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Is it Possible to Prevent Sports Injuries?

Review of Controlled Clinical Trials and Recommendations for Future Work

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Abstract

Sports injuries are one of the most common injuries in modern western societies. Treating sports injuries is often difficult, expensive and time consuming, and thus, preventive strategies and activities are justified on medical as well as economic grounds.

A successful injury surveillance and prevention requires valid pre- and post-intervention data on the extent of the problem. The aetiology, risk factors and exact mechanisms of injuries need to be identified before initiating a measure or programme for preventing sports injuries, and measurement of the outcome (injury) must include a standardised definition of the injury and its severity, as well as a systematic method of collecting the information. Valid and reliable measurement of the exposure includes exact information about the population at risk and exposure time. The true efficacy of a preventive measure or programme can be best evaluated through a well-planned randomised trial.

Until now, 16 randomised, controlled trials (RCT) have been published on prevention of sports injuries. According to these RCT, the general injury rate can be reduced by a multifactorial injury prevention programme in soccer (relative risk 0.25, $p < 0.001$, in the intervention group), or by ankle disk training, combined with a thorough warm-up, in European team handball [odds ratio 0.17; 95% confidence interval (CI) 0.09 to 0.32, $p < 0.01$]. Ankle sprains can be prevented by ankle supports (i.e. semirigid orthoses or air-cast braces) in high-risk sporting activities, such as soccer and basketball (Peto odds ratio 0.49; 95% CI 0.37 to 0.66), and stress fractures of the lower limb by the use of shock-absorbing insoles in footwear (Peto odds ratio 0.47; 95% CI 0.30 to 0.76).

In future studies, it is extremely important for researches to seek consultation with epidemiologists and statisticians to be certain that the study hypothesis is appropriate and that the methodology can lead to reliable and valid information. Further well-designed randomised studies are needed on preventive actions and devices that are in common use, such as preseason medical screenings, warming up, proprioceptive training, stretching, muscle strengthening, taping, protective equipment, rehabilitation programmes and education interventions (such as increasing general injury awareness among a team). The effect of a planned rule change on the injury risk in a particular sport could be tested via a RCT before execution of the change. The most urgent needs are in commonly practised or high-risk sports, such as soccer, American football, rugby, ice hockey, European team handball, karate, floorball, basketball, downhill skiing and motor sports.

The increasing promotion of physically active lifestyles to reduce the risk of chronic diseases[1-3] should also consider the possible problem of increasing numbers of accompanying injuries.[4-6] Since treating sports injuries is often difficult, expensive and time consuming, preventive strategies and activities are justified on medical as well as economic grounds.[4-8]

Several epidemiological surveys have outlined the frequency and forms of injuries in various sports events, but study comparisons are complicated by the different injury criteria used as well as inconsistency in data collection and recording.[9] The risk of acute injury seems to vary enormously between various sports; most of the endurance sports are safe compared with extremely high-risk disciplines, such as some forms of motor sports. Injury rates in popular team games, such as soccer, volleyball, basketball and ice hockey, lie between these extremities.[5,6] While endurance sports seem to have the highest rates of overuse injuries, these injuries rarely result in permanent disability. Many new modes of sports including high speeds and powerful contacts include a high risk of injury.[10]

Before initiating a measure or programme for preventing sports injuries, the extent of the problem must first be defined. Secondly, the mechanisms and factors involved need to be identified. Finally, measures likely to reduce the risk of injury should be introduced and their effect monitored (figure 1).[11]

The aim of this article is to review the controlled trials on prevention of sports injuries and describe the most important aspects associated with injury surveillance and successful injury prevention.

1. Recording Injuries and Monitoring Exposure

The expression 'injury surveillance' means an ongoing collection of data describing the occurrence of, and factors associated with, injuries. The success of any sports injury surveillance system and its widescale applicability are dependent upon valid and reliable definitions of sports injury, injury severity and sports participation.[12] Although it would be optimal to use the same sports injury surveillance method in all sports, in practice the method must be tailored to each specific sports, especially if the purpose is to identify the injury aetiology or effectiveness of preventive measures.[13,14] Sports injury surveillance systems may be unable to identify the mechanisms of injury. Specific methods, such as video monitoring and computer-based analyses are usually needed to get a reliable picture of the exact mechanisms of injuries.[15,16]

Comparison of injury rates between different studies and sports is complicated by many methodological differences,[9,17-19] and there is a need for further consensus meetings between those who are responsible for different ongoing injury surveillances. Generally, most of the injury surveillance studies can be categorised to case-series designs and cohort designs.[19] Measurement of the outcome (injury) includes definition of the injury, measurement of its severity, and method of collecting the information. Measurement of the exposure includes both definition of the population at risk and assessment of their exposure time.[20] Specifically, the occurrence of injuries (injury risks) may be calculated: (i) per total population when there are also individuals who are not exposed to the sports and its injuries; (ii) per active population at risk; or (iii) most preferably, per time unit of exposure.[21] The results should be interpreted accordingly.

Time lost from practice is often used as a criterion of injury definition and severity.[22]This seems to be one standard way of recording injuries, but is not always associated with severity of medical consequences. High numbers of medically severe injuries are rather easily collected using 'passive' methods of data collection, such as reviews of insurance claims, mail-in surveys and reviews of medical records. However, these passive methods usually give underestimates of the true injury incidence. The most complete coverage of injuries is gained if the 'no time loss' injuries are also recorded, for example, according to the method of Requa and Garrick.[18] Using this more sensitive injury definition would enable those injuries with potentially serious sequelae that would not result in time loss (e.g. laceration or mild concussion) to also be reported. This type of definition allows reasonable comparisons to be made with injury definitions used in many studies on noncompetitive sports (for example, occupational, lifestyle, recreational and fitness physical activities).

Studies using careful prospective methods supervised by the researcher lead to a more valid comparison of injury risk, but they are usually focused

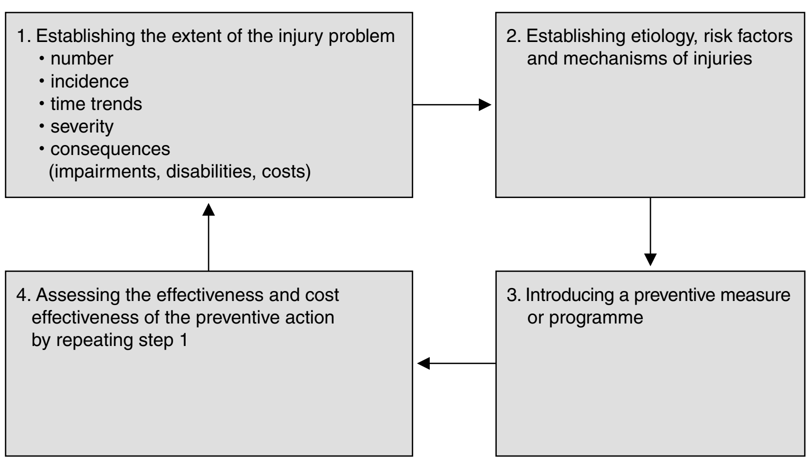

Fig. 1. The sequence of prevention of sports injuries.[11]

Table I. Important points to be considered when collecting injury surveillance data[12]

Clearly define what constitutes an injury and standardise this
Type of sports event and the particular activity at the moment of injury
Level of sports (recreational *vs* competitive)
Place where the injury occurred
Injury mechanism, acute or overuse, and what went wrong
Level of supervision
Nature of the injury (sprain, fracture etc.)
Injured body region(s)
Severity of the injury (activity lost, working time lost, need for treatment, cost of treatment, permanent damage, impairment and disability)
Characteristics of the injured person
Treatments needed (duration and nature)
Use of protective equipment
Follow-up of game rules (foul play and injury)
Cost of injury (direct, indirect)
Exposure data must be defined (population at risk and exposure time)
Estimate simplicity (*vs* education of personnel collecting data) and time needed (is it realistic?) for data collection
Acknowledge limitations or sources of error (also when reporting results)

on small groups of athletes and catch sporadic severe injuries only. A prospective approach that follows a large group of participants through a variety of exposures allows better comparisons between various activities, but may include more inaccuracies on case ascertainment, coverage and classification of injuries. Studies using 'passive' methods of data collection can cover a high number of severe injuries rather well, and based on these studies, it is possible to define the profiles of severe injuries in different types of sports. Consequently, both the case-series and cohort studies, when interpreted correctly, may provide important clues for injury prevention. Table I summarises the information that should be considered when collecting sports injury data.

2. Factors Associated with Injury Risk

Sports injuries are multirisk phenomena with various risk factors interacting at a given time.[23] In brief, factors associated with injury proneness can be classified into extrinsic and intrinsic risk factors (table II).[11,24,25] The acute sport injury rate increases with the frequency of violent contacts of the sports event,[6,26-28] but the use of protective equipment may reduce the difference in injury outcomes between sports.

Within a particular sport, the overall gender difference in the injury risk is small, but differences by age groups are more pronounced. Injuries in children are less frequent than those in adults.[6,29-31]

Athletes usually spend far more time in training than competing. Since about half of acute injuries associated with team-game athletes occur in competitions,[6]it is evident that competitions involve a higher injury risk per hour of activity than training.[10,28]

The type, frequency, intensity and duration of training play a major role in the aetiology of overuse injuries. Furthermore, excessive height, weight, muscle weakness, inflexibility, predisposing diseases and idiopathic or acquired abnormalities in the anatomy or biomechanics of the joints may predispose individuals to a local overuse injury (table II).

3. Effectiveness of Injury Prevention Measures and Programmes

Research has generally revealed that strategies designed to prevent sports injuries can be effective. Many interventions involving large groups of participants which are effective enough to measurably alter injury profiles have included changes in rules or improvements in equipment.[7,15,32-34] However, it must be noted that some measures may have no effect or even negative effects.

To address the question: 'is it possible to prevent sports injuries?', we performed a computerised literature search of the entire Medline database, covering the years 1970 to the present, and the Cochrane and Sport databases from the years 1994 to the present, using the keywords: controlled trials, athletic injuries and preventive medicine. All relevant articles were retrieved, either locally, or by interlibrary loan. The search was not limited to the English literature, and articles in all journals were considered, as were the reference lists of the published papers. The references selected were reviewed by the authors, and individually judged with regard to their contribution to the body of knowledge on this topic. Due to the diverse nature and limited numbers of randomised controlled trials (RCT), we did not use a systematic approach to qualify the papers identified. The search indicated that 16 RCT on the prevention of sports injuries were published over the last 3 decades, and these, as well as the most important nonrandomised controlled studies, are summarised below, by sports, anatomic region or type of prevention.

3.1 Soccer

One of the very first RCT was the study of Ekstrand and co-workers.[22] They showed that with a multifactorial prevention programme the injury rate in soccer could be reduced by 75% [relative risk (RR) 0.25 in the intervention group compared with control group; $p < 0.001$]. Since the programme was multifactorial – consisting of correction of training, provision of optimum equipment, prophylactic ankle taping, controlled rehabilitation, exclusion of players with severe knee instability, information about the importance of disciplined play and increased risk of injury at training camps, and team supervision by a doctor and physiotherapist – it remained unclear which parts of the programme were effective and which were not. Another limitation of this valuable and pioneering study included the fact that the recording of injuries was not blinded. Furthermore, no other investigation has repeated this somewhat complex and time consuming programme. In a more recent study involving female soccer players,[35] 42 players were randomly selected from a group of 300 players to participate in a multifactorial 7-week training programme before the start of the season. The programme combined sports-specific cardiovascular conditioning, plyometric training, sport cord drills, strength training and flexibility exercises to improve speed and agility. After the playing season, 14% of the players randomised to the training programme had sustained injuries, compared with 34% of those in the control group (RR 0.47; $p = 0.0085$). Again, the effectiveness of the different methods included in the preseason training programme could not be assessed. Moreover, the exposure time was not recorded and thus the true injury risks could not be assessed.

Table II. Extrinsic and intrinsic risk factors for sports injuries[11,24,25]

Extrinsic risk factors
Exposure
Type of sports
Exposure time
Position in the team
Level of competition
Training
Type
Amount
Frequency
Intensity
Environment
Type of playing surface
Indoor *vs* outdoor
Weather conditions
Time of season
Human factors (team mates, opponent, referee, coach, spectators)
Equipment
Protective equipment
Playing equipment (e.g. racket, stick etc.)
Footwear, clothing
Intrinsic risk factors
Physical characteristics
Age
Gender
Somatotype
Previous injury
Physical fitness
Joint mobility
Muscle tightness, weaknesses
Ligamentous instability
Anatomic abnormalities (malalignments)
Motor abilities
Sports-specific skills
Psychological profile
Motivation
Risk taking
Stress coping

3.2 European Team Handball

Wedderkopp et al.[36] investigated, in a randomised manner, the effect of regular 10- to 15-minute ankle disk training sessions combined with a thorough warm-up before all practice sessions among young female players in European team handball. They observed a 76% decrease in the risk of a new injury [odds ratio 0.17; 95% confidence interval (CI) 0.09 to 0.32] in the intervention group. The efficacy of this simple programme was very good and it may be that part of this efficacy was due to increased awareness of the personal injury risk among the intervention group players (the so-called attention effect or co-intervention effect). The significant role of increased general awareness on an individual's personal injury risk has been shown in successful prevention programmes of occupational accidents.[37]

3.3 Long-Distance Running

Jakobsen and others[38] investigated whether a multifactorial preventive programme would decrease the number of injuries among long-distance runners. The programme consisted of a health examination, instructions on proper warm-up and stretching, selection of well-fitting running shoes, individually tailored running programmes and easy access to medical treatment. As a result, the risk of injury decreased 51% (RR 0.49; $p < 0.005$) in competition, while no change was seen in training-induced injuries. Again, the effectiveness (or ineffectiveness) of any single action in the programme remained unclear.

3.4 Ankle Injuries

Five randomised studies with data from 3954 participants focused on prevention of ankle injuries.[39-43] Four of these studies[39,41-43] examined ankle stabilisers and provided high-quality evidence that use of semirigid ankle stabilisers reduces the risk of ankle sprains, especially among those with previous ankle instability problems. Quinn et al.[44] reported in their systematic Cochrane review a 51% reduction in the number of ankle sprains in individuals allocated to these external ankle supports (Peto odds ratio 0.49; 95% CI 0.37 to 0.66).

Barrett and co-workers[40] showed that there is no strong relationship between the shoe type used (high- versus low-top) and ankle sprains in basketball players, indicating that the protective effect of 'high-top' shoes remains to be established. Tropp et al.[39] reported a reduction in ankle sprains among those participating in balance and coordination training on an ankle disk (RR 0.18; $p < 0.01$).

3.5 Knee Injuries

One randomised study has been conducted on the prevention of knee injuries. Sitler and colleagues[45] found that a prophylactic knee brace reduced knee injuries (especially medial collateral ligament injuries) among defensive players in American football (RR 0.44; $p < 0.005$). However, knee braces did not decrease the severity of these injuries.

Many nonrandomised studies have also investigated the prevention of knee injuries. Caraffa et al.[46] found in their 3-year prospective controlled trial that proprioceptive ankle disk training decreased the risk of anterior cruciate ligament injuries 87% (RR 0.13; $p < 0.001$) among soccer players. The efficacy of this intervention was extremely good and it would be important to repeat this study in a randomised manner. Furthermore, Ettlinger et al.[16] observed that the occurrence of anterior cruciate ligament injuries in alpine skiers could be reduced more than 60% using standardised training programmes before the skiing season. In this controlled study, the on-slope staff from 20 ski areas (n = 4700) were trained to avoid high-risk behaviour, to recognise potentially dangerous situations, and to respond quickly and effectively whenever these conditions were encountered. One limitation of this study was that the skiing or exposure time was not recorded, although skier visits to the areas were similar throughout the 3-year follow-up period, and thus, the observed trend was not likely to be biased. Finally, Hewett et al.[47] reported, in their nonrandomised controlled study (n = 829), a significantly lower incidence (0.12 injuries per 1000 athletes per year) of knee injuries among female athletes after a specific plyometric training programme, compared with untrained controls (0.43 injuries per 1000 athletes per year).

3.6 Stretching

Many measures commonly thought and taught to prevent sports injuries lack consistent scientific evidence. With regard to stretching, 2 well-organised randomised studies failed to show any positive effect of stretching on individual injury risk. Van Mechelen et al.[48] reported a RR of 1.12 (95% CI 0.56 to 2.72), and Pope et al.[49] a hazard ratio of 0.95 (95% CI 0.77 to 1.18), for their intervention groups, respectively.

3.7 Protective Equipment

The good preventive effect of ankle stabilisers has been shown in randomised studies.[39,41-43] Five randomised trials have provided evidence that the use of shock-absorbing insoles in footwear reduces the incidence of stress fractures in athletes.[50-54] Gillespie and Grant[55] calculated, in their systematic Cochrane review, that according to these trials the use of shock-absorbing insoles reduced the risk of stress fracture by 53% (Peto odds ratio 0.47; 95% CI 0.30 to 0.76). However, these authors expressed concern over the relatively poor quality of these 5 trials.

In nonrandomised studies, selection of those who use protective equipment and those who do not may cause a bias. On the other hand, a well-performed nonrandomised study may also give reliable results and it is possible that, for example, in downhill skiing a true causal relationship exists between standardised adjustment of bindings and reductions in risk of lower extremity injury,[15,56] as well as between the use of wrist guards and elbow pads and reduced risk of upper extremity injury in in-line skating.[33] In geriatric medicine, for example, there is high-quality evidence from a recent randomised trial that a shield-type external hip protector reduces the risk of hip fracture among ambulatory frail older adults.[57]

4. Targets for Injury Prevention and Research

There is a continuous need for high-quality scientific studies on the effects of various types of injury prevention and it is important that there is a system of collecting data on all injuries occurring in new modes of sports as well as on the catastrophic injuries in all types of sports.

The injury profiles in different sports events vary widely.[6] An example of the differences the new modes of sports may create is the profile of snowboarding injuries, which differs from that of classic downhill skiing, the upper limb fractures being more common in snowboarding.[58] Current existing data on injury profiles and injury mechanisms in different sports could be used to educate participants, since a sound knowledge of risks is likely to have a preventive effect.[16,37]

To avoid injuries, the preventive measures proven to be effective should be taught to young athletes despite the fact that their injury risk is low. In general, there needs to be a greater focus on diminishing rough and violent contacts between athletes. Ice hockey can be used as an example of sports-specific measures. To avoid spinal cord injuries in ice hockey, aggressive checking, particularly from behind and near the rink boards, should be minimised by game rules and strict officiating. Aggressive stick use may partly account for the high number of hand and wrist fractures in hockey players and should be controlled for.[6]

Although facial injuries are common in a considerable number of sports, they have declined thanks to more routine use of helmets and facemasks.[59] In the US alone, there was estimated to be more than 1600 eye injuries in different forms of hockey in 1997.[60] However, from 1977 no significant eye injuries have been reported among the more than 1 million players wearing a certified full hockey face-shield.[61]

Many sports injuries are the result of unavoidable accidents, but there are also many others that could be prevented. Measures, such as improved game rules supported by strict officiating, should always be incorporated with the aim of decreasing the number of violent contacts between participants. Supervision of the rules and the use of protective equipment are important during competitions and training sessions. Existing protective equipment also needs attention, since some injuries afflict body parts that are already protected. With respect to the intervention of protective equipment, studies too often lack valid pre- and post-intervention data. Also, additional information from injury surveillance, such as the type of protective equipment, its condition, and a description of the events leading to injury, would be most valuable.[62] Mouth guard use should be urgently encouraged for many sports, such as ice hockey and karate. In ice hockey a full-face mask is recommended for everybody as the half face-visors can increase the risk of dental injuries. Regardless of which dental treatment alternative is chosen, a young athlete with a fractured tooth will face several treatment periods in the years ahead, with each subsequent treatment usually being more costly.[63]

The scientific evidence that bicycle helmets protect against head, brain, and facial injuries has been well established by case-control studies.[64] Also, there are a number of suggested means by which concussions in sports could be reduced, although in many cases the evidence for the effect is theoretical rather than scientifically proven.[65] These measures include rule changes to avoid head impact, neck muscle conditioning, mouth guard use, and the use of helmets and head protectors. It is good to remember that the use of protective devices may also lead to unexpected consequences. For example, skiers wearing helmets may ski harder, closer to their limit and in worse conditions assuming that the helmet will protect their head when in fact their change in behaviour leads to even greater risk of injury. In karate, the protective padding introduced for hands and feet seems to have reduced the number of severe injuries, but may simultaneously have increased the risk for mild injuries.[66,67] Overall, the use of more protective padding might be successfully combined with further modifications of the game rules.

It may be difficult to prevent ankle and knee injuries. The options to reduce ankle injuries include ankle disk training, taping and bracing.[36,39,40,42,43,68,69] A systematic review of the literature provides good evidence for the beneficial effect of ankle supports in the form of semirigid orthoses or air-cast braces to prevent ankle sprain during high-risk sporting activities (e.g. soccer, basketball).[44] However, any potential prophylactic effect should be balanced against the baseline injury risk at the activity performed, the supply and cost of the particular device, and for some, the possible or perceived loss of performance. Based on the existing literature, Robbins and Waked[70] concluded that a sense of foot position in humans is precise when barefoot, but is distorted by athletic footwear, which accounts for the high frequency of ankle sprains in shod athletes. They suggested that the best solution for reducing ankle sprains in shod athletes is the use of more advanced footwear to retain maximal tactile sensitivity, thereby maintaining an awareness of foot position. Although prophylactic ankle stabilisers seem to prevent some ankle injuries, again, further research is required with other prophylactic interventions and their general applicability.[44,71,72]

Trials testing the utility of knee braces in athletes without earlier knee injuries have shown a decrease in the rate of knee ligament injuries, but not in overall injury rates or severity of the sustained injuries.[46,73] Knee injuries are of concern since they may progress to osteoarthritic changes in later life.[74] Regular ankle disk training might be the most promising strategy to prevent both ankle and knee injuries.[36]

Slow progression of training gives time for various mechanisms of the tissues to gradually adopt to increasing loads, and is the basis for the prevention of overuse injuries.[75] Correction of biomechanical faults using, for example, orthotic devices may prevent some of these injuries, although consistent, reliable scientific evidence is lacking.[76]

When trying to prevent sports injuries one should realise that participation in sports is a form of behaviour. Usually the introduction of preventive measures implies a change or modification of behaviour of the athlete. It may very well be that the desired preventive behaviour conflicts with the actual sport behaviour, for instance, because it is believed by the athlete that the preventive behaviour will negatively affect the sports performance. When introducing preventive measures and when evaluating the effect of such measures it is therefore necessary to have a good knowledge of the determinants of both sports and preventive behaviour. Determinants that in many models explain preventive behaviour are knowledge, attitude, social influence, barriers and self-efficacy.[77]

5. Conclusions and Future Recommendations

Controlled studies have indicated that it is possible to prevent sports injuries. Based on existing knowledge of the injury profiles and mechanisms we should be able to teach recreational and competitive athletes the typical sports-specific injuries and their risks. To get this information for all new sporting events we need specific injury monitoring. In addition to the group-level preventive strategies, the athletic trainers, coaches and team physicians have a continuous challenge to identify injury-prone individuals and tailor their training and rehabilitation programmes so that injury risk is minimised. Cooperation between investigators, physicians, sports organisations and policy makers is also important,[78] and there is a continuous need to investigate the possibilities for rule changes and regulations concerning protective and other equipment. Careful video analyses of the mechanisms of sports injuries would likely reveal new ways to decrease the number of injuries.

Many questions regarding prevention of sports injuries remain to be answered. In future studies, it is extremely important for researches to seek consultation with epidemiologists and statisticians to be certain that the study hypothesis is appropriate and that the methodology used can lead to reliable and valid information. Further well-designed randomised studies are needed on preventive actions and devices that are in common use, such as preseason medical screenings, warming up, proprioceptive training, stretching, muscle strengthening, taping, protective equipment, rehabilitation programmes, and education interventions (such as increasing general injury awareness among a team). In addition, the effect of a planned rule change on the injury risk in a particular sport could be tested via a RCT before execution of the change. The most urgent needs are for commonly practised or high-risk sports such as soccer, American football, rugby, ice hockey, European team handball, karate, floorball, basketball, downhill skiing and motor sports.

In future studies, we should better consider the efficacy of various preventive interventions for those individuals without previous sports injuries, and for women and children. Issues concerning the acceptability, compliance, cost effectiveness and long-term adherence of the preventive measure should also not be forgotten.

Finally, in many low-to-moderate intensity non-competitive activities (occupational, lifestyle, recreational and fitness physical activities) there is no knowledge of the extent of the injury problem, including the involved risk factors and mechanisms of the injuries. Thus, in this field there is an urgent need for extensive basic epidemiological investigations, followed by well-planned prevention trials.

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