Chapter 35
Implementing and Evaluating Interventions

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Why Intervention Research?

Advances in real-world injury prevention will be achieved only if research efforts are directed toward fully understanding the implementation context, while continuing to build the evidence base for the efficacy and effectiveness of interventions (Finch 2006). Throughout earlier chapters of this book, guidance has been given on the design, conduct, and analysis of research studies leading to understanding both injury causation and reduction. This chapter is concerned with theoretical underpinnings of research needed to address intervention implementation and effectiveness research. This is particularly important for injury prevention because understanding the barriers and facilitators to the widespread adoption and sustainability of interventions is vital to ensuring effective and sustainable injury prevention.

Overall, while there is a relatively large literature relating to the rationale, design, and development of injury interventions and their evaluation in efficacy studies, there have been few published effectiveness studies describing aspects of injury prevention implementation. This is a major gap because the studies that do describe the presence (or absence) of injury prevention benefits associated with interventions are unable to explain the reason for the benefits or lack thereof. Too often, we are left with only knowledge that something did or did not work in one study, and there is no guidance on how to translate those findings to another setting or a similar injury problem. For example, recent studies describing the benefits of an exercise training program to prevent injuries in community soccer have shown only limited success, because few of the targeted participants adopted the program and there was a perception that it was not relevant to the real-world community sport setting in which it was implemented (Kilding et al. 2008; Soligard et al. 2008; Steffen et al. 2008). Similarly, there are challenges when translating "ideal" falls-prevention interventions involving risk factor assessment and home-based interventions, because implemented versions of the same program need to be modified to suit community settings and hence may no longer be effective (Hendriks et al. 2008). There can also be suboptimal uptake of Tai Chi falls prevention interventions and low levels of ongoing adoption that can compromise study effectiveness (Logghe et al. 2011). Without additional information about some of the important implementation factors (e.g., program uptake, pragmatic

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changes to interventions for delivery purposes, etc), reasons for the lack of success could not have been identified in these studies.

There are many reasons why implemented programs and their evaluations can fail and these can be summarized as (Bierrman 2006; Stame 2010):

- Program theory failure in which the developed intervention either (a) is too complex for the setting in which it is implemented or (b) does not lead to the desired behavior change because of the way it was designed.
- Implementation failure in which the intervention does not adequately address (a) the implementers' own behaviors in relation to intervention delivery or (b) the context in which it is to be delivered.
- Methodology failure in which (a) internal and/or external validity are compromised; (b) the evaluation plan and tools are not up to the task required of them to demonstrate the outcomes of the intervention; or (c) no concurrent process evaluation has been undertaken to explain unexpected observations or to confirm expectations.

When injury studies have considered implementation issues, this has typically been as a minor component of an effectiveness study, with most studies evaluating only some aspects of intervention implementation. There is no doubt that there are many complexities involved in conducting implementation research in real world settings. Many studies only report injury outcomes without also examining the required intermediary behavior change, such as exercise adoption or protective equipment use, which is necessary to link those reductions firmly to the implemented preventive measures. In contrast, others have only reported these proxy or intermediary outcomes and assumed that they will lead to the desired injury outcome (Rivara 2008). The vast majority of studies do not even consider whether the intervention target groups actually adopted, or complied with, the intervention. Nor do they recognize that individual safety behavior change is also significantly influenced by other factors such as the form of the intervention delivery, the person delivering it, and the broader ecological system in which the intervention has taken place.

There is no doubt that there is a complex relationship between desired injury reduction benefits and how interventions are packaged, delivered, and promoted (Nilsen 2004; MacKay and Vincenten 2009). It has been argued that the conduct of well-designed large-scale intervention effectiveness trials has been hampered because of a lack of theoretical considerations in their design, implementation, and evaluation (Thompson and Sacks 2001; Glasgow et al. 2003; Glasgow et al. 2004; Timpka et al. 2006; Armstrong et al. 2008; Catford 2009; Ward et al. 2009). Prevention research efforts will only develop further if they begin to incorporate such considerations, as has also been demonstrated to be the case for injury prevention research (Trifiletti et al. 2005; McGlashan and Finch 2010). Moreover, as also discussed elsewhere in this book, many different implementation and intervention delivery approaches could be considered to support prevention efforts, either in isolation or jointly. These range from educational/behavior change strategies (Christoffel and Gallagher 2006; Robertson 2007; Provvidenza and Johnston 2009) to environmental modifications (Christoffel and Gallagher 2006; Robertson 2007), to making policy/law changes (Scott 2004; Christoffel and Gallagher 2006; Robertson 2007), to public awareness/advocacy (Henley 2004; Christoffel and Gallagher 2006), and stakeholder engagement (Brussoni et al. 2006; Christoffel and Gallagher 2006; MacKay and Vincenten 2009).

To further injury prevention, it will be necessary for implementation studies to have a firm theoretical basis. Because of the general lack of international implementation research in any aspect of injury prevention, there is very little direct information about how best to conduct intervention studies in relevant community settings. While some theoretical considerations have been developed specifically for some safety programs (e.g., safe communities (Nilsen 2006)), and specific settings (e.g., sports injury prevention delivery contexts (Finch and Donaldson 2010)), most of the available

Table 35.1 Reported use of explicit behavioral and social science theory applications in injury prevention research

How the behavioral or social science theory was used	Review of 37 papers describing theory use in unintentional injury studies published during 1998–2001 (Trifiletti et al. 2005)	Review of 11 papers describing theory use in sports injury prevention studies published prior to June 2009 (McGlashan and Finch 2010)[a]
To guide program design and/or implementation and/or evaluation measures[c]	43[b]	8
To develop or evaluate a measured theory or model constructs	7	7
To test application of a theory	5	4
Other (including not stated)	6	3

[a]Only one of the sports injury studies applied two theories; all others only reported use of a single theory
[b]This number exceeds the total number of papers reviewed because several papers used more than one theory and so this refers to the number of theory applications
[c]This is a large category that combines several types of studies but was used in both review papers to categorize the studies. Most of the reviewed studies in those two papers did not evaluate the effectiveness of injury prevention interventions

examples come from broader health promotion or behavioral science applications. Table 35.1 summarizes how behavioral and social science theory has been used to date in the small number of injury prevention studies that report it, highlighting this as a major knowledge gap. Overall, very few studies have reported theory use and, when they have, this has been most commonly in terms of program/implementation/evaluation design (Trifiletti et al. 2005; McGlashan and Finch 2010).

Theoretical considerations have important implications for how intervention studies are conducted and reported. Improved reporting standards for implementation studies are needed to provide a more comprehensive analysis of the factors affecting intervention uptake and effectiveness (Finch 2006; Roen et al. 2006). Application of health promotion frameworks to evaluate the public health impact of interventions could also potentially help to better understand contextual and policy influences in this setting.

Despite the availability of injury prevention interventions with proven or likely efficacy, it is clear that limited research attention has focused on understanding the intervention implementation context and processes, including barriers and facilitators to sustainable programs. To address this challenge, injury prevention research aimed at demonstrating real world uptake of interventions needs to:

- Draw on available evidence for the efficacy of interventions in terms of reductions in both injury and injury risk, as well as intermediate behavioral measures (sometimes referred to as impact measures).
- Engage relevant stakeholders and end user groups in implementation and injury prevention research from the outset.
- Continue to partner with these stakeholder groups in further intervention and intervention delivery developments.
- Develop multifaceted and multi-action strategic approaches toward injury prevention in relevant real-world culturally relevant settings.
- Develop and evaluate strategic implementation plans designed to address key barriers and facilitators toward intervention uptake at all levels.
- Adopt a multidisciplinary approach that embraces both qualitative and quantitative research methodologies.
- Include measures of cost-effectiveness for sustained program implementation.

Effectiveness Versus Efficacy

Research studies for demonstrating the preventive potential of injury interventions can be broadly categorized into two types: efficacy and effectiveness (Table 35.2). The differences between the design and conduct of efficacy and effectiveness studies have been discussed by a number of authors (Glasgow et al. 2003; Finch 2006; Mallonee et al. 2006; Prochaska et al. 2007; Glasgow 2008; van

Table 35.2 A comparison of the key features in the design and conduct of efficacy and effectiveness studies

Component	Efficacy studies	Effectiveness studies	Considerations for the design and evaluation of interventions in implementation studies
Study design	• Highly controlled • Examples are RCTs and controlled laboratory studies	• Level of control is much less • Allow assessment of relevant implementation factors • Examples include quasi-experimental, pre-post, interrupted-time series	• Include randomization of units to intervention implementation groups • Control groups add strength and reduce the chance of ecological fallacy
Intervention delivery	• Under full research team control • Well-defined protocols must be adhered to • Deliverers employed by the researchers	• Interventions and/or accompanying resources are delivered or implemented by others not directly employed by the research team	• Motivation and commitment of deliverers, as well as their usual practices, are important • Potential barriers/enablers of the intended delivery to be assessed before finalization of the intervention design and its full implementation
Study participants, intervention allocation, and targeting	• Under the strict control of researchers • Analysis according to intention-to-treat principles • Participants are a relatively homogenous group that meet specific criteria	• Allocation plan is determined by the researchers but undertaken by others • Intervention is delivered to a defined group or population (i.e., a heterogeneous group)	• Different levels of intervention uptake need to be monitored • Reasons for why there is/is not uptake should be assessed
Sample size and length of study	• Adequate numbers of study participants needed to ensure power • Follow-up over large amounts of time	• Of shorter duration • Involves many more study participants	• Shorter-duration studies can show immediate behavior/knowledge change effects • Longer studies needed to show sustainability and maintenance of these changes
Intervention protocol and setting constraints	• Rigidly structured • Must be adhered to • Interventions cannot be modified but are developed specifically with the specific target population in mind • No assessment of generalizability across settings	• Protocol and interventions must be flexible enough to allow adaptations for the specific context and setting/s if necessary during implementation • Can assess the extent to which the intervention can be successfully used in different settings	• Engaging stakeholders in the development of the delivery plan • Pilot testing of the intervention and delivery plan are needed • Community feedback should be sought

(continued)

Table 35.2 (continued)

Component	Efficacy studies	Effectiveness studies	Considerations for the design and evaluation of interventions in implementation studies
Staffing, local infrastructure, and funding issues	• Very labor intensive • Require full funding for both intervention delivery and evaluation data • Involve a limited number of staff with specific training in the study protocol	• Intervention delivery is usually the responsibility of the real-world agencies/individuals • Only limited support for implementation from research funds • Involve people with different training experiences • Evaluation often conducted and funded by researchers	• Stakeholder engagement and buy-in needed from the outset • Intervention programs more likely successful if these groups are also involved as equal partners during all stages of an implementation trial and evaluation

Adapted from (Finch 2009)

Tiggelen et al. 2008; Finch 2009). Table 35.2 summarizes the key features of these study types and highlights some of the particular challenges that arise in the conduct of implementation studies.

In efficacy studies, the preventive effect of interventions is assessed under ideal and tightly controlled conditions and individual injury reduction outcomes are desired to be demonstrated. The highest form of this research evidence is from randomized controlled trials (RCTs), though other experimental designs can also contribute knowledge. The high level of control is necessary to ensure large effect sizes, corresponding to the preventive capacity of the intervention under study. The vast majority of injury prevention intervention trials are efficacy studies.

Effectiveness research is undertaken when the preventive effect of the intervention is assessed under everyday circumstances. This implies little or no control over how the intervention is implemented, though in practice this may be hard to ensure. The goal of effectiveness studies is to determine the extent to which the intervention actually prevents injuries when delivered as it would be used in real world practice. Broader implementation research studies measure and report factors such as how the intervention was delivered as well as how it was complied with and used. This focus is necessary because if efficacious interventions are not widely adopted, complied with and sustained as ongoing practice, then it is very unlikely they will have any significant or long-lasting injury prevention impact (Finch 2006).

Intervention Research Requires Appreciation and Understanding of Ecological Systems

The above discussion has highlighted that for full impact, any intervention aimed at individual-focused injury reductions must consider the broader context in which implementation of the intervention needs to occur. Individuals, while the target of prevention programs, are heavily influenced by the groups they belong to and the broader social and cultural norms related to the injury risk behavior being targeted. Recognition of this is conceptualized in ecological models of injury prevention (Eime et al. 2004; Sleet and Gielen 2004; Allegrante et al. 2006; Allegrante et al. 2010). Importantly, the more individual-based approaches cannot alter environmental (physical, social, or cultural) factors that influence the initiation and maintenance of safety behavior. Ecological models, on the other hand, identify intrapersonal factors, sociocultural factors, policies, physical environments, etc., as levels of influence on injury prevention behaviors. As such, they recognize

that many factors combine to influence an individual's protective or risk-reduction behavior (and any decisions to not adopt the behavior).

The injury iceberg model proposed by Hanson et al. (2005) is a conceptual explanation of this ecological model for the application to community safety interventions. It emphasizes that latent failures can occur when implementing community safety programs if interpersonal, organizational, community, and societal levels of influence of community safety are not considered from the outset. Too often injury intervention studies ignore most, if not all, of these influences and only focus on intrapersonal factors (Allegrante et al. 2006; Allegrante et al. 2010).

The only sports injury prevention study to apply the ecological model to date (McGlashan and Finch 2010) developed and evaluated a comprehensive protective eyewear promotion program for squash players (Eime et al. 2004). Through surveys of squash players and venue managers, it was determined that protective eyewear was not readily available, and that players' behaviors, knowledge, and attitudes did not favor its use. A protective eyewear promotion program was developed with components to inform and educate players and squash venue operators of the risk of eye injury and of appropriate protective eyewear. Other components of the program addressed the availability of the eyewear and incentives for players to use it. A reported structural strength of the ecological intervention was the strong collaborative links across multidisciplinary researchers, the squash sport governing body, eyewear manufacturers, squash venue personnel and players, from the outset. This also allowed some attempts toward longer-term dissemination and sustainability of more widespread eye injury prevention measures in the sport. The evaluation outcomes of the program, published separately, demonstrated significant effects on knowledge about appropriate eyewear use (Eime et al. 2005).

There is an apparent disconnect in the literature between what is called an "ecological design" and studies informed by the ecological model, as described here. It is important to realize that they are not necessarily the same thing. In the former, standard epidemiological study designs (including RCTs) are used but the unit of analysis is a group, rather than the individual (Hingson et al. 2001; Connor 2004; Rivara 2008). However, this does not mean that studies adopting this design necessarily consider the full range of ecological determinants of the outcome of interest. By definition, however, many studies using the ecological model of behavior change do need to adopt some aspects of ecological study designs because they are necessarily concerned with group or population-level outcomes, not just individual behavior change.

Rivara (2008) discussed a range of outcomes that were appropriate to injury research ranging from serious injury (such as death and hospitalization) to moderate/mild injury to injury-free events to behaviors and knowledge/attitudes. While he discussed the use of ecological study designs, he only considered these outcomes at the individual level. A review of the effectiveness of community-based injury prevention programs (Nilsen 2005) also found that most studies only reported injury rate reductions and were not concerned at all with contextual factors that could explain the study findings or provide additional information about the interventions being tested.

Figure 35.1 provides an extension of Rivara's (2008) pyramid of outcomes, which stresses the need for outcomes across other levels of the ecological context for injury prevention and also recognizes the overlapping influence that different levels can operate on each other. Thus, ecologically driven intervention implementation studies need to specifically focus on understanding drivers of behavior and related behavior change across multiple levels. Many behavioral models (Ajzen 1985; Ajzen 1991; Eime et al. 2005; Gielen et al. 2006a) emphasize that intention to undertake a behavior is an important outcome stage in its own right and so this has also been added as an outcome level to Rivara's original list. Importantly, intervention implementation studies do not ignore the injury outcomes or recording of injury-free events because they are effectiveness studies, but they do give more weight to the behaviorally orientated factors.

The remainder of this chapter presents three specific theoretical frameworks and approaches that show good promise for injury prevention intervention research. These include the use of Intervention

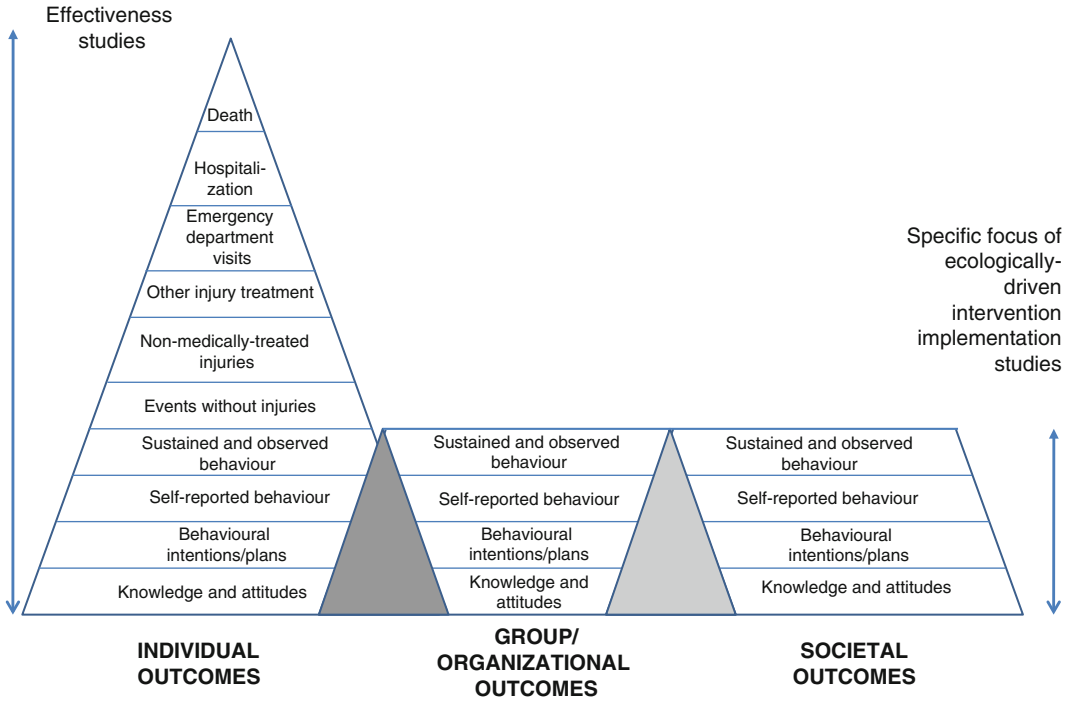

Fig. 35.1 The pyramid of outcomes used for ecologically driven intervention implementation studies. The shaded areas represent areas of mutually overlapping influences. Societal outcomes can also be directly related to individual outcomes. (Adapted from Rivara 2008)

Mapping is a tool to assist in the intervention development process itself, Diffusion of Innovations theory to guide efforts in the planning of intervention strategies, and the RE-AIM framework (reach, effectiveness, adoption, implementation, maintenance) most commonly (but not exclusively) used as an evaluation and evaluation planning tool. The injury literature that has applied these theoretical approaches to date is also summarized, particularly as it pertains to unintentional injury prevention.

It is acknowledged that these are not the only frameworks, models, or approaches that can be used for injury intervention research. While some studies may have a theoretical underpinning to their research, this is not always stated. Some authors describe other systematic approaches that could be used (e.g., Nold and Bochmann 2010; Winston and Jacobsen 2010), and these broadly mirror the systematic approaches advocated in the following sections.

Intervention Mapping

While there has been an increasing number of published papers describing so-called injury intervention implementation studies and evaluating the impact of interventions on both injury and process outcomes, there is surprisingly little information about how interventions were developed in the first place or how they were actually delivered. Most studies will mention that they have taken an evidence-based approach toward defining their intervention and that they have then implemented it according to scientific principles. However, specific information describing exactly how the intervention was packaged for its delivery, or how it was refined for the particular setting of its targeting, are details that are often not reported in the literature. Yet it is exactly this information that

has the greatest potential to further and improve implementation studies because it gives valuable additional cues as to why certain things do/do not work and what may need to be done to ensure program sustainability or translation to other groups or settings. Moreover, interventions that are effective in one setting may not necessarily be effective in others; some modification will be needed for each new contextual setting. Information about how the intervention was developed and delivered in the first place can inform this.

Developing interventions for implementation that will be fully effective is a complex process that involves many components, not just previous efficacy evidence that they should work. Interventions that are developed from a theoretical basis are likely to be more successful than others. However, it is also important that consideration be given to the practical strategies that will need to be adopted, or refined from the theoretical foundation, when considering any implementation study. This is the premise behind the Intervention Mapping approach toward the planning of interventions (Bartholomew et al. 2006). This approach considers intervention delivery to be necessary within an ecological framework in which behavioral and social science considerations are paramount. Intervention Mapping draws on previous behavioral change models as applied to complex societal systems such as the PRECEDE-PROCEED model (Green and Kreuter 1991) and Diffusion of Innovations theory (Rogers 2003). However, its authors also recognize that no single behavioral change theory is fully applicable to all contexts and interventions. Therefore, the approach allows intervention developers and implementers to draw on the best theoretical basis for their setting (Bartholomew et al. 2006).

The Intervention Mapping approach provides guidance for decision making across all stages of the intervention process from intervention planning and implementation processes to the final evaluation (Bartholomew et al. 2006). The Intervention Mapping protocol provides a systematic summary of the necessary steps and tasks that need to be undertaken to ensure the combining of empirical evidence, relevant theoretical constructs, contextual knowledge, and context-specific experience to inform the development, implementation and evaluation of health promotion/injury prevention interventions. Document matrices are advocated as a means of recording decisions about how to influence the desired behavior change within the specific social and physical environments embedded within ecological systems necessary to prevent injuries. While such a systematic approach has the potential to both help plan and implement effective interventions, it also has the added benefit of assisting with understanding why any intervention does or does not work.

Intervention Mapping achieves this through six steps:

1. Conducting a needs assessment or problem analysis.
2. Creating matrices of change objectives based on the determinants of behavior and environmental conditions.
3. Selecting relevant theory-based intervention methods and practical strategies.
4. Translating methods and strategies into an organized program.
5. Planning for adoption, implementation, and sustainability of the program.
6. Generating an evaluation plan.

Figure 35.2 summarizes the specific tasks that should be undertaken in each step. Importantly, while represented in a linear form, these steps and tasks should be undertaken in an iterative manner with new information being fed back to reinform earlier steps. For detailed guidance on how to complete this Intervention Mapping process, with examples, the reader is referred to the book by Bartholomew and colleagues (Bartholomew et al. 2006).

Completion of each of the six Intervention Mapping steps requires working through the following core processes in an interactive way that incorporates feedback loops and revision of prior decisions, as appropriate (Bartholomew et al. 2006):

- Pose a relevant question.
- Brainstorm a provisional list of answers or range of possible solutions.

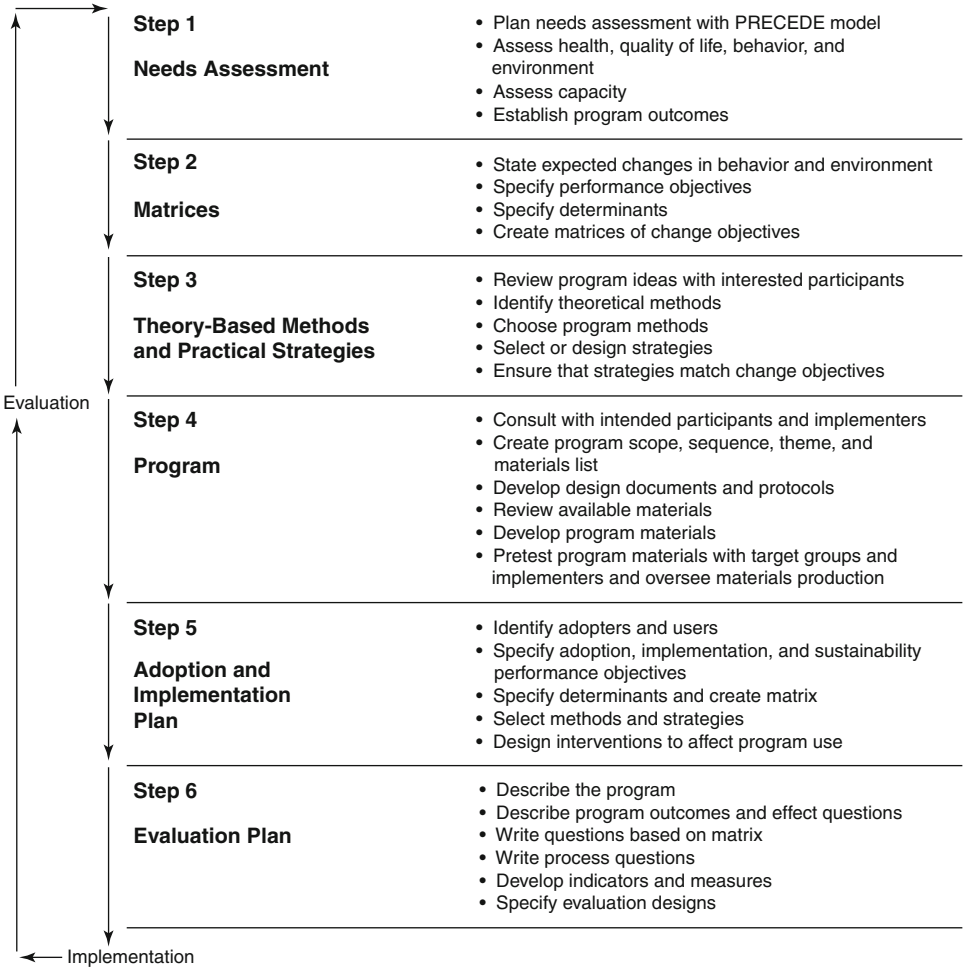

Fig. 35.2 The intervention mapping process reproduced from Bartholomew et al. (2006) Planning health promotion programs. An intervention mapping approach. Jossey-Bass, San Francisco. Reprinted with permission of John Wiley and Sons, Inc

- Review the available literature related to the topic – both peer and non-peer reviewed.
- Access and identify an appropriate theoretical approach and use this to further develop or justify the solutions.
- Conduct new research and acquire new data through the lens of the identified theoretical approach.
- Formulate the final answers/responses to the initial question posed, or its revised form.

In the injury context, Intervention Mapping has been reported in three contexts: a parent education intervention to prevent violence in school students in the USA (Murray et al. 1998); safety interventions in metalworking shops also in the USA (Brosseau et al. 2007); and a Dutch school-based physical activity injury prevention program (Collard et al. 2009a). Each of these studies used an iterative Intervention Mapping approach in which underpinning theoretical considerations appropriate to the specific context were integrated with existing evidence from published literature and new data collected from the target population during the intervention development phase. Two of the studies

reported use of a five-step process, as advocated in the first edition of Intervention Mapping (Bartholomew et al. 1998), which did not include the needs assessment phase as one of the major stages. In the most recent edition (Bartholomew et al. 2006), the needs assessment is added as the first of six crucial steps.

As part of an initial needs assessment, staff at two public middle schools in Texas identified parental monitoring of their children as a potential modifiable behavior that could influence the level of violence among adolescents and so this was recommended as the target for a brief school-based intervention (Murray et al. 1998). Data to inform the Intervention Mapping process were obtained through self-reported surveys completed by students and both qualitative and quantitative information collected through parental telephone interviews and focus group sessions; this was considered at all stages of the intervention development process. Staff from the two schools were involved in both the data collection phase and the development of the intervention and its delivery plan which had theoretical underpinnings from social cognitive theory (Bandura 1986), the theory of planned behavior (Ajzen 1985; Ajzen 1991), and the transtheoretical model (Prochaska et al. 1997). The identified intervention strategy was educational newsletters for parents, which was later shown to be popular and to be associated with higher levels of parental monitoring (Murray et al. 1999).

The Intervention Mapping approach was also found to provide valuable new insights into strategies for the development and delivery of interventions to reduce the risk of injuries in people engaged in metalworking businesses (Brosseau et al. 2007). Separate intervention variations were considered for owners of businesses and employees within them. Both considered personal, social, and environmental determinants of machine-related hazards and amputations and drew on the social cognitive theory. Information fed into the interactive information mapping process came from consultations with an advisory board with members across all relevant sectors; a review of machine safety documents, regulations, and standards; direct discussions with employees; safety audits of machines in businesses; presentation of draft materials to the expert groups and pilot businesses; and piloting of the intervention. The authors considered that the use of Implementation Mapping allowed them to develop a robust uniform intervention that could still be adapted to be applicable at multiple sites.

Focus group sessions, supplemented with a small number of interviews, were initially conducted with physical education teachers from 12 Dutch secondary schools to develop an intervention that could improve knowledge in teachers, students, and their parents about injury prevention in physical activity (Collard et al. 2009a, b). Knowledge needs and educational formats were determined through application of the attitude, social influence, and self-efficacy (ASE) model (De Vries et al. 1995), which combines the Theory of Planned Behavior (Ajzen 1985; Ajzen 1991) and Social Cognitive Theory (Bandura 1986). Although it is not clear from the paper how the target group members contributed to all stages of the mapping, the developed intervention materials were piloted with teachers and children from six schools, with the assumption that their acceptance by these two groups also indicated that they would be acceptable to the parents. The intervention was subsequently implemented in a cluster randomized trial in 40 Dutch schools (Collard et al. 2010b). While it had an overall nonsignificant effect on injury rates, there was a significantly reduced rate of injuries in children who were classified as being low-active. The design of this study has since been suggested as the basis of a more general approach toward intervention development for sports injury prevention (Collard et al. 2009b). Interestingly, the finding that the intervention was effective only in part of the target population mirrors the findings from the controlled evaluation of "RiskWatch," another teacher-led UK school-based intervention covering different safety behaviors (Kendrick et al. 2007) and further justifies the need to conduct detailed process evaluations alongside each intervention.

Designing appropriate interventions and accompanying intervention strategies and evaluation plans is a complex and time-consuming process. While the Intervention Mapping approach does not

remove this, it does provide a systematic approach toward undertaking this important activity. When used fully and interactively, it ensures that the views, needs, and desired behavioral actions of each ecological level target group are considered at all stages of the planning and evaluating process.

Diffusion of Innovations

As mentioned in the last section, successful implementation and implementation studies require both a well-defined and targeted intervention and detailed information about the context in which it is to be implemented and how this will affect adoption of the intervention. Intervention Mapping provides a systematic approach for achieving both of these goals. Because full understanding of the implementation context is critical to successful interventions and their diffusion through the target groups, it is worth discussing this aspect further.

One of the most successful approaches toward understanding the uptake of interventions is the Diffusion of Innovations theory, first proposed by Rogers as early as 1962 (Rogers 2004). The importance of this theory is demonstrated by its subsequent underpinning of aspects of Intervention Mapping (Bartholomew et al. 2006) and the RE-AIM framework (Glasgow et al. 1999) to be discussed in the next section. Indeed, the theory is one of the most-cited social theories in public health application. However, despite its wide application in other areas of health promotion and public health and its clear relevance to injury prevention initiatives (Nelson and Moffit 1988; Aldoory and Bonzo 2005; Gielen et al. 2006a, b; Collard et al. 2010a, b), it appears to have had only limited application to the injury field to date (Trifiletti et al. 2005; McGlashan and Finch 2010).

The strength of the theory lies with its focus on communication of new ideas (or innovations) within multi-level ecological structures that require some form of behavioral, social, or other change across one or more levels for the innovation to be considered effective. Rogers (2003) provides the following definitions for the main components in the diffusion process:

- Innovation – an idea, practice, or object perceived as new by an individual or other unit of adoption; attributes of the innovation are paramount to its subsequent adoption.
- Communication channel – the means by which messages get from one individual to another. There are various ways this can be achieved, depending upon the specific purpose such as social marketing/mass media (Henley 2004; Christoffel and Gallagher 2006), advocacy (Pitt and Spinks 2004; Christoffel and Gallagher 2006), or through public/policy agencies (Foster et al. 2004; Christoffel and Gallagher 2006).
- Innovation-diffusion process – whereby an individual passes from first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision. This relies on key societal members who are opinion leaders or change agents.
- Innovativeness – the degree to which an individual (or other adopter unit) is relatively earlier in adopting new ideas than other members of their social system. The concept of adopter category is relevant here as different individuals will respond to the intervention in different ways.
- Rate of adoption – relative speed with which an innovation is adopted by members of a social system. Not all interventions will be adopted at the same rate of uptake.
- Social system – a structured set of interrelated units (e.g., people) that are engaged in joint problem solving to accomplish a common goal. This includes defining opinion leaders, change agents, and other influencers of opinion or adoption.
- Consequences – the changes that occur to an individual or social system because of the adoption or rejection of an innovation.

According to the theory, the attributes of any new interventions that would need to be considered are (Rogers 2003):

- Relative advantage – the degree to which the new intervention is conceived to be better than existing programs or practices.
- Compatibility – the degree to which the new intervention is consistent with the existing values, past experiences, and needs of people targeted by it (i.e., the potential adopters).
- Complexity – the extent to which a new intervention is perceived to be easy (or difficult) to understand and use.
- Trialability – the extent to which a new intervention may be tested by potential adopters.
- Observability – the extent to which the new intervention and its benefits are visible to others.

Interventions which are ranked more positively with regard to advantage, compatibility, trialability, and observability and which are also perceived to be easier to use and understand will be taken up more readily and more rapidly than other interventions.

As Rogers (2003) himself defines it, diffusion is "the process through which an innovation, defined as an idea perceived as new, spreads via certain communication channels over time among members of a social system." The Diffusion of Innovations model can be used to determine both the level and rate of intervention uptake, so that different interventions can be compared both within target groups and across them. Accordingly, members of a social system can be characterized as belonging to one of five ideal categories (Rogers 2003):

- Innovators – people who are very ready to adopt new innovations, even before the full value to society has been shown; they are very much ahead of most other people in terms of their willingness to try new ideas. Their behavior involves a certain amount of risk and they need to accept the consequences of adopting an innovation that may not be successful. Innovators have a very important role in terms of introducing new ideas to community groups and play "a gate-keeping role in the flow of new ideas into a system."
- Early adopters – highly influential opinion leaders in any system who are seen as the people to give general advice about the suitability and usefulness of new innovations. For this reason, they are often seen as the change agents for ensuring rapid diffusion of new ideas. Once enough early adopters take on the innovation or intervention, they can then trigger rapid diffusion – i.e., they form a critical mass.
- Early majority – while they do not adopt interventions as rapidly as the two previously mentioned groups, they do so more rapidly than the average person within a societal system does. They are, therefore, a very important group in ensuring high uptake rates and comprise about one-third of any societal group. While it takes them longer to decide to take up an intervention than those earlier groups, once they do so they become very strong supporters and hence help convince other members also to take on the behavior.
- Late majority – like the early majority, this group also comprises about one-third of the population. They tend to be more skeptical about the innovation than earlier groups but generally will later adopt it if their concerns about the new idea are removed or if there are significant peer-influences or economic reasons for doing so.
- Laggards – these people tend to be suspicious of new ideas and interventions and of change agents operating to introduce them. It takes considerable time and persuasion, most commonly from their own peers, before they will adopt new innovations.

The practical implication of this adopter categorization is that different strategies will be needed to target different members of the same community groups depending upon their readiness-to-adopt category, somewhat akin to the implications of the transtheoretical model (Prochaska et al. 1997) for individual behavior change interventions. Importantly, Diffusion of Innovations theory considers the communication process to be one whereby ideas within a societal system converge to a common

understanding (or misunderstanding), as a result of individual members creating new knowledge and experiences and sharing this with other members of that system.

Of course, to have long lasting public health effects, any intervention that is adopted needs to be sustained and the desired behavior change and structural systems to support this maintained. With regard to sustained adoption of any prevention program with ongoing desired injury prevention benefits, intervention studies should monitor the level to which the innovation is taken up by members of the target group, including their knowledge about it and how they use it; how the intervention is used in practice and ongoing implementation and continued use of the innovation (Gielen et al. 2006a, b).

Trifiletti et al. (2005) undertook a review of the extent to which the Diffusion of Innovations (and other behavioral and social science theories) had been used in research on unintentional injury prevention. For the period 1988–2001, they were able to identify 12 studies that had applied the Diffusion of Innovations to injury problems, but only two of these papers had applied it to unintentional injury, in this case both were bicycle helmet use studies (Farley et al. 1996; Farley et al. 1997). More recently, a similar review of theory use in sports injury research published prior to mid-2009 (McGlashan and Finch 2010) found only two studies to have since applied the theory to sports injury prevention: one study related to helmet use in recreational activities undertaken in ski areas (Andersen et al. 2004) the other to coach education in relation to sports concussion (Sawyer et al. 2010).

In the helmet study, skiers and snowboarders were both observed and interviewed in ski fields in northwestern USA and Canada (Andersen et al. 2004). Collected data were used to test three specific hypotheses arising from application of the Diffusion of Innovations theory that (1) prevalence of helmet use by skiers and snowboarders would have increased over time; (2) helmet use would be greater among certain groups (i.e., in the more educated guests, frequent skiers/snowboarders, experts and intermediates, and snowboarders); and (3) the rate of increase in helmet use would be higher in some groups (i.e., guests residing in the Rocky Mountain region and Canada, who were experts, skied or snowboarded the largest proportion of days, and snowboarders). The results confirmed the first two hypotheses but there was no statistical support for the third. The authors interpreted this result as providing no support for the critical mass concept within Diffusion of Innovations which essentially states that there is a specific point at which enough people in a population undertake the desired behavior to make further diffusion of the innovation self-maintaining (Rogers 2003). Two possible explanations for this were provided: either that 1-year follow-up is not long enough to test for "critical mass" effects or that the marketing of helmets in the preceding 2 years had reached all adopter groups equally, so there was no differential uptake across them.

In the concussion education study, the Centers for Disease Control developed a toolkit entitled "Heads Up: Concussion in high school sport" to be used by coaches to prevent and manage concussion in school athletes in the USA (Sawyer et al. 2010). To inform the development, dissemination plan and evaluation, 497 high school athletic coaches were surveyed about their demographics; receipt of the toolkit; actual or intended use to the toolkit and reasons for this; their views on the overall appeal, ease of use and usefulness of the content; expected benefits of the toolkit, especially in relation to other prevention methods and resources; and whether they would recommend it to others. The responses were found to support the premises of the Diffusion of Innovations theory and provided clear guidance for the ongoing targeting of the toolkit to coaches.

The most recent injury intervention study to apply the Diffusion of Innovations involved assessment of the adoption and implementation of an educational program for the prevention of intentional incidents (with high potential for injury) (Henderson et al. 2006). The intervention was aimed at professionals who provided mental health programs to children who had been identified as firesetters, and hence were at risk of lighting future fires. The paper also described the dissemination characteristics of the program as a guide to wider diffusion in the future. The study concluded that a better understanding of the Diffusion of Innovations theory components was necessary to close the

research-practice gap, particularly with regard to educating and engaging health professionals and service providers in community programs for injury prevention.

As noted by Meyer (2004), much of the initial work using Diffusion of Innovations theory was based on quantitative methodologies with consequent limitations. With the increasing recognition that both qualitative and mixed-methods approaches are needed to fully understanding injury prevention interventions and their implementation settings, application of the Diffusion of Innovations theory has much potential to contribute to injury prevention intervention studies in the future.

The RE-AIM Framework

The RE-AIM framework is a health promotion model with high applicability to injury prevention because it could underpin much implementation research (Finch 2009). The RE-AIM Framework was first proposed by Glasgow and colleagues (Glasgow et al. 1999) as a tool for evaluating the effectiveness of implemented programs with a large behavior change focus (Glasgow et al. 1999; Glasgow et al. 2003). It has since been used in a variety of program implementation contexts, most commonly focusing on individually targeted behavior change through exercise programs for people with arthritis (Gyurcsik and Brittain 2006), lifestyle interventions targeting cardiovascular disease risk factors (Besculides et al. 2008), other community-based behavioral interventions (Dzewaltowski et al. 2004), and knowledge translation systems in emergency departments (Bernstein et al. 2009). It has recently been advocated as a suitable model for the delivery and evaluation of sports injury prevention interventions (Finch 2009).

The RE-AIM Framework has a strong underpinning of health promotion theory and approaches (such as Diffusion of Innovations theory) and so is very relevant to the evaluation of injury prevention interventions, though the extent of its use is still in its infancy in this context. It draws from health promotion concepts, such as Diffusion of Innovations theory, that stress that desired health behaviors will only be achieved if the delivered interventions are available to the target group, adopted by them, and used as they were intended and that this use is sustained over time for ongoing prevention benefits. It, therefore, incorporates important aspects relating to individuals' responses and readiness in relation to targeted interventions, as well as the more public health-oriented benefits. In both its development and application, it has been shown to be highly robust and translatable across implementation settings (Glasgow et al. 1999; Glasgow et al. 2006; Jilcott et al. 2007). For any implementation study, understanding and representing the context in which the intervention is to be implemented and evaluated is a key component in its success. As will be shown in the injury examples below, the actual measures chosen within each of the framework dimensions can be set according to the specific contextual implementation feature of interest.

The RE-AIM framework has five key dimensions for assessing interventions that are useful for guiding thinking about the full complexities of the implementation context (Glasgow et al. 1999; Glasgow et al. 2003; Glasgow et al. 2006):

- Reach – the proportion (number) of the target population who are approached to take up the intervention and the representativeness of that group; this domain is relevant at the level of individuals.
- Effectiveness – the success rate if implemented as intended, as well as documentation of both positive and negative outcomes of the intervention. In some studies, this component has collected intervention efficacy, which may be more appropriate if this aspect of an intervention has not yet been developed. Outcomes here have most commonly been focused on individuals.
- Adoption – the proportion or number and representativeness of people, settings, practices, and plans that adopt the intervention. This dimension includes setting level factors.

- Implementation – the extent to which the intervention is implemented as intended in the real world. This dimension considered important factors associated with the delivery of the intervention within the setting of its application. The dimension is a setting-level assessment.
- Maintenance – the extent to which the intervention is sustained over time. This aspect is often categorized according to both individual-level and setting-level maintenance.

An underutilized strength of the RE-AIM framework is the capacity for all dimensions to be applied across all levels of the ecological framework for injury prevention and not just the levels initially proposed by the authors (Glasgow et al. 1999; Glasgow et al. 2003; Glasgow et al. 2006). This has recently been expanded upon in detail specifically for the sports injury prevention context (Finch and Donaldson 2010).

To date, seven published injury prevention studies have reported use of the RE-AIM Framework, all within the past 2 years. Two studies were within the context of falls prevention in older people (Li et al. 2008; Day et al. 2010), and five within sports injury prevention applications (Collard et al. 2010a; Finch and Donaldson 2010; Saunders et al. 2010; Finch et al. 2011a, b). In these injury studies, the RE-AIM framework has been used in several ways and these provide models for its application to other injury problems:

- As a model for undertaking and evaluating contextual influences on injury prevention in ecological systems (Finch and Donaldson 2010). This paper explains how RE-AIM could be used to understand the implementation impact of sports safety interventions that need to be implemented across several settings to be fully effective. In particular, it stresses that care needs to be taken when directly applying the RE-AIM framework to safety interventions implemented in the community sport setting because the definition for each dimension will depend on the specific level targeted. While many interventions will be targeted at only the individual sports participant, implementation of most sports injury interventions is multifaceted and complex and often needs to be targeted at multiple levels, as it will involve actions on the part of others such as coaches, sports administrators, peak sports bodies, etc. For this reason, a Sports Setting Matrix adaptation of RE-AIM was developed that outlined evaluation dimensions against each level of the sports safety delivery system.
- As study protocols (Day et al. 2010; Finch et al. 2011a), these two papers explain how the RE-AIM Framework has been used to design program delivery and evaluation plans from the outset. The context for the Day et al. (2010) protocol is the design of an evaluation plan to assess a large-scale system-wide prevention program for falls in older people. The second protocol is for the design and evaluation of a national program (including both intervention and delivery plan development and testing) to prevent football-related lower limb injuries (Finch et al. 2011). This study adopts the sports setting matrix adaptation of RE-AIM (Finch and Donaldson 2010).
- To inform the development of an intervention delivery plan for a larger-scale effectiveness RCT (Finch et al. 2011b). This study used both the RE-AIM framework and health belief model (Janz and Becker 1984) to identify the likely barriers and facilitators that would be experienced by football players if they were targeted by an exercise program to prevent lower limb injuries in their sport.
- As part of a process evaluation – the most common application. In an American county, a Tai Chi group exercise program to prevent falls in community dwelling older people was delivered through community health services (Li et al. 2008). The study had a major focus on the reach, adoption, and implementation RE-AIM dimensions which were all monitored at the end of the 12-week implementation period in the exercise participants. Effectiveness dimensions were analyzed in older people who participated in the Tai Chi program through identified changes determined through a pre-post test design. Adoption and maintenance dimensions were assessed at both the level of the exercise participant and the community health center. At 12 weeks, the study was too short to assess maintenance effects but some indicators of likely

drivers of that longer term uptake were also assessed. A study in Dutch school children reported the translatability and flexibility elements from a RE-AIM evaluation of a school-based program aimed at preventing physical activity-related injuries (Collard et al. 2010a). While there were some positive intervention effects, these were small and the RE-AIM evaluation was able to demonstrate that this most likely related to the intervention not being fully implemented as planned. The third study applied RE-AIM in interpreting coaches' feedback on the implementation of a safe landings program through targeted coach education sessions followed by coach delivery of the principles to their teams of junior netball players (Saunders et al. 2010). Evaluation against the RE-AIM dimensions enabled the authors to identify aspects of the intervention that could be improved to maximize future uptake and sustainability of the trialed intervention.

As shown from the above injury examples, the RE-AIM framework has been most commonly applied as an evaluation tool and that has been the case across other health issue applications. However, as other of the above injury application examples show, it has broader application as a planning tool and as a method to review intervention studies as is also promoted by its authors on the comprehensive RE-AIM website (see http://www.re-aim.org/).

There has been some criticism about the scientific application of RE-AIM in an analytical sense, and the rigor with which various dimensions have been measured and reported in published studies (Hoepsell et al. 2011). A recent extension to the CONSORT guidelines for randomized trial reporting has included some new aspects relating to the reporting of results from so-called pragmatic trials which are designed to inform decisions about practice changes as the result of interventions and these are relevant to RE-AIM type studies (Zwarenstein et al. 2008). Hoepsell et al. (2011) have recently outlined an epidemiological framework for reporting the public health impact from studies using RE-AIM that should also assist with the quality of studies in the future, particularly with regard to the reach component and external validity considerations.

Translation of the Findings from Intervention Research into Policy Initiative and Sustained Programs

A major goal of all injury research is to prevent injuries, so it is important that the research does not stop with producing effectiveness evidence. While this chapter has focused on only three theory-driven approaches, it is acknowledged that other approaches have been reported in the injury prevention literature. Often these have adopted similar components to those discussed above. For example, a systematic staged and evidence-informed approach toward identifying what might work to promote smoke alarm installation was conducted in the UK based on guidelines developed by the UK Health agency to translate research into policy (Brussoni et al. 2006). Injury prevention practitioner and policy-maker engagement was ensured through a participatory project that considered issues such as policy drivers and funding opportunities; multi-agency partnerships; program design considerations, targeting of interventions, and likely program implementation barriers and facilitators. Similarly, an evaluation of knowledge transfer of sports concussion education assessed this in terms of: the optimal target audience, what message should be delivered, who should deliver the message, how the educational message/s should be delivered and the impact of the knowledge transfer on professionals' knowledge, awareness, and attitudes (Provvidenza and Johnston 2009).

Translation research can be seen as an extension of intervention research in which investigations are undertaken into the processes for ensuring that the evidence is formally integrated into policy and practice is undertaken. There is an emerging body of literature about how such studies could be undertaken but it is beyond the scope of this chapter to discuss it in detail. However, the interested reader is referred to recent health promotion and health policy literature on this topic (Bowen and Zwi 2005; Buse et al. 2005; Choi et al. 2009; Morandi 2009). Some recent injury examples include studies that have explored engaging policy makers in road safety (Tran et al. 2008), falls prevention (Finch et al. 2009), and other injury prevention efforts (Mitton et al. 2008).

Importantly, multi-agency engagement of all major stakeholders from the outset would enhance the long-term success of intervention programs, particularly in terms of their sustainability through incorporation into formal policies and practices. Translation research would include the documenting and analysis of this process to develop an understanding of why, how, and when specific decisions were made. Specific questions that could be addressed in the translation research activities, drawing from the excellent discussion of these issues by Christoffel and Gallagher (2006), include:

- Which groups are most likely to benefit from (a) adoption of the specific injury intervention and/or (b) the evaluated intervention package, including delivery plan?
- What are the key components to delivering evidence-based injury prevention packages that could be used to inform state/national strategic approaches to implementing other safety or health promotion interventions in the community setting?
- What unique, but complementary, role could each stakeholder agency play in a future strategic approach to safety?

Researchers can participate in discussions with stakeholder agencies to identify potential roles in any future strategic approaches (which will be determined from results of previous phases). This process should be documented and analyzed to develop an understanding of why, how, and when decisions were made. Lessons learned from the intervention delivery in the implementation trial should be reviewed and the direct relevance to other sports identified through these researcher and stakeholder consultations. Policy makers, in particular, require good effectiveness evidence about interventions they are considering but this must include information about their likely translatability to other contexts, with varying characteristics (Finch et al. 2009).

Active engagement of the stakeholder groups through all aspects of the research will also increase the profile of, and acceptance of, injury prevention activities more generally (MacKay and Vincenten 2009). They will also generate background support for safety initiatives within their organizations, structures, and cultural groups that will translate to increased knowledge and awareness among a range of relevant consumers (Peterson et al. 2007). These activities will include fostering research into the translation of safety evidence and should include dissemination of information through specific scientific sessions at relevant research and practitioner conferences and industry forums convened by stakeholder groups; such forums plan and deliver sports safety and injury risk management advice for community delivery bodies and participants. Finally, researchers should work with stakeholder agencies to write and publish regular plain-language articles describing latest advances in safety targeted at their members as well as publishing their high-quality science in appropriate forums.

If the injury research community does not rise to this challenge our field will continue to suffer from the major information gap already identified by Nilson and Yorkston (2007) as a "critical need to understand the reasons why some community-based programs succeed and seemingly equivalent programs fail." Moreover, increased and sustained efforts will be needed to make sure that the results of our intervention implementation are then successfully disseminated to those who will need to put them to use – both policy makers and injury practitioners.

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