Summary/samenvatting
Summary

Ready? From evidence to practice

Sport injuries present a significant health problem at an individual and public health level, and counteract the many inherent health benefits related to regular physical activity and sport participation. Consequently, the prevention of sport injuries is important to maintain and increase an active lifestyle. Actual prevention of sport injuries in real-world sport settings depends on a large-scale adoption and proper use of evidence-based preventive measures by the target population. Numerous studies and systematic reviews have evaluated the efficacy and effectiveness of preventive interventions on the risk of sport injuries, and as such provided a wide evidence base for implementation efforts. However, available data on sport injuries substantiate a suboptimal use of effective preventive measures in practice, and effective implementation is still considered an important challenge. Next to a wide evidence base on effective injury preventive intervention, knowledge is required on intervention strategies to reach the target population and to affect their preventive behaviour. A range of potentially relevant strategies should be considered, including education, contextual modifications, and rule and regulation changes. As such, the main objective of this thesis was to gain insight into the effectiveness of intervention strategies to translate and implement available evidence on sport injury prevention to a broad practical context, and consequently promote actual sport injury prevention.

The research described in this thesis is presented in two parts. First, systematic reviews are presented evaluating available evidence on what works in sport injury prevention (Set). Second, effect and process evaluations of three interventions were included as Dutch examples of how different intervention strategies can contribute to effective implementation (Go!).

Set. Available evidence on what works in sport injury prevention

Intervention strategies to prevent sport injuries

Implementation of preventive measures requires behavioural change on the part of an athlete to adopt and use evidence-based preventive measures as intended. Chapter 2 describes a systematic review aimed to identify intervention strategies for the prevention of acute sport injuries evaluated in the scientific literature, and to identify potential intervention strategies not yet evaluated (i.e. potential knowledge gaps), using a modified version of the Haddon matrix. The modified version of the Haddon matrix represented 20 potential intervention strategies for sport injury prevention. These strategies range from those primarily targeted at behavioural modifications on the part of an individual (e.g. specific training programmes or education), through strategies geared at the sport activity (i.e. rule and regulation changes in sport, and use of appropriate equipment) to those predominantly based on contextual modifications. This latter category includes policy changes and interventions aimed at behavioural change on the part of relevant others within the sport injury context (e.g. coaches, allied health staff, sporting federations). Five electronic databases were searched for relevant studies, including a control group/condition, prospective data collection, and a quantitative injury outcome measure.
Our search strategy resulted in the inclusion of 155 studies, mostly randomised controlled trials (RCTs, 43%) and controlled trials (CTs, 15%), next to observational study designs. Results showed that interventions primarily targeted behavioural modifications in individuals, most often through training programmes aimed at building individuals’ capacity before the injury event to reduce the injury risk (‘pre-event’ phase), or targeted the use of equipment to avoid injury in the ‘event phase’. Studies in the area of rule and regulation changes, education, psychological and cognitive skills training, and contextual modifications were underrepresented. Studies specifically aimed to prevent re-injuries (‘post-event’ phase) were a minority. Based on these results, additional research is necessary to build on the current evidence regarding the effectiveness of these intervention strategies. The overview provided in this review can facilitate future sport injury prevention efforts by identifying possible strategies to choose from, given a specific injury problem and a sport injury context. Next, this approach has proven to be useful to reveal potential gaps in the knowledge base regarding the prevention of sport injuries, thereby providing new opportunities for sport injury prevention research.

**Key intervention components and relevant contexts**

Aim of the systematic review described in Chapter 3 was to summarise available evidence on the effectiveness of neuromuscular training (NMT) to prevent ankle sprains, resulting in an overview of effective components and contexts of NMT programmes. This study was included as an example of how available evidence can be used to extract additional information on essential ‘key’ intervention components that impact (most) on injury prevention, and on contexts in which interventions have shown to be effective, which in turn may be helpful to develop effective and adoptable interventions.

An electronic literature search of PubMed, SPORTDiscus and EMBASE was conducted to identify published RCTs, CTs, and pretest-posttest designs on the preventive effect of NMT for ankle sprains in sport. Methodological quality of relevant studies was assessed, and only high-quality studies were included in the meta-analyses. A total of 30 studies were included in the analyses (24 RCTs, 3 CTs, 3 pretest-posttest designs). Studies showed a great diversity in preventive effects and methodological quality (quality score ranged between 47% and 100%). However, the diversity in preventive effect was independent of study quality and study design. A total of 14 studies focussed solely on the effectiveness of balance training, and 16 studies evaluated the effect of balance training combined with adjunct interventions. Pooled data showed a significant reduction in the occurrence of ankle sprains (relative risk (RR)=0.60; 95% CI 0.51 to 0.71). Single-component interventions specifically targeted at ankle sprains achieved preventive effects (RR=0.58; 95% CI 0.48 to 0.72), as opposed to multi-component interventions (RR=0.67; 95% CI 0.37 to 1.24). With respect to interventions targeted at lower extremity or general injuries, significant effects were found on the prevention of ankle sprains using both single-component (RR=0.71; 95% CI 0.52 to 0.97) and multi-component interventions (RR 0.55; 95% CI 0.41 to 0.74). The evidence for a preventive effect on first-time ankle sprains remains inconclusive, as opposed to the effect of NMT on recurrent ankle sprains and in a general sporting population.

Based on this study it can be concluded that a key element of NMT to prevent ankle sprains is balance training, irrespective of the use of balance boards or other balance devices, and that both single-component and multi-component NMT interventions are effective in reducing ankle sprains. Therefore, the type of intervention most fitting to the context should be chosen for implementation efforts.
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Go! The Dutch experience
Studies evaluating the effectiveness of different intervention strategies
As a next step, evidence on what works needs to be translated to and implemented in everyday life. The second part of this thesis describes effect and process evaluations of three nationwide interventions that were implemented in the Netherlands, as part of (inter) national policies on sport injury prevention. The interventions aimed to increase the broad uptake of evidence-based preventive measures in real-world sport settings, using different intervention strategies.

Effectiveness of rule modification in sport
The study in Chapter 4 exemplifies rule modification in sport as intervention strategy. Fédération Internationale de Football Association (FIFA) introduced the shinguard law in 1990, which made wearing shinguards mandatory during matches. The effect of introducing this law in the Netherlands in the 1999/2000-soccer season was evaluated using time trend analysis on injury data, covering 25 years of continuous registration (1986–2010) of all emergency department treatments in a random, representative sample of Dutch hospitals. All injuries sustained in football by patients aged 6–65 years were included, differentiating lower leg injuries expected to be preventable by shinguards from other injuries.

Results showed that the incidence of lower leg soccer injuries decreased significantly following the introduction of the shinguard law (1996–2000: -20%; 2001–2005: -25%), whereas the incidence of all other soccer injuries did not. This effect was more prominent during weekends (i.e. predominantly on match days). No gender differences were observed. Based on the study design used, no conclusions can be drawn regarding the causal effects of the rule modification and the incidence of lower leg injuries. However, the available evidence indicated a preventive effect of the shinguard law with respect to lower leg injuries, underlining the relevance of rule modification as an effective preventive measure at a group or societal level.

Effectiveness of an intervention programme based on health communication
Chapter 5 describes a study evaluating the effectiveness and reach of a nationwide intervention to increase voluntary helmet use in adult Dutch recreational skiers and snowboarders (DRSS). Main motive for developing this intervention programme was low and inconsistent helmet use in this population. The in-season intervention ‘Use your head, wear a helmet’ was first implemented nationwide in the 2010/2011-winter sport season. Multiple intervention components were included, implemented at an individual level within the setting of Dutch indoor ski halls (i.e. ‘strongman game’ machine, informative flyers), and at a national level using health communication elements (i.e. informative website, press release, website banners and advertisements). A prospective single-cohort study was used to evaluate the impact of intervention exposure on determinants of helmet use (i.e. risk perception, knowledge, attitudes) and self-reported helmet use using online questionnaires. A random sample of 363 DRSS from an existing Dutch panel participated in this study. A second independent sample of 363 DRSS was used to assess intervention reach. Multiple regression analyses were used to evaluate the effect of intervention exposure on individual changes in outcome measures over the intervention season.
Intervention exposure had a significant, positive effect on self-reported helmet use in DRSS ($\beta=0.23$; 95% CI 0.017 to 0.44). Subgroup analyses revealed that this effect was found only in female DRSS, young skiers, and intermediate skiers. No significant, positive associations were found between intervention exposure and any of the determinants of helmet use. However, subgroup analyses revealed intervention effects on risk perception and knowledge in specific subpopulations. Overall intervention reach was 28.1%, with differences found between skiers and snowboarders. This study showed that a nationwide intervention programme could be successful to influence preventive behaviour. Differences in intervention reach and effectiveness between subgroups of a target population should be considered when developing and evaluating interventions.

**Use of eHealth: an app-based neuromuscular training programme to prevent ankle sprains**

Both eHealth and mHealth are regarded as practical tools in the dissemination of preventive measures and interventions. For this purpose the Dutch ‘Versterk je enkel’ app (‘Strengthen your ankle’ app; free of charge) was developed, including an efficacious NMT programme for the prevention of ankle sprain recurrences. This study evaluated the implementation effectiveness of this app in the Netherlands within its practical context, using the Reach Effectiveness Adoption Implementation Maintenance (RE-AIM) Framework (Chapter 6).

Data for the evaluation of the app were objectively registered through Google Analytics and analysed after follow-ups of 18 months (iOS version) and 15 months (Android version), respectively. Users questionnaires provided a qualitative view of the objectively assessed measures ($n=82$) to gain insight into the demographics of users, users’ reasons to download the app, app-user experience, and use of the embedded preventive programme.

App reach was low, with 2.6% of the projected target population. User ratings for the app’s relevancy, clarity, usefulness, appeal, information and reliability were high. However, app usage indicated that compliance with the embedded programme was low. Although the app was well received by the users, targeted efforts will be required to ensure proper uptake and usage of the app by the target population. This may in general hold true for eHealth and mHealth efforts aimed at athlete care and injury prevention.

**Conclusions**

Main objective of this thesis was to gain insight into the effectiveness of intervention strategies to translate and implement available evidence on sport injury prevention to a broad practical context. Results presented in this thesis indicate that a range of potentially relevant intervention strategies is available to support and strengthen implementation efforts. However, not all strategies are based on sufficient evidence or are relevant for all sport injury contexts. Results showed that the majority of evidence targeted behavioural modifications in individuals. Additional research is needed to build on the evidence base for specific intervention strategies, including rule and regulation changes, policies, product and other contextual modifications. Although the evidence base of these strategies is lagging compared to other strategies, the available evidence is promising and provides new opportunities for sport injury prevention. This is especially true as these strategies rely less on behavioural modification on the part of the individual athlete and have the potential to reach and affect large populations. Moreover, addi-
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tional (subgroup) analyses can yield information on essential intervention components and contexts, which can be translated into more usable interventions without impacting effectiveness. Joined efforts of science and practice are needed to understand the working mechanisms of effective interventions, support effective implementation through evidence-based interventions that are adopted and complied with, and to stimulate practice-driven research that fits the needs of specific sport injury contexts.