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REVIEW

A new framework for research leading to sports injury prevention

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Summary This paper proposes a new sports injury research framework, the Translating Research into Injury Prevention Practice framework, or TRIPP. This model builds on the fact that only research that can, and will, be adopted by sports participants, their coaches and sporting bodies will prevent injuries. Future advances in sports injury prevention will only be achieved if research efforts are directed towards understanding the implementation context for injury prevention, as well as continuing to build the evidence base for their efficacy and effectiveness of interventions. There is no doubt that intervention research in the sporting field can be difficult and many challenges need to be overcome; however, that should not be put up as a barrier towards undertaking it. Over the next few years, sports injury researchers will need to think carefully about the “best” study designs and analysis tools to achieve this. All reported sports injury studies, of whatever design, should include information on key implementation factors such as player/club recruitment rates and other biases as well as the rate of uptake of the interventions being tested, including reasons for use/non-use. However, it will only be broad research endeavours that adopt the TRIPP six-staged approach that will lead to real-world injury prevention gains.

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Introduction

Arguably, the most commonly cited model of sports injury prevention over the past decade has been that initially articulated by van Mechelen and his colleagues in 1992.¹ This represented a translation of the standard public health prevention model² to the sports injury context. The model outlined a four-stage approach to sports injury prevention as shown in the right hand column of Fig. 1.

There are a number of limitations, however, associated with this four-stage approach and the extent to which it has been implemented in practice. Firstly, the general sports injury research field is still needing to largely move beyond stage 2.^{3,4} Many studies still only report the descriptive inci-

dence of injury during sport and even these studies are hampered by methodological limitations such as unvalidated surveys of self-report information; long periods of recall leading to recall bias; poor definition of injury and injury severity; univariate statistical descriptions of the data; no concurrent collection of, or adjustment, for exposure; and descriptions of medically-treated cases from non-representative samples, etc.

There is no doubt that the four-stage model of sports injury prevention has been a valuable tool to guide injury research over the past decade. From a research development point of view, it clearly outlines the direction of required evidence needed to build our evidence base about sports injuries and their causal factors. Furthermore, it adopts a broad

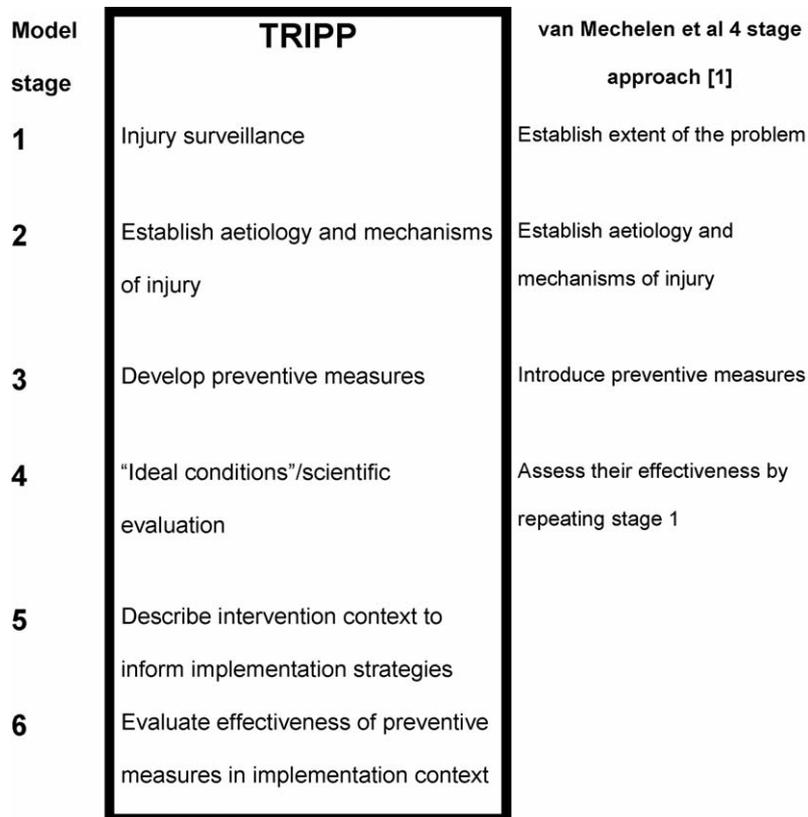


Fig. 1 The Translating Research into Injury Prevention Practice (TRIPP) framework for research leading to real-world sports injury prevention.

risk management/epidemiological control model to addressing the problem similar to those proposed for general injury control.^{5,6} However, the model fails to adequately describe the directions required for research that leads to direct injury prevention.

The most serious limitation of the van Mechelen et al.¹ model is that it does not consider the need for research into implementation issues, once prevention measures have been proven effective. To prevent injuries, sports injury prevention measures need to be acceptable, adopted and complied with by the athletes and sports bodies they are targeted at. If the athletes, coaches or sports administrators we are trying to work with will not use or adopt any of the prevention measures that we advocate, then all of our preventive efforts will fail. Sports bodies will not implement sports safety policies until they are sure that the safety measures actually prevent injuries, are acceptable to their participants, do not change the essential nature or appeal of the sport, and do not adversely affect participation or performance.⁷

Before successful preventive efforts can be achieved, let alone implemented, the determinants and influences of sports safety behaviours need to be understood.⁷ A critical shortcoming of the van Mechelen et al.¹ model is that it does not consider this aspect at all. Whilst the model strongly, and correctly, advocates for an evidence base about the efficacy of prevention measures, good efficacy or effectiveness research, alone, does not ensure uptake of the interventions and hence prevention of injuries. In fact, a lack of consideration of, and information about, the uptake of preventive measures may be one of the major factors that explains the negative or null effect results reported for some field-based studies of implemented preventive actions. It is a concerning assessment of much sports injury research endeavour that very few studies actually talk about intervention uptake issues in the presentation of their findings.

A new research framework

Advances in sports injury prevention will only be achieved if research efforts are directed towards understanding the implementation context for injury prevention, as well as continuing to build the evidence base for their efficacy and effectiveness. For this reason, a new research framework, the Translating Research into Injury Prevention Practice framework, or TRIPP, is proposed. This framework is outlined in Fig. 1, with a comparison to the four-stage model of van Mechelen et al.¹

The TRIPP framework recognises that a complete evidence base for prevention requires:

- (a) a detailed understanding of the aetiology of injuries;
- (b) development of interventions to directly address the identified mechanisms of injury;
- (c) formal testing of these interventions under controlled conditions (i.e., efficacy research);
- (d) understanding of the sporting and individual athlete behaviours context in which the interventions are to be implemented;
- (e) potential modification of interventions to take this implementation context into account;
- (f) assessment of potential factors associated with the real-world introduction and application of safety measures and development of implementation strategies to accompany the real-world "roll-out" of the interventions; and
- (g) formal evaluation of the effectiveness of injury prevention measures within the implementation context.

Although an appreciation of the need to consider the implementation context has been recognised in models of general injury control since the late 1990s,^{8,9} this is the first time these concepts have been formally applied to a framework for sports injury research. There are also particular implementation challenges in the sports injury context,⁷ compared to other injury settings such as road trauma or firearms use, that justify a context-specific framework.

Stages in the TRIPP framework

The TRIPP framework is conceptualised as a series of necessary steps in building the evidence base for prevention (Fig. 1). The following paragraphs expand on these steps and outline the range of research approaches required at each stage.

TRIPP Stage 1

The TRIPP Stage 1 is that of injury surveillance. As noted by other commentators,^{3,10,11} there is a very real need for the sports injury research field to move away from studies that solely focus on describing the problem, particularly in individual participant groups (e.g., one team in one sport from one country or region, or one sports event at one point in time). Indeed, injury surveillance should not be seen as an end, in itself. Rather, high-quality injury surveillance information is crucial for informing all other stages and it should

be considered to be the methodological tool to be used in all other TRIPP stages. Nonetheless, injury surveillance activities will only contribute to this if valid and reliable methodologies are developed and adopted to allow for the routine, ongoing monitoring and reporting of sports. There is also the need to ensure standardised sports injury and exposure definitions.^{3,11,12} One area where particular methodological development is needed is that of appropriate statistical methods that assess both spatial (across places) and temporal (over time) trends in injury incidence, after adjustment for exposure. For example, epidemiological monitoring of trends in participant-adjusted injury incidence rates across regions, or countries or even sports, would help to fully quantify the burden of sports injuries and the relative risk of injury across different sporting activities.

TRIPP Stage 2

The TRIPP Stage 2 corresponds to understanding the aetiology of why injuries occur. Prevention cannot be instigated until this information is available because the specific focus and targeting of prevention programs is unclear. Meeuwisse¹³ proposed a multifactorial model for assessing causality as long ago as 1994. Unfortunately, this sort of research is still not done universally and Bahr and Krosshaug⁴ have recently argued strongly for a greater focus in this area. Aetiological research requires multidisciplinary approaches to fully elucidate the mechanisms of injury and other factors associated with injury causes and severity. For example, biomechanical approaches can help to understand what is actually going on in the body; clinical research can identify what rehabilitation strategies could be effective and why; behavioural studies can identify what motivates people to adopt certain risk or safety behaviours; epidemiological studies quantify the distribution and determinants of injury risk. In the epidemiological context, case-control studies of injured/uninjured sports participants have become relatively common but have limited power in reliably identifying risk factors because of their retrospective nature and issues relating to the appropriate selection of both cases and controls. Cohort studies, where groups of uninjured participants are followed up over time until they get injured, are more powerful for identifying risk and protective factors but conducting them can be much more challenging and so very few of them have been reported. Importantly, epidemiological studies, per se, cannot elucidate the direct mechanisms of injury but can yield important indications of what risk factors could potentially be modi-

fied to reduce injury risk. Other sports medicine approaches, particularly those with a biomechanical focus, are needed to fully understand these mechanisms.^{14,15}

TRIPP Stage 3

The TRIPP Stage 3 involves the identification of potential solutions to the injury problem and development of appropriate preventive measures. This needs to be strongly guided by TRIPP Stage 2 where potential risk and protective factors have been identified. Similarly, multidisciplinary approaches are needed particularly from the disciplines of biomechanics, sports science, behavioural psychology, health promotion, sports medicine, etc.^{4,15} This stage is not an epidemiological phase, but findings from epidemiological studies are crucial for informing it. Too often, preventive measures are suggested on the basis of anecdotal experiences or current practice with little thought given to why these measures may or may not work. Understanding of the mechanisms of injury from TRIPP Stage 2 and countermeasure development needs to be well grounded in the theoretical underpinnings and knowledge of the baseline disciplines. This stage might therefore include laboratory-based studies on models of the human system (e.g., cadaver, animal or human tissue) or simulations of the likely protective effects of these measures on this system (e.g., dummy, computerised models, crash test simulations).

TRIPP Stage 4

The TRIPP Stage 4 corresponds to intervention efficacy assessment and is essentially an "ideal conditions" evaluation of the preventive measures that arise from TRIPP Stage 3. Some settings for these evaluations include laboratory testing on a small number of participants, small group assessments, focus groups, or clinical settings. What is not so well appreciated is that controlled field-based studies, including randomised controlled trials of interventions, are also performed under a largely "ideal conditions" setting. This is because such studies are conducted within an artificial environment where the investigators deliver the intervention in a very controlled and targeted manner; sports administrators; coaches; players; etc. are convinced to participate in the study by researchers pre-armed with scientific knowledge; the participating teams and players are provided with staff and other resources, such as specific training equipment; players/teams are provided with reminders and incentives for their ongoing participation and

adoption of safety behaviours; injury and exposure data are collected by project staff or by people paid and trained by the research team; responsibility for reporting of results is with the researchers. Unfortunately, it is generally the case that none of these influences or resources are available to the players or clubs once these studies have finished and very few sporting clubs have the necessary financial or manpower infrastructure to maintain the same level of activity.

There is no doubt that research endeavours corresponding to TRIPP Stage 4 directly contribute to the increasing evidence base about the efficacy of interventions and to scientific publications. However, it is unlikely that they will lead to real-world sports injury prevention, *per se*. Having said this, there is still scope to significantly contribute to relevant knowledge in this area if the following are monitored routinely: player recruitment and assessment of any non-recruitment bias; level of uptake of, or compliance with, implemented interventions; reasons for use/non-use of the interventions being tested; drop-out rates across study arms to rule out any systematic bias due to the intervention; adverse effects of the interventions including both injury and behavioural outcomes. This information is needed by the broader sports injury research community to inform the ongoing design of sports injury prevention evaluations, including controlled trials. Unfortunately, studies with negative findings can be hard to publish in the peer-review literature and so this information does not always appear in scientific or medical journals. Editors of journals that publish sports injury research need to be encouraged to publish such studies, particularly when these implementation issues are discussed and their impact on study results presented.

TRIPP Stage 5

The TRIPP Stage 5 is necessary to understand how the outcomes of the efficacy research can be translated into actions that can be actually implemented in the real-world context of on-field sports behaviours and sports delivery and can be best understood as the stage of developing and understanding the implementation context. One of the most important questions that need to be answered in this stage is: What are current safety behaviours and do they need to change? It may be that some players are currently adopting the sorts of safety behaviours that the aetiological and ideal conditions evaluations suggest but yet the interventions are not effective for other reasons. On the other hand, if safety measures are not adopted we need to know why. The question then becomes: What are

the motivators/barriers to uptake? Valuable lessons will be learnt by a better understanding of the knowledge and attitudes of players, coaches and sports bodies in relation to the frequency, causes and prevention of injuries as they occur in their sport. This will be linked to an understanding of the risk perceptions of all those involved in sport and how likely they perceive their risk of injury to be.

From a broad implementation point of view, knowledge of the safety/injury culture of the sport is important to understand cues to action and how best to work with sports to improve safety. As any implementation must occur within the sport and/or a particular sporting body, a full appreciation of the sporting infrastructure available for safety, in terms of manpower, finances and equipment and other resources is needed.

Before designing wide-scale implementation of prevention measures it is also necessary to know how likely it is that the developed interventions will be adopted. Related questions are "by whom?" and "under what circumstances?". It has been suggested that some players may change their behaviours if certain safety measures, e.g., protective headgear, are adopted.¹⁶ Whilst there is very little direct scientific evidence to support such claims, any implementation plan needs to take this into account. Taken together, this information about the likely uptake and impact of protective measures on behaviours needs to be synthesised and considered together to determine how the intervention could best be targeted and "marketed" to sport bodies and their participants.

TRIPP Stage 6

The TRIPP Stage 6 is the final stage in the loop and involves both implementing the intervention in a real-world context and evaluating its effectiveness. In other words, determining how effective the scientifically proven interventions are when applied to the real-world context of player behaviours and sporting culture. This stage involves taking the intervention shown to be effective in TRIPP Stage 4 and implementing it taking into account the sports safety contextual cues identified in TRIPP Stage 5. The result will be a measure of the effect of injury prevention in the real world. Good examples of this sort of evaluation are those of the Protective Eye-wear Promotion for squash players¹⁷ and the Tackling Rugby Injury Program in New Zealand.^{18,19}

The feedback loop for the evaluation is shown in Fig. 2 and must involve concurrent application of both TRIPP Stage 1 and TRIPP Stage 5 and consid-

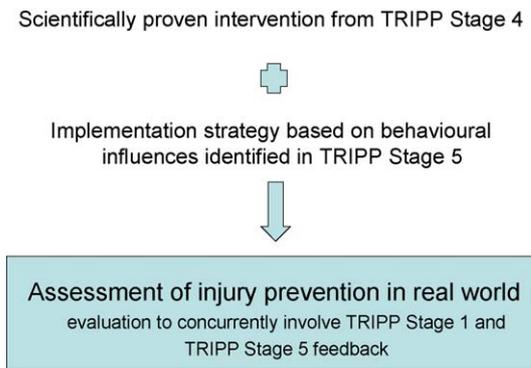


Fig. 2 Evaluating the real-world impact of sports injury prevention measures.

eration of the complex relationships between the two.

Experiences informing the development of the TRIPP framework

The TRIPP framework has both been developed from an accumulation of my research team's direct experience in the design, conduct and analysis of controlled evaluations of the value of protective headgear and mouthguards in Australian football^{20–23} and protective eyewear in squash^{7,17,24,25} players. Conclusions for future sports injury prevention research, drawn from the experiences of this work, are the following.

1. Sporting bodies and clubs are supportive of intervention research, and will promote the adoption of safety behaviours, when safety is a major motivator for their core business (i.e., either to perform better or to increase participation numbers).²³ There is no doubt that the nature of a particular intervention, irrespective of how well it is designed or the rationale for its scientific basis, is a deterrent to its use if it is not already part of sporting culture or closely aligned to it. For example, in an RCT of protective headgear in Australian footballers, very few players adopted the required safety behaviour and wore the headgear.²¹ On the other hand, extensive surveying of squash players was undertaken to understand what would motivate them to try protective eyewear before an intervention aimed at increasing this safety behaviour was implemented.⁷
2. Players and sporting clubs will participate in intervention research if they are fully informed about the study and the intervention being trialled.^{22,23} Players will adopt the safety

behaviours if they are easy to adopt; they are part of the culture of the sport or can be promoted in such a way as to not contradict the accepted culture; they are used by their peers and significant role models; they are widely and professionally promoted in a well-targeted manner that is directly relevant to the particular sport; and if they are informed of the benefits of using them; if they assist with for performance excellence.^{17,21}

3. Whilst randomised controlled trials are theoretically ideal, they are hard to conduct—particularly taking into account the broad safety culture of a sport and the safety behaviours of its participants.^{20,21} Ecological study designs are promising for assessing the value of interventions^{17,26} and are becoming more common in the sports injury research context. However, they do require the use of appropriate statistical methodology that takes into account potential clustering effects and other dependencies in the data.²⁷

Summary

In summary, implementation research is necessary to ensure that prevention methods are adopted. Importantly, the sports injury research field must move away from conducting isolated cross-sectional and descriptive studies to determine injury profiles. There is no doubt that intervention research in the field can be difficult and many challenges need to be overcome; however, that should not be put up as a barrier towards undertaking it. Over the next few years, sports injury researchers will need to think carefully about the “best” study designs and analysis tools to achieve this. All sports injury prevention effectiveness studies, of whatever design, should include information on key implementation factors such as player/club recruitment rates and other biases as well as the rate of uptake of the interventions being tested, including reasons for use/non-use. This will require the sports injury research field to develop guidelines for the recording and reporting of implementation factors. However, it will only be broad research endeavours that adopt the TRIPP six-staged approach that will lead to real-world injury prevention gains.

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