its members, and its strengths. This starting point is more than a description of a health or injury problem as commonly applied in sports medicine research; i.e. ankle sprains are the most common injuries. It is a description of a health problem, its impact on quality of life, behavioural and environmental causes, and determinants of behaviour and environmental causes, also taking facilitators and barriers into account. If a health or injury problem is approached in this way, in a sense the resulting intervention program is built around the acting behaviours.

Yet, we often lack knowledge about the functional components of the intervention (i.e. active ingredients of the program) and their relationship with the desired outcomes. Knowing what makes an intervention effective is critical to future dissemination and the scale-up of effective interventions. This knowledge helps to inform more efficient and cost-effective implementation of interventions and measures, and moreover, can lead to confident decisions about the level of adaptation allowed, whilst still retaining as much effectiveness as possible. Intervention developers should, therefore, describe the logic model for behaviour change of an intervention, i.e. the theory of how the program affects outcomes and how the program is implemented in the context of the delivery setting. This logic model can consequently be tested during implementation evaluation by means of mediation analyses.

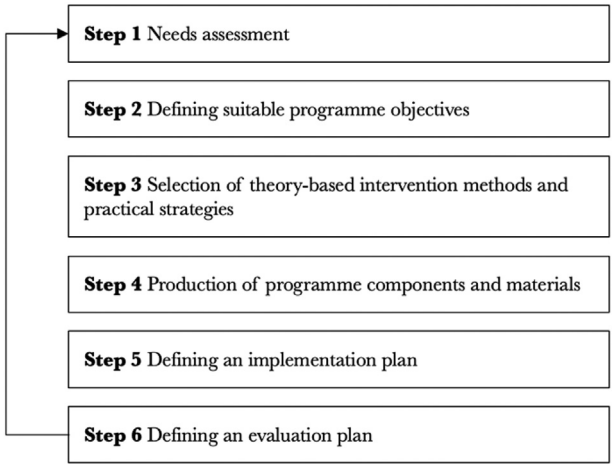

Fig. 5. Steps of the Intervention Mapping protocol [28,33].

Implementation plan

As part of intervention development and described in the above-mentioned TRIPP Framework [3] and IM protocol, an implementation plan should be developed to guide and support implementers through adoption, implementation and sustainable use of the program or measures to prevent sports injuries. Yet, an implementation plan is rarely part of the development process of injury prevention programs. Due to lack of time and resources, the implementation strategy usually consists of a description of the implementation of the intervention program in the research setting, in which the researcher is often intervening in the implementation process by conducting measures as well as supporting implementation. Attention to long-term sustainability of the program is typically limited and usually depends on the persistence of the principal investigator. Using a systematic approach such as IM results in a theory- and evidence-based development of the intervention program and tailored implementation plan (consisting of several implementation strategies), involving views and experiences of different stakeholders and end-users. Tailored implementation strategies will increase the likelihood of successful uptake, implementation and ultimately effectiveness in a practical sports context.

Step 5 of the IM protocol provides guidance on how to develop a plan to support wider dissemination, tailored to the needs of its potential users (i.e. implementers such as coaches and physiotherapists). IM step 5 is useful for new programs to plan for initial implementation to ensure that the program is used as intended during a feasibility or evaluation trial, but also for programs that already have been implemented and evaluated in order to enhance wide-spread dissemination or scale-up after the research phase. Within the IM protocol, step 5 basically consists of all previous steps but targeted at the program users. First one needs to identify potential program users (adopters, implementers). Next, objectives and outcomes for the users regarding adoption, implementation and continuation need to be specified. These objectives refer to changes in behaviour, and motivation and abilities of the user to implement the program as intended. When changing behaviours of implementers, there is a parallel to previously mentioned models for changing athletes' behaviour, but then the focus is not in injury prevention behaviour, but on implementation behaviour to improve implementation in practice. Again, determinants amongst others that drive implementation behaviour are knowledge and attitude, social influence and self-efficacy. Finally, by combining these behaviours and their determinants in matrices, the objectives can be translated into essential elements and practical implementation strategies bundled into an implementation plan [33].

Implementation strategies

Implementation strategies can be single component or “discrete” strategies (e.g. disseminating educational materials, feedback, support); however, most are multifaceted and multilevel, involving more than one discrete component. Using an expert panel, Powell et al. [34] have reached consensus on a final compilation of 73 implementation strategies, which is useful for selecting appropriate approaches for different settings. Although these strategies were drawn from implementing clinical innovations in (mental) health settings, they can easily be translated to the sport and injury prevention field.

The first step in selecting and tailoring implementation strategies is to assess factors that influence implementation processes and outcomes. Several frameworks have been identified that describe factors that influence implementation (i.e. determinants). Although all frameworks are slightly different, they do show a large amount of overlap. Many frameworks are multilevel, identifying determinants at different levels, from the individual user or adopter (e.g. coach, physiotherapist) to the organization and beyond [35–38]. Although many frameworks have been developed for other research fields, the classification of factors can be applied to injury prevention. These factors can either facilitate or impede implementation. For instance, if coaches are not properly trained for delivery, they might deliver only a small part of the program or refuse to implement the program at all. Barriers to implementation can potentially lead to negative adaptations or even termination of the training program. Therefore, it is important to identify and address these factors in order to ensure optimal implementation.

After completing a context assessment to identify barriers and facilitators to implementing injury prevention programs, frameworks can help to tailor implementation strategies to mitigate barriers and leverage facilitators. Consensus methods such as Concept Mapping can be used to determine which determinants are most important and actionable from the perspectives of a wide range of stakeholders [39]. Lastly, strategies need to be translated into implementation materials. Examples of translating strategies into materials for injury prevention are role modelling, such as using a star coach to teach other coaches on how to implement a program in practice. Another example is providing interactive assistance during implementation, for example by an app or support office. One can also think about financial strategies, such as providing financial support to implement a specific training program.

Yet, most implementation frameworks lack information on how researchers should apply this process of linking strategies to barriers. Therefore, the Consolidated Framework for Implementation Research (CFIR) has recently launched a practical tool to match factors to implementation strategies (https://cfirguide.org/). In addition, Koorts et al. [40] developed the PRACTIS guide describing practical methods for four iterative steps planning for implementation and scale-up:

- Step 1) Characterize the parameters of the implementation setting; They provide a practical checklist with questions one can ask different stakeholders to think about the different aspects involved in implementation and sustainability.
- Step 2) Identify and engage key stakeholders across multiple levels within the delivery system(s);
- Step 3) Identify contextual barriers and facilitators to implementation, and;
- Step 4) Address potential barriers to effective implementation.

Although they provide practical guidance for planning for implementation and scale-up, the PRACTIS guide does not contain concrete directions on how to address barriers. The implementation science field slowly moves forward from not only identifying facilitators and barriers, which is describes in multiple articles, but also describing on how to address them. As such the PRACTIS guide provides two practical examples and the availability of the practical CFIR tool will facilitate this linking process as well.

Implementation evaluation

Process evaluation

Implementation evaluation can provide insight into the dynamic nature of implementation processes and contextual key factors that contribute to achieving effectiveness from injury prevention programs beyond the research setting (e.g. insight into the black box of implementation processes, often still an afterthought in evaluations). Evaluation of implementation revolves around proper uptake, use and sustainability of intervention messages and components. A structured process evaluation can answer question such as: Why was your program (not) effective? What quantity and quality of the program was delivered? What is the working mechanism of a program? What contextual factors influenced delivery? And what is needed for post-evaluation scale-up? Implementation evaluation (including process evaluations) can be conducted during all phases of dissemination, e.g. during feasibility testing, during implementation as part of a research project (for example, parallel to a RCT), or during full scale implementation.

Multiple approaches to evaluate the implementation process exist, of which the RE-AIM framework arguably is the most commonly used for this purpose [40–42]. The RE-AIM framework designed by Glasgow et al. [41] was originally developed to evaluate the public health impact of health promotion interventions. This framework describes five interacting dimensions (reach, effectiveness, adoption, implementation, and maintenance). A framework such as RE-AIM is useful to answer implementation questions as it evaluates 'proven' measures within their implementation context.

Given the multilevel, hierarchical delivery of community sport, Finch et al. [42] extended the original RE-AIM framework to accommodate different dimensions that could be assessed across the sports delivery hierarchy and the delivery-setting complexity: RE-AIM Sport Setting Matrix (SSM) framework. Examples of operationalisation of the different aspect of RE-AIM are:

- Reach: absolute number or proportion of individuals in the target population (coaches and athletes) who are willing to participate in a given program;
- Effectiveness: The extent to which the program is effective in reducing injuries (compared to usual care);
- Adoption: absolute number or proportion of individuals in the target population who are initiating/adopting the program;
- Implementation: extent to which the program is implemented/used as intended;
- Maintenance: extent to which the program becomes routine and part of policy.

Yet, other approaches are also available, such as the practical guidance for the design of process evaluations of complex interventions developed by the UK Medical Research Council (MRC) [43]. This guide differentiates between three features essential to understanding the process through which outcomes are achieved: context, implementation and mechanisms of impact:

- Context: questions how the social and physical environments in which the program is introduced influence the delivery and functioning of the intervention, and how the intervention might be replicated within the specific context in the future. This also refers to the previously mentioned facilitators and barriers for implementation.
- Implementation: questions how delivery is achieved and what is actually delivered. This includes describing the structures, resources and processes through which delivery is achieved, and the quantity and quality of what is delivered, any adaptations made to the program, and the socio-demographic characteristics of the participants approached and recruited by the intervention.
- Mechanisms of impact: investigates how program users and coaches respond to and interact with the program, and how the intervention triggers change. The causal assumptions of the way in which the program operates (i.e. mediation paths) can also be investigated.

Regardless of which framework is used to develop a process evaluation, it is important to make sure that relevant research questions are asked, measured with the best available instruments, and preferably using a mixed-methods approach in which qualitative research can contribute to the understanding of the quantitative data.

Design of implementation studies

Implementation questions can only be properly answered when there is an effective intervention available. Therefore, the focus does not need to be on establishing the preventive effect of the intervention again. Distinguishing implementation effectiveness from intervention effectiveness is critical for transporting interventions from controlled research settings to real life sport settings. Luckily, there are several approaches to prioritize implementation outcomes and assess the generalizability of intervention effects. Pragmatic trials, hybrid effectiveness-implementation trials and participatory research approaches are study designs appropriate for implementation research [44,45]. Hybrid study designs combine assessing effectiveness and implementation in one study. Curran et al. [44] propose 3 hybrid types: (1) testing effects of a program on relevant outcomes (such as injury occurrence) while observing and gathering information on implementation; (2) dual testing of effectiveness and implementation interventions/strategies; and (3) testing of an implementation strategy while observing and gathering information on the program's impact on relevant outcomes. The latter type implies that the primary aim of the study is to determine utility of an implementation intervention/strategy. By randomising between implementation as usual, and implementation using a specified strategy, effectiveness of the strategy can be tested. This answers

the research question of which method works better in facilitating implementation of the program, thereby informing sustainable implementation. Injury outcomes can also be measured, but that is regarded as a secondary outcome.

Additionally, in recent years there has been an increased interest in applying 'systems science' thinking and methods (e.g. social network analysis, agent-based modelling and system dynamics) in implementation science [46]. Systems science methods can help researchers, program implementers, and decision makers to understand the complex factors influencing successful implementation and scale up of injury prevention programs in real life, and to identify implementation challenges underlying by system complexity. Within implementation science, as outlined above, the broader context (such as an athlete, its coach or physiotherapist, related sports organisation or leagues, and (inter)national legislation) is already taken into account when developing implementation strategies. System science advances the implementation science field by also looking at feedback loops, interactive pathways between different levels in the context and testing these interactions. Yet, system science thinking is still in its infancy, but has great potential.

Implementation outcomes

A critical issue in the field of implementation science is how to conceptualize and evaluate success. Studies of implementation use varying approaches to measure how well strategies to prevent sports injuries have been implemented. Some define implementation success by measuring outcomes at the end user (athlete) level, while other studies measure the outcomes at the level of the implementer (for example the level of adherence of a coach to deliver neuromuscular training during every warm up session). Other implementation studies define success only in terms of how well the strategy has reached the target population. Measurement of implementation outcomes, such as intervention feasibility and implementation cost, can be also used as a proximal indicator of implementation processes, success, and sustainability.

In order to move the implementation science field forward, Proctor et al. [47] have developed a taxonomy of 62 implementation outcomes that can be applied to evaluate implementation endeavours. On the basis of a narrative literature review, they propose eight conceptually distinct outcomes for potential evaluation: acceptability, adoption (also referred to as uptake), appropriateness, implementation costs, feasibility, fidelity, penetration (integration of a practice within a specific setting) and sustainability (also referred to as maintenance or institutionalization), in addition to organisational outcomes and end-user outcomes. Implementation researchers can use these variables to assess how well implementation has occurred or to provide insights about how these factors contribute to other important injury outcomes. In addition, measuring 'standardised' implementation outcomes will advance understanding of implementation processes of injury prevention programs, enable comparison of study results, and enhance efficiency in implementation research.

Summary

Although safety in sports and physical activity is an important prerequisite for continuing participation and maintenance of a healthy, physically active lifestyle, to date little effort has been placed upon moving evidence into preventive practice. In this manuscript, we have outlined the differences in scope and design of various research questions, ranging from efficacy to implementation outcomes. Each of these is needed to move towards effective solutions to injury problems in sport and physical activity, but only implementation questions really deal with solving problems in a practical context. This manuscript has provided the practitioner and researcher with practical steps that may aid in preparing and evaluating implementation towards sustainable use of injury preventive measures. After all, vast resources should only be invested in injury preventive measures and programs that are translatable into practice and have a potential to really affect the health and continuing sport participation of the target population.

Practice points

- The sequence of prevention is arguably the most extensively used theoretical framework in sports injury prevention, yet does not accommodate for implementation research.
- Frameworks have been postulated that proceed further upon the evaluation step of the sequence of prevention, adding implementation after the original four steps.
- While established interventions have not been developed from a practical application viewpoint, measures may not be synchronised to practice by which implementation is hampered.
- Vast resources should only be invested in injury preventive measures and programs that are translated to practice and have a potential to affect the target population.

Research agenda

- Intervention development and adaptability for widespread and sustained implementation should be prioritized early in intervention planning and should include active engagement from end-users and stakeholders.
- Development of an implementation plan should evolve from identifying facilitating and hindering factors matched to evidence-based implementation strategies.
- Ongoing stakeholder involvement throughout the planning, implementation and dissemination processes should help increase the fit between the intervention, implementers and the implementation context, and prevent evolving issues that might hinder scale-up.

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Conflicts of interest

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