Injury characteristics in children's football and perspectives for prevention

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Roland Rössler
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auf Antrag von

Fakultätsverantwortlicher	Prof. Dr. Arno Schmidt-Trucksäss
Dissertationsleitung	PD Dr. Oliver Faude
Korreferent	Prof. Dr. Lukas Zahner
Externer Experte	Prof. Dr. Ivan Martin
Externer Experte	Prof. Dr. Billy Sperlich

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Dekan
Prof. Dr. Thomas C. Gasser

Table of contents

Figures V

Tables VI

Acknowledgements VII

Summary XI

List of abbreviations XV

List of papers XVI

1 Introduction and background 17
- 1.1 The need for physical activity 17
- 1.2 Football – a healthy and joyful physical activity setting 18
- 1.3 Football and injuries 18
- 1.4 Injury surveillance 19
- 1.5 Injury prevention – what for? 21
- 1.6 The development of an injury prevention programme 22
- 1.7 Existing evidence of sport injury prevention 23
- 1.8 References 25

2 Aims of the thesis 38

3 Publication I: Exercise-based injury prevention in child and adolescent sport: a systematic review and meta-analysis 39

4 Publication II: Soccer Injuries in Players Aged 7 to 12 Years: A Descriptive Epidemiological Study Over 2 Seasons 70

5 Publication III: Risk factors for soccer injuries in players aged 7 to 12 years 96

6 Publication IV: A new injury prevention programme for children's football – FIFA 11+ Kids – can improve motor performance: a cluster-randomised controlled trial 116

7 Synthesis, discussion, and perspectives 140
- 7.1 Summary of the main results 141
- 7.2 Synthesis and general discussion 144
  - 7.2.1 Injury prevention in youth sport 144
  - 7.2.2 General epidemiology of injuries in children’s football 147
  - 7.2.3 Risk factors for football injuries 149
  - 7.2.4 “FIFA 11+ Kids” and motor performance 152
  - 7.2.5 Feasibility of “FIFA 11+ Kids” – unpublished results 152
- 7.3 Methodological considerations 156
  - 7.3.1 Methodological framework 156
  - 7.3.2 Potential limitations 157

7.4 Importance of the project and perspectives 160
7.5 Outlook: Results of the "FIFA 11+ Kids" cluster RCT 163
7.6 Summarising the history of "FIFA 11+" 164
7.7 Conclusion 166
7.8 References 167

8 Appendix/Supplemental material 182
8.1 Contribution to the PhD project 182
8.2 Supplemental material related to Publication I 186
8.3 Supplemental material related to Publication II 190
8.4 Supplemental material related to Publication III 191
8.5 Online injury/exposure recording system: "TeamRec" 193
8.6 "FIFA 11+ Kids" manual 195
8.7 "FIFA 11+ Kids" short-version of the manual 215

Figures

Figure 1-1: “Sequence of prevention” adapted from van Mechelen et al. (1992).......... 23

Figure 3-1: Flow diagram of the literature selection process.. 48

Figure 3-2: Overall effect of exercise-based sport injury prevention programs (sorted by weight). SE = standard error, IV = inverse-variance, CI = confidence interval.. 56

Figure 3-3: Effects of exercise-based sport injury prevention programs focusing on “all”, “lower extremity”, “knee”, and “ankle” injuries (sorted by weight). SE = standard error, IV = inverse-variance, CI = confidence interval................. 57

Figure 3-4: Effects of exercise-based injury prevention programs in football (outdoor only), basketball, and handball (sorted by weight). SE = standard error, IV = inverse-variance, CI = confidence interval... 57

Figure 4-1: Incidence of training and match injuries with 95% CI; P-values of comparisons between incidence rates of age groups. 80

Figure 5-1: Kaplan-Meier curves for overall injuries of (A) age categories (under-9, under-11 and under-13 years of age); (B) girls and boys; (C) age-adjusted body height (body height percentiles split by median)...................................... 108

Figure 6-1: CONSORT Flow Diagram. 122

Figure 6-2: Outcomes in standardised (Cohen) units with 90% confidence intervals. The probabilities of an effect being harmful/trivial/beneficial are expressed as percentage values. Clinical inference is provided. Abbreviations: COP dom = centre of pressure path length during single leg stance on the dominant leg; Y-B CS = Y-balance-test composite score; DJ = drop jump; RSI = reactive strength index; CMJ = counter movement jump; SLJ = standing long jump; Wall volley = wall volley test................................. 132

Figure 7-1: Typical errors occurring during exercise number 1 of the “FIFA 11+ Kids” programme. Left: Inappropriate leg alignment and hip axes during single leg stance; Middle: Internal rotation of the foot; Right: External rotation of the foot.. 146

Figure 7-2: Player performing level 2 of the exercise “Spiderman” of the first “FIFA 11+ Kids” version. A clear hip flexion is visible which leads to a reduction in hamstring activation... 155

Tables

Table 3-1: Overview of studies investigating exercise-based injury prevention programs (alphabetical order by first author). 50

Table 4-1: Number of player seasons and anthropometric data (mean (SD)) for different age groups. 80

Table 4-2: Exposure time, number and severity of injuries in training and matches. 81

Table 4-3: Location of injury and related comparison of incidence in different age groups. 82

Table 4-4: Type of injury and related comparison of incidence in different age groups. 83

Table 4-5: Injury mechanisms and related comparison of incidence in different age groups. 84

Table 4-6: Injury location and injury type. 85

Table 5-1: Cox mixed effects model stratified by age group (accounting for recurrent injuries and team-clustering). Hazard ratios (HR) with 95%-confidence 105

Table 5-2: Cox mixed effects model stratified by age group (accounting for recurrent injuries and team-clustering). Hazard ratios (HR) with 95%-confidence 106

Table 5-3: Exposure time, number of injuries, injury incidence rate [injuries/1000h], and rate ratio with corresponding p-value. Natural grass is the reference 107

Table 6-1: The “FIFA 11+ Kids” exercises. 125

Table 6-2: Number of players, number of athlete sessions and anthropometric pre and post data (mean (SD)). 131

Table 6-3: Mean values of test results (SD), differences between intervention and control group (90%-CI), and P-values of mixed modelling. 131

Table 7-1: Questionnaire for the coaches with corresponding answers. In case of equal answers those were summarised and ordered by their frequency (top down). Positive answers are symbolised with a “+”, negative answers with a “–”, and general statements with a “o”. 153

Table 7-2: Questionnaire for the children and corresponding answers. 155

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Summary

Sport and physical activity for children is widely recommended to support a healthy lifestyle. Football is the most popular sport worldwide. Given its popularity, football is an excellent setting to fulfil sufficient physical activity levels. Football can induce considerable beneficial health effects. However, injuries may be an unfortunate consequence of participating in sport. In light of the large number of players football injuries relate to a public health issue. Therefore, the application of suitable injury prevention seems indicated. Epidemiological data are required as a basis for the development of a tailored injury prevention programme. Our topical review on football injuries in child and adolescent players revealed a clear paucity of such data relating to the youngest age groups (players under 13 years of age).

This PhD project envisaged four aims:

- to quantify the efficacy of exercise-based injury prevention programmes in child and adolescent sport in general and with respect to different characteristics of the target group, the injury prevention programme, and the outcome variables. Therefore, we conducted a systematic review with meta-analysis.
- to analyse the incidence and characteristics of football injuries in children aged 7 to 12 years in a large-scale prospective epidemiological study.
- to analyse injury risk factors based on our prospective data.
- to develop an age-specific injury prevention programme for children's football and to test this programme regarding its feasibility and its effects on motor performance in a pilot study in 7 to 12 year old players.

Injury prevention meta-analysis
For our meta-analysis we conducted a systematic literature search in six databases and found 21 relevant studies. The original studies included a total of 27,561 athletes (median age 16.7 years; range 10.7 to 17.8). The overall injury rate ratio between intervention and control group was 0.54 (95%-confidence interval 0.45, 0.67), $P < 0.001$. Injury prevention programmes that included jumping/plyometric exercises showed a larger ($P = 0.002$) injury preventive effect than studies without such exercises.

The results provide good evidence and clearly demonstrate beneficial effects of exercise-based injury prevention in youth sports. A practically relevant overall injury reduction of 46% has been observed. Based on these findings, in particular multimodal programmes including jumping/plyometric exercises can be recommended. However, there is a considerable lack of data for children (under 14 years of age). We concluded that future research should focus on these age-groups.

Football injuries in children

We conducted a prospective epidemiological study on injuries in children's football over two seasons in Switzerland and the Czech Republic. Exposure of players during training and match play (in hours) and injury data were reported by coaches via an internet-based registration system. Location, type, and severity of injuries were classified according to an established consensus. We calculated injury incidence rates (injuries per 1,000 hours of football exposure). An injury was defined as any physical complaint sustained during a scheduled training session or match play resulting in at least one of the following: (1) inability to complete the current match or training session, (2) absence from subsequent training sessions or matches, and/or (3) injury requiring medical attention.

We recorded 6,038 player-seasons with 395,295 hours of football exposure. The mean age of the players was 9.3 (SD 1.9) years, and 3.9% of the participants were girls. During the study period 417 injuries were reported. Most injuries (76%) were located in the lower limbs and 16% in the upper limbs. Joint and ligament injuries comprised 31%, contusions 23%, muscle and tendon injuries 19%, and fractures and bone injuries 15% of all injuries. About a quarter (24%) of all injuries led to more than 28 days of absence from sport participation and was therefore classified as "severe". The overall injury incidence was 0.61 (95%-CI 0.53, 0.69) injuries per 1,000 hours of football exposure during training sessions and 4.57 (95%-CI 4.00, 5.23) during match play. Injury incidence rates increased with increasing age.

A comparison between the findings of our prospective study on injuries in children's football and our topical review (that mostly included older players) showed differences in injury patterns. Children sustained a relatively high proportion of fractures and bone stress and injuries to the upper limbs. This clearly underlines the necessity of an age-specific injury prevention programme for children's football.

Risk factors for football injuries

This project aimed at investigating risk factors for football injuries in children. We analysed time-to-injury data of our prospective epidemiological study using standard as well as extended Cox models accounting for correlations on team- and intra-person-level. We analysed injury risk in relation to age, sex, playing position, preferred foot, and with regard to age-independent body height, body mass, and BMI. Further, we analysed injury risk in relation to playing surface.

The overall injury risk was increased by 46% ($P < 0.001$) per year of life. Injury risk was higher in age-adjusted taller players (higher percentile-rank). Injury risk was increased on artificial turf (39%; $P < 0.001$) and lower during indoor sessions (32%; $P < 0.001$) compared to natural grass.

Age is known as a risk factor from older players and was confirmed to be a risk factor in children's football. The playing surface has been discussed earlier as a risk factor. However, latest generation turfs did not show an increased injury risk compared to natural grass in different studies on older (mostly high-level) players. Injury risk in relation to sex should be further investigated in future studies.

Development of "FIFA 11+ Kids"

Based on the gathered knowledge, we developed a tailored injury prevention programme for children's football called "FIFA 11+ Kids" which takes age-specific injury patterns of the youngest players into account. "FIFA 11+ Kids" is a 15-minute warm-up programme. In its first version it consisted of 7 different exercises each with 3 levels (with increasing difficulty). The programme focuses on (1) spatial orientation, anticipation, and attention especially while dual-tasking (to avoid unintended contact with players or objects) (2) neuromuscular performance, body stability, and movement coordination (to prepare the body for the physical demands of playing football and to reduce the number of falls) and (3) appropriate falling techniques (to minimise the injury risk when falling). We slightly modified "FIFA 11+ Kids" based on the practical experiences during the pilot study. The main changes were 2 additional levels for each of the 7 exercises.

"FIFA 11+ Kids" – motor performance (pilot study)

We conducted a cluster-RCT (pilot study) to evaluate the feasibility of "FIFA 11+ Kids" and to test potential effects on motor performance in 7 to 12 year old children. We were interested in effects on motor performance, as effective injury prevention programmes generally influence modifiable risk factors (e.g. lack in balance, power or strength). We stratified 12 football teams (players aged 7 to 12 years) into an intervention (N = 56 players) and a control group (N = 67). The intervention group conducted the 15-min warm-up programme "FIFA 11+ Kids" twice a week for 10 weeks. The control group followed a standard warm-up (sham treatment). During pre- and post-tests we assessed parameters to determine balance, agility, power/strength, and football-specific skill/technique of the children. We used magnitude-based inferences and linear mixed-effects models to analyse the performance test results. We observed beneficial effects favouring the intervention group in dynamic balance, agility, jumping performance, and football-specific skill/technique.

The observed improvements of motor performance indicate that "FIFA 11+ Kids" can positively influence intrinsic injury risk factors. Importantly, no negative side effects of the programme were observed. Coaches' as well as players' feedback regarding the feasibility of the programme were positive.

Outlook: "FIFA 11+ Kids" prevents injuries

In our subsequent large-scale cluster-RCT (that goes beyond the scope of the PhD project) "FIFA 11+ Kids" has proven to be efficacious in reducing injuries in children's football. Considerable effects were found for overall, match, training, lower extremity, and specifically severe injuries. The observed overall injury reduction of 48% is comparable to studies in older youth football players (which we included in our meta-analysis). Based on these findings a broad implementation of "FIFA 11+ Kids" can be recommended to reduce injuries and to support the health benefits of playing football in the long term.

List of abbreviations

ACL	Anterior Cruciate Ligament
BMI	Body Mass Index
CI	Confidence Interval
cat.	Category
FIFA	Fédération Internationale de Football Association
F-MARC	FIFA-Medical Assessment and Research Centre
HR	Hazard Rate
MTR	Match-Training-Ratio
RCT	Randomised Controlled Trial

List of papers

Alongside the PhD-relevant publications, the project was flanked by a review article:

- Faude O, Rössler R, Junge A. Football injuries in children and adolescent players: are there clues for prevention? Sports Med. 2013;43(9):819-37.

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I Short Title: Injury prevention meta-analysis

- Rössler R, Donath L, Verhagen E, Junge A, Schweizer T, Faude O. Exercise-based injury prevention in child and adolescent sport: a systematic review and meta-analysis. Sports Med. 2014;44(12):1733-48.

II Short Title: Football injuries in children

- Rössler R, Junge A, Chomiak J, Dvorak J, Faude O. Soccer Injuries in Players Aged 7 to 12 Years: A Descriptive Epidemiological Study Over 2 Seasons. Am J Sports Med. 2016;44(2):309-17.

III Short Title: Risk factors for football injuries

- Rössler R, Junge A, Chomiak J, Nemec K, Dvorak J, Lichtenstein E, Faude O. Risk factors for football injuries in young players aged 7 to 12 years. (under review).

IV Short Title: "FIFA 11+ Kids" – motor performance (pilot study)

- Rössler R, Donath L, Bizzini M, Faude O. A new injury prevention programme for children's football - FIFA 11+ Kids – can improve motor performance: a cluster-randomised controlled trial. J Sports Sci. 2016;34(6):549-56.

Further, the first publication of the subsequent large-scale study is currently under review:

- Rössler R, Junge A, Bizzini M, Verhagen E, Chomiak J, aus der Fünten K, Meyer T, Dvorak J, Lichtenstein E, Beaudouin F, Faude O. A warm-up programme to prevent injuries in children's football: cluster randomised controlled trial. (under review).

1 Introduction and background

1.1 The need for physical activity

Physical inactivity, overweight/obesity, and high blood pressure are in the top five risks for worldwide mortality according to the latest report of the World Health Organization.[1] Globally, mean BMI has increased since 1980.[2] Obesity is now recognised as one of the most urgent public health problems,[3, 4] reducing both, life expectancy and quality of life.[5] It has been conservatively estimated, that physical inactivity led to USD 53.8 billion of costs for the health-care system worldwide in 2013.[6]

Approximately one quarter of adolescents in developed countries is overweight or obese.[7, 8] The United Nations and the International Olympic Committee have emphasised that organised sport is crucial to reduce the global burden of obesity in childhood and adolescence.[9, 10] It has been shown that participation in organised sport can reduce the prevalence of obesity during adolescence.[11]

Physical activity has proven to cause immediate beneficial effects regarding health risk factors, cardiorespiratory and neuromuscular fitness, bone density, psychological health, as well as mental development in children and adolescents.[12-14] In addition, participation in organised youth sport is positively associated with higher levels of adult physical activity.[15, 16] Hence, youth sport has important implications for long-term individual and public health.

These findings suggest the urgent need of developing sport-related skills as well as habits of a healthy lifestyle during childhood.[17] Perceived sports competency, playing sport outside, as well as cardiorespiratory fitness during childhood and adolescence were positively associated with being persistently active during the transition from adolescence to adulthood.[18, 19] Therefore, it is crucial to promote physical activity for children, as an active lifestyle established during childhood is an important basis for a lifelong healthy behaviour.[20-22] In addition, it has been shown that physical activity is positively associated with cognitive function in children.[14, 21] Thus, from an individual as well as from a socio-economic health-care perspective, it is important to promote sufficient amounts of physical activity during childhood.[23] Therefore, every effort must be made to foster physical activity starting from a young age.[24, 25]

1.2 Football – a healthy and joyful physical activity setting

Football is the world's most popular sport with over 270 million active players of which the majority is younger than 18 years of age.[26] Studies in healthy participants and patient groups suggest that playing football positively affects fitness and health parameters of individuals across the lifespan.[27, 28] Therefore, football has a great potential to support a healthy lifestyle.[29, 30]

Football includes frequent changes in movement direction and speed.[31-33] The high exercise intensity and the intermittent nature of football are regarded as one of the underlying reasons for a broad range of beneficial effects.[34] Studies in children and adults have shown that structural adaptations and improvements of the heart function can be induced by playing football.[35-38] Systolic and diastolic blood pressure as well as heart rate at rest have shown to be reduced,[36, 38, 39] muscle mass and bone mineral density were increased,[34, 35, 40, 41] and maximum oxygen uptake was clearly elevated after regular football exposure.[36-38, 42]

Further, recreational football has been shown to be a valuable setting for psychosocial interactions with beneficial effects on general well-being, motivation, social capital, and quality of life.[43-45] Thus, football is a healthy activity that provides a valuable opportunity to increase recruitment as well as adherence to physical activity.[27]

1.3 Football and injuries

Playing football involves many high-impact situations during player-to-player contact, cutting manoeuvres, and falls, which result in a notable risk of injury.[46] Due to the high number of players, football injuries relate to a burden for many individuals and the society as a whole.

Population-based descriptive studies investigated football injuries in players under 19 years of age based on data from presentations to emergency departments.[47-50] However, these data do not allow the calculation of exposure-related incidence rates (see Chapter 1.4). Further, these data are representative only for injuries, which were medically treated.

Our review on injuries in football players younger than 19 years of age provides a comprehensive knowledge base of injuries in youth football.[31] Numerous prospective epidemiological studies investigated injury characteristics in youth and adult football players.[51-86] However, only few and relatively small prospective studies reported separate data of football injuries in children under 13 years of age.[57, 63, 77] Our review suggests that data regarding the youngest age-groups are rare and that corresponding studies did not provide solid evidence.

Based on the findings of our review, it could be assumed that maturation influences incidence and characteristics of injuries.[31] Early maturing players have shown to have higher injury rates compared to late maturing players.[63] Child football players seem to have more fractures, fewer strains and sprains, and more injuries of the upper body compared to youth players. Skeletal and coordinative immaturity may lead to specific injury characteristics in children's football.[31] Growth-related issues are clearly an age-specific phenomenon.[87] Only limited data from methodologically inconsistent studies in the youngest players are available. Therefore, we concluded that sound epidemiological data from children's football had to be assessed.[31]

1.4 Injury surveillance

The consensus statement of the Fédération Internationale de Football Association (FIFA) on injury definitions and data collection procedures in studies on football injuries is a broadly accepted guideline.[88] When followed, it improves comparability between studies and the ability for meta-analytical assessments. According to this consensus statement a football injury is defined as:

> "Any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time loss from football activities. An injury that results in a player receiving medical attention is referred to as a "medical attention" injury, and an injury that results in a player being unable to take a full part in future football training or match play as a "time loss" injury."[88]

Many studies, regardless of the type of sport, used the time loss injury definition.[52, 79, 89-95] Thereby, time loss describes the inability to participate in sport (leading to a loss of match and/or training time). However, when including time loss injuries only, the frequency of training and match sessions influences the accuracy of the injury recording.

Especially minor injuries (e.g. inability to participate in sport for one day after injury) could be missed in low-level football because these teams do not train on a daily basis. Therefore, such slight injuries could be overlooked in low-level football, as players may not miss the subsequent training session or match play. In consequence, a comparison to data from higher levels of play could be biased. Further, (direct) access to medical care might influence the decision whether a player will be playing the day after an injury and, thus, may systematically affect injury recording.

To improve practical decision making by coaches whether a complaint had to be recorded as an injury or not, we decided to use a slightly modified version of the above mentioned injury definition. This definition has been applied earlier in youth football.[96] In our studies an injury was defined as any physical complaint sustained by a child during a scheduled training session or match play resulting in (a) the inability to complete the current match or training session, and/or (b) the absence from subsequent training sessions or matches, and/or (c) the injury requiring medical attention.

The classification of injury severity is crucial for the comparability between studies. Different criteria have been used to describe the severity of injuries (e.g. sporting time lost, working time lost, nature and duration of injury, type of treatment, permanent damage, as well as direct and indirect costs).[97] The most common classification of injury severity is based on the number of days absent from sport participation. However, different category ranges have been used. The National Athletic Injury Registration System (NAIRS) classifies injuries as “minor” (1-7 days of absence), “moderate” (8-21 days), or “major” (> 21 days).[97] Another system categorised injuries as “minor” (1-7 days of absence), “moderate” (8-28 days), and “major” (> 28 days).[98] The above mentioned FIFA consensus statement differentiates “slight” (0 days of absence), “minimal” (1-3 days), “mild” (4-7 days), “moderate” (8-28 days), “severe” (> 28 days), and “career ending” injuries.[88] Many studies have utilised the latter (or a very similar) classification system, allowing solid comparability.[52, 54, 92, 94, 95, 99-109]

Football exposure relates to training and match play and describes the time (in hours) or the number of sessions at risk. Exposure can be measured on an individual or team-based level. More complex statistical analyses (i.e. Cox models) require individual exposure data.[110]

Preferably, injury incidence is expressed as the number of injuries per 1,000 player-hours which is in line with the recommendations of the above mentioned consensus statement.

However, in studies from the United States incidence is often defined as injuries per 1,000 athlete exposures.[111-121] In these cases, the duration of training sessions or matches is not taken into account when calculating exposure. Hence, the comparability of studies might be limited due to differences in calculating injury incidence.

Study data needs to be assessed prospectively. A comparison of retrospectively collected injury data (assessed via questionnaires completed by the players at the end of the observation period) with prospectively collected data (obtained weekly by a physician during one year of follow-up) revealed inacceptable differences. The retrospectively assessed questionnaire data clearly showed a lower incidence of injuries than the data which was collected on a weekly basis. Only about one third of moderate injuries and less than one tenth of mild injuries have been remembered retrospectively. The authors concluded that the shorter the period of symptoms and the longer the time since occurrence, the more frequently the injury was forgotten.[122]

1.5 Injury prevention – what for?

Participation in sport bears a risk of sustaining injuries. Sport and recreational activities are among the leading causes of injury in youth.[123-125] In a Swiss survey sport-related injuries (organised and non-organised sports) represented 55% to 60% of all self-reported injuries in 9- to 19-year-olds.[126] Also data from the United States,[127] Canada,[123] France, the Netherlands, and the United Kingdom [128] show that organised sport is the main cause of injury in adolescents. Further data from Sweden show that sport is the most common cause of injuries in 11- to 18-year-olds.[129] Prospectively assessed injury incidences in child and youth sport range between 0.50 (95%-CI 0.29, 0.71) per 1,000 hours of physical education classes for 10- to 12-year-old children and 63.0 (95%-CI 57.5, 69.1) injuries per 1,000 match hours in under-18 male rugby union football players.[130, 131]

Injuries in young athletes can result in a reduction in current involvement in physical activity and may even lead to a dropout from sport,[132-134] which may have a considerable impact on future health as well as on quality of life.[135] The economic burden associated with injury involves medical, financial, and human resources at many levels. As such, negative consequences of injuries relate to the individual and the society as a whole.[136-138]

In the United States, annually there were an estimated 2.6 million sports- and recreation-related medical visits among 5- to 24-year-olds during 1997 and 1998.[139] Again in the United States, the costs of treating physical activity-related injuries in children aged 6 to 12 years have been estimated to be USD 1.8 billion per annum in 1997.[140] Further, an estimated half a million severe injuries (loss of more than 21 days of sport participation) among high school athletes in the United States have been reported for the period from 2005 to 2007.[141] Based on the same data set the number of football-related injuries (all levels of severity) among high school athletes has been estimated as nationally about 800,000 in the corresponding time period.[142]

In the Netherlands, direct medical costs of physical activity-related injuries in children were estimated at €170 million (plus indirect costs of €420 million) in 2003.[143] In Australia, sport-related injuries in children younger than 15 years accounted for 3.1 times the number of years lost to disability, 1.9 times the number of bed-days and 2.6 times the direct hospital costs compared to traffic accidents. From 2002 to 2011, the number of sport injuries leading to hospitalisation showed an annually increase of 4.3% (95%-CI 3.4%, 5.4%).[144]

Injuries are an unfortunate consequence of participation in sport and every effort must be made to prevent their occurrence. The strong need for physical activity on the one hand and the negative outcome of injuries on the other hand clearly demonstrate the importance and necessity of sport injury prevention – especially in children.

1.6 The development of an injury prevention programme

The “sequence of prevention” is a four-step approach to sport injury prevention (Figure 1-1).[97] According to this framework, sound prospective epidemiological data on incidences and characteristics of injuries have to be assessed as a first step. In a second step, factors and mechanisms leading to sport injuries have to be identified and described. In a third step, a tailored injury prevention programme has to be developed (based on the knowledge gathered in step 1 and step 2). Finally, the effect of the injury prevention programme has to be evaluated (step 4).[97, 145, 146] Ideally, step 4 is accomplished in a randomised controlled intervention study where the intervention programme is compared to a standard procedure (i.e. usual care).[147]

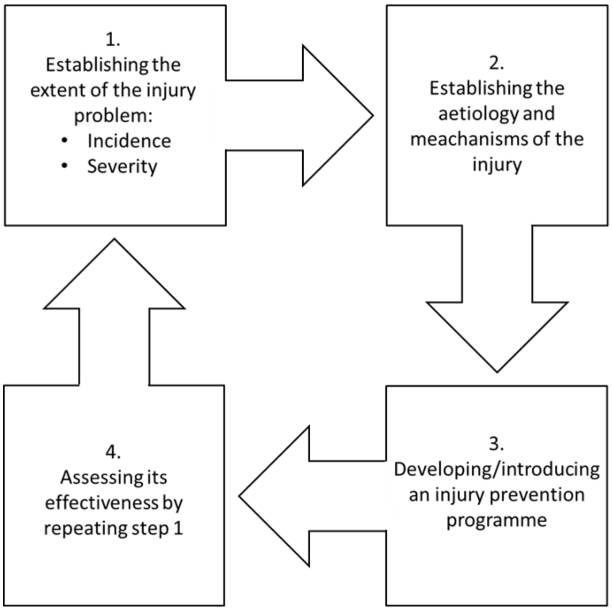

Figure 1-1: “Sequence of prevention” adapted from van Mechelen et al. (1992).

The goal of the PhD project at hand was to cover the first three steps of this model. The fourth step was planned and accomplished as a subsequent study by our working group.

The above described framework has been extended. This adapted model called “Translating Research into Injury Prevention Practice” (TRIPP) includes two further steps which cover the implementation process and the effectiveness-assessment of the injury prevention programme in the real-life setting.[147] As the name implies, this model acknowledges the critical steps to bring science into practice. Over the last years, this topic has gained increasing attention and might establish as a new field of research to assess public health outcomes and cost-effectiveness of injury prevention.[148-159]

1.7 Existing evidence of sport injury prevention

From an individual and a public health perspective it is necessary to counter potential risks of sport injuries. Many studies investigated exercise-based injury prevention programmes in adult and youth athletes over 13 years of age in football,[96, 98, 104, 113, 118, 159-174] as well as in other sports.[90, 119, 120, 175-187] There is solid evidence that the occurrence of lower limb injuries (specifically of the knee and ankle) is related to the quality of neuromuscular control during dynamic activities which might be improved with specific exercises.[135, 188, 189] Thereby, jumping/landing as well as balance exercises are of special interest in the literature.[33, 176, 180, 190-194] It could be argued that such neuromuscular exercises may also be suitable to indirectly reduce other types of injury (e.g. contact- or fall-related injuries). This reasoning is substantiated by the fact that enhancements in stability and strength of the lower extremities may improve control in critical situations such as landing, cutting, or pivoting to change direction or speed. Therefore, players who are able to withstand and control the biomechanical loads in such high-impact situations may also be able to avoid or, at least, resist unintended body contact. This in turn could also reduce the risk of falling.[33, 190] Thus, improving neuromuscular control is regarded as a promising approach to reduce injuries.[176, 188, 190, 191]

The programmes of the above mentioned studies generally aim at influencing intrinsic modifiable injury risk factors such as a lack in power, strength, or balance with team-based injury prevention strategies consisting of specific (neuromuscular) exercises. The reported injury reduction effects mostly range between 20% and 80% depending on the type of sport, target group, age, sex, level of play as well as other factors that influence injury incidence and preventive effects.

Injury prevention in children's football (under 13 years of age) has not been investigated yet.[31] This is surprising, given the popularity of football and the large number of child participants.

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2 Aims of the thesis

The objectives of the PhD project were the analysis of injury characteristics in children's football and the evaluation of existing injury prevention programmes in organised youth sports. Further, based on this knowledge, it was aimed to develop an age-specific injury prevention programme for children's football. Alongside the PhD-relevant publications, the project was flanked by a review article which analysed available information on injury incidence, mechanisms, location, type, and severity of injuries in youth football players:

"Faude O, Rössler R, Junge A. Football injuries in children and adolescent players: are there clues for prevention? Sports Med. 2013;43(9):819-37."

The specific goals of the PhD-relevant studies were:

Publication I: Injury prevention meta-analysis

To quantify the effect of exercise-based injury prevention in children and adolescents in organised sport based on a meta-analysis of (cluster-) RCTs and controlled intervention studies. Further, to describe the characteristics of the study population and the intervention, to calculate cumulative effects and effects for specific subgroups, as well as to provide recommendations for future research.

Publication II: Football injuries in children

To analyse the incidence and characteristics of football injuries in children aged 7 to 12 years.

Publication III: Risk factors for football injuries

To analyse risk factors of football injuries in children aged 7 to 12 years.

Publication IV: "FIFA 11+ Kids" – motor performance (pilot study)

To evaluate our new injury prevention programme "FIFA 11+ Kids" regarding adaptations in motor performance and movement skills in players aged 7 to 12 years.

3 Publication I: Exercise-based injury prevention in child and adolescent sport: a systematic review and meta-analysis

Roland Rössler
Lars Donath
Evert Verhagen
Astrid Junge
Thomas Schweizer
Oliver Faude

Short Title: Injury prevention meta-analysis

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*Minor editorial modifications have been made to harmonise the thesis. Appendices are consecutively numbered throughout the different manuscripts.

Exercise-based injury prevention in child and adolescent sport: a systematic review and meta-analysis

Roland Rössler (PhD Student)[1], Lars Donath (Researcher)[1], Evert Verhagen (Assistant Professor)[2,3], Astrid Junge (Professor and Head of Research)[4,5], Thomas Schweizer (Research Assistant)[1], Oliver Faude (Senior Researcher)[1]

[1]Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland
[2]Department of Public and Occupational Health, EMGO+ Institute for Health and Care Research, VU University Medical Center, Amsterdam, The Netherlands
[3]Australian Centre for Research into Injury in Sport and its Prevention (ACRISP), Federation University Australia, Victoria, Australia
[4]FIFA-Medical Assessment and Research Centre (F-MARC), Zurich, Switzerland
[5]Medical School Hamburg (MSH), Hamburg, Germany

Corresponding author:
Roland Rössler
University of Basel
Department of Sport, Exercise and Health
Birsstrasse 320B, 4052 Basel, Switzerland
email: roland.roessler@unibas.ch
phone: +41 61 377 87 39

Abstract

Background

The promotion of sport and physical activity during early years is widely recommended to support a healthy lifestyle but being engaged in sport bears the risk of sustaining injuries. Injuries, in turn, can lead to a reduction in current and future involvement in physical activity and, therefore, may negatively affect future health as well as quality of life. Thus, sports injury prevention is of particular importance in youth.

Objective

To quantify the effectiveness of exercise-based injury prevention programs in child and adolescent sport in general and with respect to different characteristics of the target group, injury prevention program, and outcome variables.

Data sources

An internet-based literature search was conducted in six databases (CINAHL, Cochrane, EMBASE, ISI Web of Science, PubMed, SPORTDiscus) using the following search terms with Boolean conjunction: (sport injur* OR athletic injur* OR sport accident*) AND (prevent* OR prophylaxis OR avoidance) AND (child* OR adolescent OR youth).

Study selection

Randomized controlled trials and controlled intervention studies in organized sport, published in English in a peer reviewed journal, analyzing the effects of an exercise-based injury prevention program in athletes younger than 19 years.

Data extraction

Two reviewers evaluated eligibility and methodological quality. Main outcome extracted was the rate ratio (RR). Statistical analyses were conducted using the inverse-variance random effects model.

Results

Twenty-one trials on a total of 27,561 athletes (median age 16.7 (10.7 - 17.8) years) were included. The overall RR was 0.54 [95% CI 0.45, 0.67] ($P < 0.001$). Girls profited more from injury prevention than boys ($P = 0.05$). Both, prevention programs with a focus on specific injuries (RR = 0.48 [95% CI 0.37, 0.63]) and those aiming on all injuries (RR = 0.62 [95% CI 0.48, 0.81]) showed significant reduction effects. Preseason and in-season interventions were similarly beneficial ($P = 0.93$). Studies on programs that include jumping/plyometric exercises showed a significant better ($P = 0.002$) injury preventive effect

(RR = 0.45 [95% CI 0.35, 0.57], Z = 6.35, $P < 0.001$) than studies without such exercises (RR = 0.74 [95% CI 0.61, 0.90], Z = 3.03, P = 0.002).

Conclusions

The results provide good evidence and clearly demonstrate beneficial effects of exercise-based injury prevention programs in youth sports, as they can result in statistically significant and practically relevant injury reduction. Especially multimodal programs including jumping/plyometric exercises can be recommended. However, there is a considerable lack of data for children (under 14 years) and for individual sports in general. Future research should include these groups and focus on the effect of specific exercises and compliance.

Key Points

- There is good evidence that exercise-based injury prevention programs can result in an injury reduction of around 46% in organized youth sport.
- Jumping/plyometric exercises appear to be particularly relevant for injury reduction.
- The beneficial effects are independent of whether the program is implemented during the preseason or in-season.

Introduction

Physical inactivity is one of the leading causes of chronic diseases, and largely contributes to the burden of disease, death, and disability worldwide. Physical activity (PA) has proven to cause immediate positive effects on health risk factors, skeletal and psychological health, as well as on mental, cardiorespiratory and neuromuscular fitness in children and adolescents.[1-3] In addition, participation in organized youth sport is positively associated with a higher level of adult PA.[4, 5] It can be stated that youth sport has important implications for long-term individual and public health benefits. Therefore, PA must be fostered starting from young age.[6, 7]

However, participating in sports bears a risk of sustaining an injury. Sport and recreational activities are the leading cause of injury in youth.[8-10] Injuries in young athletes can lead to a reduction in current and future involvement in PA.[11] This, in turn may have considerable impact on future health as well as on quality of life.[12] The economic burden associated with injury involves medical, financial, and human resources at many levels. As such, it relates to the individual and society as a whole.[13-15]

In a Swiss survey sport-related injuries (organized and non-organized sports) represented 55% to 60% of all self-reported injuries in 9 to 19-year-olds.[16] Data from the United States,[17] Canada,[8] France, the Netherlands, and the United Kingdom [18] show that organized sport is the main cause of injury in adolescents. This is further supported by recent data from Sweden showing that sport is the most common cause of injuries in 11 to 18-year-olds.[19] Prospectively assessed injury incidences range between 0.50 [95% CI 0.29, 0.71] per 1,000 hours of PE (physical education) classes for 10 to 12-year-old children and 63.0 [95% CI 57.5, 69.1] injuries per 1,000 match hours in U18 male rugby union football players.[20, 21]

In the United States, children aged 6 to 12 years spend an average of 5 to 6.5 hours per week doing sport.[22] It is estimated that each year more than one third of school-age children sustain a physical activity-related injury which needs medical care. Based on 30 million children and adolescents participating in sports in the US, the costs of treating these injuries were estimated to be $1.8 billion per annum in 1997.[23] In the Netherlands direct medical costs of PA injuries in children were estimated at €170 million (plus indirect costs of €420 million) in 2003.[24] In Australia sport-related injuries in children younger than 15 years, accounted for 3.1 times the number of years lost to disability, 1.9 times the number of bed-days and 2.6 times the direct hospital costs compared to road trauma. From 2002 to 2011 the number of sports injuries leading to hospitalization showed a significant yearly increase of 4.3% [95% CI 3.4%, 5.4%].[25]

Injuries are an unfortunate consequence of participation in sport, and every effort must be made to prevent their occurrence. The strong need for PA on the one hand and the negative outcome of sport-related injuries on the other hand clearly demonstrate the importance and necessity of sports injury prevention in youth.

Few narrative [26-29] or systematic [12, 30-34] reviews on risk factors and/or injury prevention in children and adolescents have been published. To the best of our knowledge, no meta-analysis quantitatively investigated the effectiveness of exercise-based programs to reduce sport-related injuries in children and adolescents. Thus, the aim of this meta-analysis was to quantify the effectiveness of exercise-based injury prevention programs in organized sports in under-19-year-old athletes. The detailed objectives were:

1) To quantify the effect of exercise-based injury prevention in children and adolescents based on a meta-analysis of (cluster-) randomized controlled trials and controlled intervention studies in organized sports.
2) To describe the characteristics of the study population and the intervention.
3) To calculate cumulative effects and effects for specific subgroups.
4) To provide recommendations for future research.

Methods

Literature search strategy and selection of studies

The present meta-analysis was conducted without an open-access research protocol. Relevant studies were identified using an internet-based search in six databases from inception until 14 October 2013 (Appendix 1). The following search terms were used with Boolean conjunction: (sport injur* OR athletic injur* OR sport accident*) AND (prevent* OR prophylaxis OR avoidance) AND (child* OR adolescent OR youth). The search was conducted by two researchers (RR and TS) independently. Moreover citation tracking and hand searching of key primary and review articles were carried out.

The inclusion criteria were:

- Full-text paper published in English in a peer-reviewed journal.
- Prospective controlled intervention study (randomized controlled trial, quasi-experimental, case control or cohort design) with one group not receiving any intervention.
- Assessing the effect of an injury prevention program in organized sports.
- Intervention program based on/utilized physical exercises.
- Participants were younger than 19 years
- Outcome variables include number of injuries and exposure data and/or injury incidence.

The exclusion criteria were:

- Combined injury data from organized and unorganized sports (e.g. global injury incidence of high school sports and leisure time PA) without specifying separated data.
- Study on (only) currently injured athletes or sample with a specific health problem (e.g. obesity).

According to the above-mentioned criteria, final inclusion/exclusion decision was made by two researchers (OF and RR).

Assessment of methodological quality

The methodological quality of eligible studies was rated using a study quality score developed by Abernethy and Bleakley for a review on the same topic.[30] The scale consists of a 9-item checklist whereby for each item 0, 1 or 2 points are attainable enabling a maximum rating of 18 points (Appendix 2).

To increase rating accuracy, two researchers (LD and RR) independently conducted the rating process. The raters were not blinded to study authors, place of publication, and results. In case of disagreement that arose between the first two raters a third rater (OF) was consulted and consensus was achieved.

Data extraction

Relevant study data were independently extracted by two researchers (RR and TS). These data comprised amongst others: country, study design, number, age, and sex of the athletes in the intervention and the control group, type of sport and level of performance, content, duration and implementation of the prevention program, compliance, study duration, injury definition, number of injuries, and exposure measurement.

Statistical analysis

We used the data of the primary outcome of each study. Whenever reported in the publication, the rate ratio (RR) adjusted for clustering was used. Otherwise raw data (number of injuries and exposure measure) were extracted and used to calculate the RR of the study. In some cases [35-42] values had to be calculated (using the incidence rate and the number of injuries/the exposure measure). If necessary, injury incidence rates were calculated for each study arm (intervention and control group). These injury incidences represent a proportion of the injury frequency based on either a time component (e.g. per 1,000 player hours) or a countable number (e.g. per 1,000 athlete sessions). The rate ratio was then calculated by dividing the injury rate of the intervention group by the injury rate of the control group.

A natural logarithm transformation of all RRs was conducted. According to the Cochrane Manual the standard error of the natural-logarithm-transformed RRs was calculated.[43] The inconsistency statistic was used to measure the heterogeneity of the included studies. Because the observed value was moderate to high (71%) within the group of eligible studies,[44] the analysis was conducted using a random effects model.[45] The inverse-variance method according to Deeks and Higgins (2010) was calculated by means of the Cochrane Review Manager Software (RevMan 5.1, Cochrane Collaboration, Oxford, UK; Appendix 3).[46] To assess the risk of a potential publication bias, a funnel plot was created (Appendix 4).

Three risk-of-bias-related sensitivity analyses to detect potential influences of methodological differences between studies were conducted:

- influence of study quality
- influence of randomization
- influence of type of exposure measurement

Comparison of effects between the following subgroups was accomplished:

- boys / girls
- elite level / sub-elite level
- football (soccer) / handball / basketball
- preseason / in-season / preseason and in-season
- balance exercises / jumping and plyometric exercises
- all / specific injuries (lower extremity, knee, and ankle injuries)

To test for a potential "shift in injury severity" due to the intervention, three injury categories were compared:

- mild / moderate/ severe injuries

Results

Trial flow

Of 1,835 potentially relevant articles, 94 full-texts were retrieved of which 70 did not meet the inclusion criteria and 3 met the exclusion criteria (Figure 3-1). The remaining 21 studies were included in the quantitative analysis.

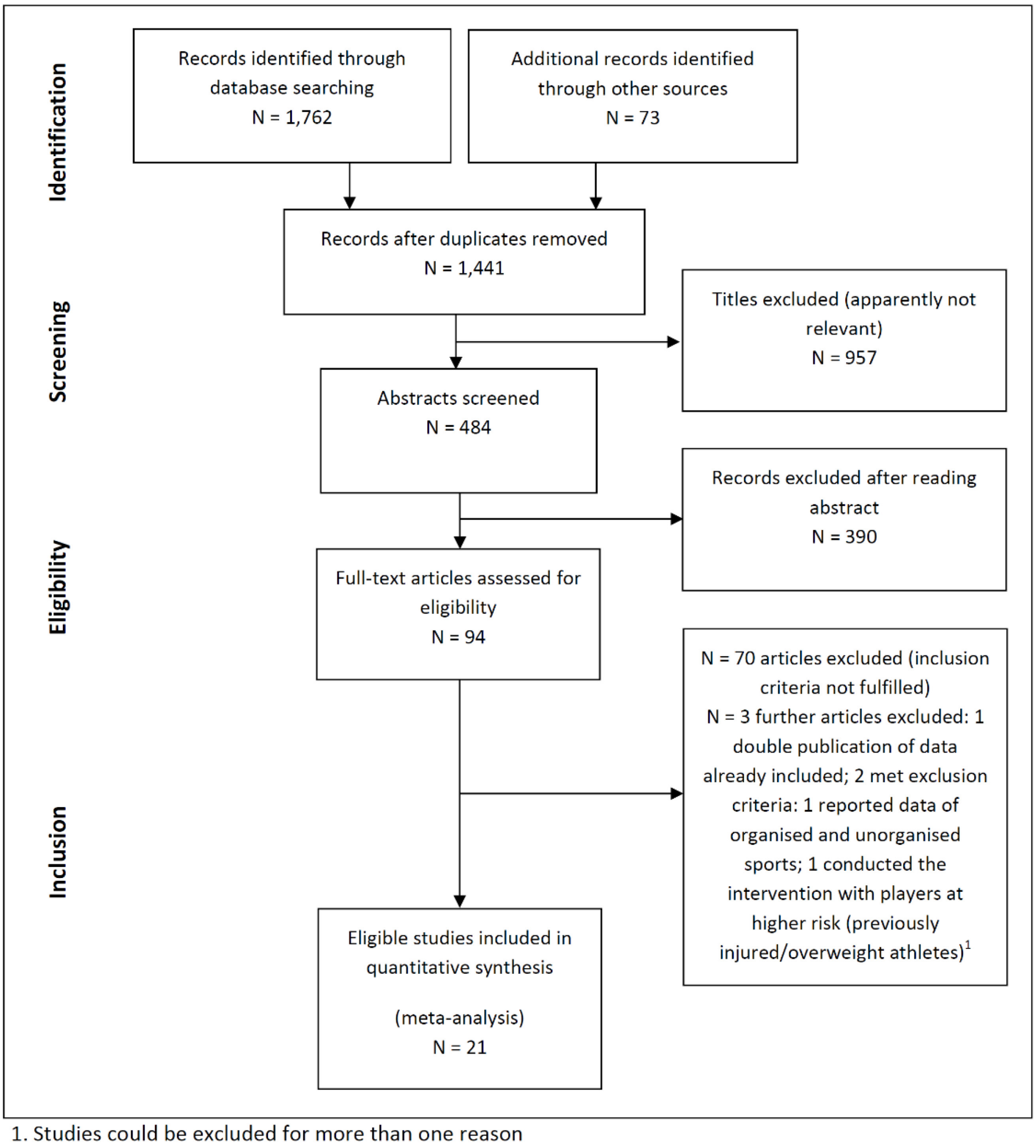

Figure 3-1: Flow diagram of the literature selection process.

Characteristics of study population, intervention and outcome variables

The included studies comprised 27,561 athletes with a median sample size of 829 (range 50 - 5,703) per study (Table 3-1). The median age of those studies which reported athlete age was 16.7 (10.7 - 17.8) years. Only one study focused on primary school children under the age of 14 years,[47] and some others included children younger than 14 years but did not report separate age-related data.[48-52] Ten studies involved girls only,[35, 36, 38, 40-42, 50, 52-54] four boys,[37, 39, 51, 55] and seven studies both sexes.[47-49, 56-59] In total just 12.7% of participants were boys. Four studies (10.5%) investigated the elite level,[39, 51, 53, 55, 56] 15 (82.2%) the sub-elite level,[35-38, 40-42, 48-50, 52, 54, 57-59] and one study (7.3%) participants of physical education classes at school.[47]

Nine studies exclusively analyzed football players,[35, 37, 39, 40, 48, 50, 52-54] and four further studies included football together with other types of sport.[36, 38, 41, 58] Two studies focused on handball [42, 59] and three on basketball.[49, 51, 56] Ten studies aimed at prevention of all injuries,[35, 37, 42, 47-49, 51, 54, 55, 57] 11 at injuries in specific body parts or specific diagnosis (lower extremity, knee, or ankle injuries).[36, 38-41, 50, 52, 53, 56, 58, 59] Three studies investigated the effect of preseason conditioning on injury incidence during the subsequent season,[35, 36, 55] 15 analyzed the effects of an intervention which was conducted during the competitive season,[37-42, 47-49, 51-53, 56, 57, 59] and three did both.[50, 54, 58] Thirteen programs [35, 36, 38, 40-42, 47, 48, 50-53, 59] contained jumping/plyometric exercises, and eight [37, 39, 49, 54-58] no such exercises. Fourteen programs [38, 39, 42, 48-54, 56-59] consisted of or included balance exercises while seven studies [35-37, 40, 41, 47, 55] did not. Eighteen studies used an exposure measure based on hours or the count of training sessions/games [36-38, 40-42, 47-56, 58, 59], and three used the number of athletes or athlete seasons.[35, 39, 57] Twelve studies reported injury severity data.[37, 39, 42, 48-51, 53-55, 58, 59]

Table 3-1: Overview of studies investigating exercise-based injury prevention programs (alphabetical order by first author).

Author, year, study type, country	Athletes (n), age (y),[a] sex (% boys)	Type of sport, level of performance	Type and duration of prevention program session, frequency, difficulty, compliance	Duration and time of intervention	Injury definition and data collection method	Study quality, type of injuries, rate ratio [95% CI]
Collard et al 2010, cluster RCT, The Netherlands [47]	2011 pupils (IG 1015, CG 996), age IG 10.7 (0.8), age CG 10.7 (0.8), 49.1	Diverse sports, primary school children	5 min-training (strength, coordination, speed, and flexibility exercises) at beginning and end of each PE class and pedagogic approach focusing on children and parents, twice per week, continuous difficulty, compliance 99.9%	8 months intervention (19 months follow up during school year, January 2006 to July 2007)	Sports club injury leading to medical attention or time loss , weekly self-reported (questionnaire)	14 all injuries: 0.69 [0.28, 1.68]
Cumps et al 2007, controlled clinical pilot trial, Belgium [56]	50 players (IG 26, CG 24), age IG 17.7 (3.9), age CG 18.0 (2.7), 68	Basketball, elite	5-10 min basketball specific balance training on balance semi globes, 3 sessions per week, progressive difficulty (4 different phases), compliance n.a.	22 weeks	Medical attention and time loss, weekly self-reported (questionnaire)	10 acute lateral ankle sprain: 0.34 [0.12, 0.96]
Emery et al 2005, cluster RCT, Canada [57]	114 pupils (IG 60, CG 54), age IG 15.9 (15.6-16.1), age CG 15.8 (15.5-16.0), 50	Diverse sports, PE classes, high school	20 min proprioceptive home-based balance-training program (static and dynamic balance) including wobble board exercises, daily during 6 weeks then 1 session per week throughout season, progressive difficulty, compliance did not have a significant effect on change in dynamic balance	6 months (autumn 2001)	Medical attention or time loss, self-reported (biweekly telephone calls to all participants by physiotherapist)	13 all injuries: 0.20 [0.05, 0.88]
Emery et al 2007, cluster RCT, Canada [49]	920 players (IG 494, CG 426), age IG Median 16 (13-18), age CG Median 16 (12-18), 50.4	Basketball, sub elite (high school)	15 min warm-up routine (including aerobic, static/dynamic stretching and balance training); 20 min home exercise on wobble board, before all practice sessions (approximately 5 sessions per week), continuous difficulty, compliance 6 0.3% (home training)	1 year (one 18-week season: November 2004 to March 2005)	Medical attention, removal from current session or time loss, assessed by blinded therapist	15 all injuries: 0.80 [0.57, 1.11]

Table 3-1 continued.

Author, year, study type, country	Athletes (n), age (y),[a] sex (% boys)	Type of sport, level of performance	Type and duration of prevention program session, frequency , difficulty, compliance	Duration and time of intervention	Injury definition and data collection method	Study quality, type of injuries, rate ratio [95% CI]
Emery 2010, cluster RCT, Canada [48]	744 players (IG 380, CG 364), U13-U18 players, 44.6	Indoor football, sub elite	15 min warm-up program with neuromuscular training (core strengthening, single leg jumps, single leg balance) at the beginning of each training/match and 15 min home-based wobble board sessions, continuous difficulty, compliance n.a.	1 year (one 20-week indoor season: October 2006 to March 2007)	Medical attention, time loss or removal from a session, assessed by blinded therapist	15 all injuries: 0.62 [0.39, 0.99]
Heidt et al 2000, RCT, USA [35]	300 players (IG 42, CG 258), age 14 to 18 years, 0	Football, sub elite (high school)	Preseason conditioning program including two training sessions on (inclined) treadmill and one plyometric training session per week, progressive difficulty, compliance n.a.	7-week preseason intervention program, 1 year follow up	Time loss, assessed by blinded athletic trainer	10 all injuries: 0.42 [0.20, 0.91]
Hewett et al 1999, prospective study, USA [36]	829 players (IG 366, CG 463), age not available, 0	Football, basketball and volleyball, high school	60-90 min preseason neuromuscular training program (including flexibility, plyometrics, and weight training), 3 sessions per week, progressive difficulty, compliance 70%	6 weeks preseason intervention program, 1 school year/season	Medical attention and time loss (at least 5 days), assessed by athletic trainer and diagnosed by physician	6 ACL or MCL injuries: 0.27 [0.06, 1.23]
Junge et al 2002, prospective controlled intervention study, Switzerland [37]	194 players (IG 101, CG 93), age IG 16.7, age CG 16.3, 100	Football, high skill (45%) and low skill (55%) players	Prevention program (including warm-up and cool-down, stabilization of knee and ankle, flexibility, strength, endurance, coordination, and promotion of fair play), progressive difficulty, compliance n.a.	2 seasons (1999 and 2000) (1-year observation period)	Time loss or physical complaint for more than 2 weeks, documented weekly by physicians	9 all injuries: 0.79 [0.59, 1.06]
Kiani et al 2010, community based intervention trial, Sweden [50]	1506 players (IG 777, CG 729), age IG 14.7 (range 12.7-18.6), age CG 15.0 (range 13.0-17.6), 0	Football, sub elite	20-25 min intervention program including physical sessions (warm-up, strengthening, landing exercises) and a pedagogic approach (one seminar for athletes, parents and coaches), 2 session per week during preseason, 1 session per week during regular season, continuous difficulty, compliance 78% in preseason, 99% in regular season	February to October 2007 (one entire season and 12 weeks preseason training)	Medical attention, documented weekly by study investigator	9 acute knee injuries: 0.17 [0.04, 0.64]

Table 3-1 continued.

Author, year, study type, country	Athletes (n), age (y),[a] sex (% boys)	Type of sport, level of performance	Type and duration of prevention program session, frequency , difficulty, compliance	Duration and time of intervention	Injury definition and data collection method	Study quality, type of injuries, rate ratio [95% CI]
LaBella et al 2011, cluster RCT, USA [38]	1492 players (IG 737, CG 755) age IG 16.2 (1.5), age CG 16.2 (1.1), 0	Football and basketball, sub elite (high school)	20 min neuromuscular warm-up training (including strengthening, plyometrics, balance and agility exercises) (abbreviated version before match), mean 3.3 (SD 1.5) sessions per week, progressive difficulty, compliance 80.4%	1 season (2006 and 2007)	Time loss, documented by research assistants	13 lower extremity injuries: 0.42 [0.30, 0.59]
Longo et al 2012, cluster RCT, Italy [51]	121 players (IG 80, CG 41) age IG 13.5 (2.3), age CG 15.2 (4.6), 100	Basketball, elite (third league)	20 min neuromuscular warm-up training (including strengthening, plyometrics, balance and agility exercises) (abbreviated version before match), 6 sessions per week during the first month and 3-4 during the following months, progressive difficulty, compliance 100%	9 months (August 2009 to April 2010)	Time loss, reported by coaches and recorded by blinded orthopedic specialist	13 all injuries: 0.44 [0.22, 0.89]
Malliou et al 2004, prospective controlled intervention study, Greece [39]	100 players (IG 50, CG 50), age IG 16.7 (0.5), age CG 16.9 (0.7), 100	Football, elite	20 min proprioception training (balance training, football-specific balance training including balance exercises with Biodex Stability System, mini trampoline and balance boards), 2 sessions per week, difficulty n.a., compliance n.a.	12 months (2001 to 2002)	Time loss, biweekly by orthopedic surgeon, physiotherapist and/or trainer	8 lower extremity injuries: 0.68 [0.49, 0.95]
Mandelbaum et al 2005, prospective controlled cohort study, USA [40]	5703 players (IG 1885, CG 3818), age 14 to 18 0	Football, sub elite	20-min warm-up program (including stretching, strengthening, plyometrics and soccer specific agility drills), continuous difficulty, compliance n.a.	2 seasons (2000 and 2001)	Medical attention and confirmation via MRI and/or arthroscopic procedure, reported weekly by coach	9 non-contact ACL injuries: 0.18 [0.08, 0.42]
McGuine and Keene 2006, cluster RCT, USA [58]	765 players (IG 373, CG 392), age IG 16.4 (1.2), age CG 16.6 (1.1), 31.6	Football and basketball, sub elite (high school)	10 min balance training program with a balance board, 5 times a week during preseason, 3 times a week during regular season, progressive difficulty, compliance 91%	4 weeks preseason and during the subsequent season	Time loss, reported by certified athletic trainers	14 ankle sprains: 0.56 [0.33, 0.95]

Table 3-1 continued.

Author, year, study type, country	Athletes (n), age (y),[a] sex (% boys)	Type of sport, level of performance	Type and duration of prevention program session, frequency, difficulty, compliance	Duration and time of intervention	Injury definition and data collection method	Study quality, type of injuries, rate ratio [95% CI]
Olsen et al 2005, cluster RCT, Norway [59]	1837 players (IG 958, CG 879), age IG 16.3 (0.6), age CG 16.2 (0.6), 13.7	Handball, sub elite	15-20 min warm-up program (including running, technique, balance (with ball, wobble board or balance mat), strength and power exercises), once before the first 15 trainings, then 1 session per week, progressive difficulty, compliance 87%	1 season (8 months, September 2002 to April 2003)	Time loss or medical attention, recorded by 10 blinded research physiotherapists	16 lower extremity injuries: 0.51 [0.36, 0.73]
Pfeiffer et al 2006, prospective cohort study, USA [41]	1439 players (IG 577, CG 862), age not available, 0	Football, basketball and volleyball, high school	20-min plyometric-based exercise program, twice a week, progressive difficulty, compliance n.a.	2 seasons/years	Noncontact ACL injury resulting from a mechanism of running and cutting or landing (re-injuries excluded from the statistical analysis), documented by coaches or athletic trainers	6 non-contact ACL injuries: 2.15 [0.44, 10.66]
Scase et al 2006, non-randomized CT, Australia [55]	723 players (IG 114, CG 609), age IG 17.0 (2.5), age CG 17.0 (2.6), 100	Australian rules football, elite U18 national competition	30 min program (training of falling and landing skills), weekly during preseason (8 sessions in total), progressive difficulty, compliance n.a.	2 seasons (2002 and 2003), 8 weeks of preseason intervention	Time loss (at least 1 game), documented by team doctor physiotherapist or sports trainer	11 all injuries: 0.72 [0.52, 0.98]
Soligard et al 2008, cluster RCT, Norway [53]	1892 players (IG 1055, CG 837), age IG 15.4 (0.7), age CG 15.4 (0.7), 0	Football, sub elite	20 min warm-up program during training (including running, strength, plyometrics and balance exercises) (abbreviated version before match), approximately 2-6 sessions per week, progressive difficulty, compliance 77%	1 season (8 months) (March to October 2007)	Time loss, recorded by physical therapist and medical student	16 lower extremity injuries: 0.71 [0.49, 1.03]
Steffen et al 2008, cluster RCT, Norway [54]	2020 players (IG 1073, CG 947), age IG 15.4 (0.8), age CG 15.4 (0.8), 0	Football, sub elite U17 league players	20 min warm-up program (including jogging, core stability, balance [with balance mats], stabilization and hamstrings strength exercises), once during the first 15 training sessions, then 1 session per week, continuous difficulty, compliance 52%	1 season (March to October 2005) including 2 months of preseason	Time loss, recorded by blinded physical therapists	16 all injuries: 1.00 [0.83, 1.20]

Table 3-1 continued.

Author, year, study type, country	Athletes (n), age (y),[a] sex (% boys)	Type of sport, level of performance	Type and duration of prevention program session, frequency , difficulty, compliance	Duration and time of intervention	Injury definition and data collection method	Study quality, type of injuries, rate ratio [95% CI]
Waldén et al 2012, stratified cluster RCT, Sweden [52]	4564 players (IG 2479, CG 2085), age IG 14.0 (range 12.0-17.0), age CG 14.1 (range 12.0-17.0), 0	Football, sub elite	15 min neuromuscular warm-up program (including exercises focusing on knee control, core stability, jumping and landing technique), 2 times per week, progressive difficulty, compliance 53%	1 season (7 months in 2009)	Acute knee injury with time loss (excluding contusions), recorded by coaches	16 ACL injuries: 0.36 [0.15, 0.85]
Wedderkopp et al 1999, cluster RCT, Denmark [42]	237 players (IG 111, CG 126), age 16 to 18, 0	Handball, recreational, intermediate and elite	10-15 min balance training with ankle disks and warm-up program including jumps and medicine ball training, at all practice sessions (approximately 1-5 times per week), progressive difficulty possible, compliance n.a.	1 season (10 months, August 1995 to May 1996)	Time loss or considerable discomfort, recorded by coaches	8 all injuries: 0.26 [0.14, 0.45]

[a]Data are mean (SD) except where stated otherwise.

RCT = Randomized controlled trial, CT = Controlled trial, IG = Intervention group, CG = Control group, U13 = Under-13 year category, U17 Under-17 year category, U18 Under-18 year category, PE = Physical education, n.a. = Not available, MRI = Magnetic resonance imaging, ACL = Anterior cruciate ligament, MCL = Medial collateral ligament, CI = Confidence interval

Quality of the studies

Thirteen studies used a (cluster-) randomized design,[35, 38, 42, 47-49, 51-54, 57-59] and eight studies investigated effects compared to a control group in a non-randomized setting.[36, 37, 39-41, 50, 55, 56]

On average the quality score of the studies was 11.8 (SD 3.3), ranging from 6 to 16. The mean score of the 11 "high-quality" studies was 14.6 (SD 1.2) [38, 47-49, 51-54, 57-59] and of the 10 "poor-quality" studies 8.6 (SD 1.6).[35-37, 39-42, 50, 55, 56] The most obvious differences between these studies were definition of inclusion and exclusion criteria; description of dropouts and including dropped-out participants in the analysis; blinding of injury assessors; and randomization of participants. There were nearly no differences between "high-" and "poor-quality" studies concerning the definition of outcome measure; active surveillance/appropriate duration of study period; and description of the applied intervention program (Appendix 5).

Risk of bias

The funnel plot (Appendix 4) showed neither a perfect funnel-shape nor an obvious publication bias, although it seems that small-sized studies with indifferent effects are missing.

To determine whether the methodological quality of included studies affected the cumulative effect, "high-" and "poor-quality" studies were compared. The cumulated RR of "high-quality" (0.59 [95% CI 0.46, 0.76]) and "poor-quality" studies (0.47 [95% CI 0.33, 0.67]) was not significantly different ($P = 0.29$). Studies with a randomized design (0.54 [95% CI 0.42, 0.70]) did not significantly differ from non-randomized studies (0.54 [95% CI 0.37, 0.78], $P = 0.99$). Studies reporting exposure based on hours or number of sessions (RR = 0.55 [95% CI 0.44, 0.68]) showed a similar ($P = 0.83$) effect as studies with an exposure measurement based on athlete seasons (RR = 0.51 [95% CI 0.30, 0.89]).

Quantitative data synthesis

The cumulative analysis showed a significant overall effect of injury prevention programs in children and adolescents (RR = 0.54 [95% CI 0.45, 0.67]; Figure 3-2).

Studies showed significant beneficial prevention effects ($P < 0.001$) for minor (RR = 0.75 [95% CI 0.63, 0.88]), moderate (RR = 0.58 [95% CI 0.44, 0.78]) and severe injuries (RR = 0.68 [95% CI 0.51, 0.90]) with no significant difference ($P = 0.36$) between the three degrees of injury severity (minor ≤ 1 week of absence, moderate 1 to 2/3/4 weeks of absence, severe ≥ 2/3/4 weeks of absence). There was similar effectiveness of programs in reducing “all” (RR = 0.62 [95% CI 0.48, 0.81]), “lower extremity” (RR = 0.57 [95% CI 0.44, 0.72]), and “ankle” (RR = 0.51 [95% CI 0.31, 0.81]) injuries (Figure 3-3).

By trend (P = 0.10) injury prevention of “knee” injuries (RR = 0.32 [95% CI 0.15, 0.68]) was more effective compared to the subgroup of studies focusing on “all” injuries.

Injury prevention programs were significantly more effective when exclusively girls were targeted (RR = 0.44 [95% CI 0.28, 0.68]) than when only boys were included in the study (RR = 0.71 [95% CI 0.60, 0.85], P = 0.05). Studies on the sub-elite level (RR = 0.51 [95% CI 0.39, 0.67]) tended to show greater injury reduction than studies on elite athletes (RR = 0.67 [95% CI 0.55, 0.80], P = 0.11). Studies on programs that included jumping/plyometric exercises showed a significantly greater injury preventive effect (RR = 0.45 [95% CI 0.35, 0.57]) than studies without such exercises (RR = 0.74 [95% CI 0.61, 0.90], P = 0.003).

No significant differences were observed between studies on football, handball, and basketball (Figure 3-4); preseason conditioning, programs during season and preseason- plus in-season-conditioning (P = 0.93); and programs with and without balance exercises (P = 0.76).

Study or subgroup	log[rate ratio]	SE	Intervention Total	Control Total	Weight%	Rate ratio IV, Random, 95% CI
Steffen 2008 [54]	0	0.093	242	241	8.1	1.00 [0.83, 1.20]
Junge 2002 [37]	-0.233	0.148	77	111	7.3	0.79 [0.59, 1.06]
Scase 2006 [55]	-0.332	0.161	66	330	7.1	0.72 [0.52, 0.98]
Malliou 2004 [39]	-0.383	0.167	60	88	7.0	0.68 [0.49, 0.95]
Emery 2007 [49]	-0.228	0.169	130	141	7.0	0.80 [0.57, 1.11]
LaBella 2011 [38]	-0.873	0.174	50	96	6.9	0.42 [0.30, 0.59]
Olsen 2005 [59]	-0.672	0.181	66	115	6.8	0.51 [0.36, 0.73]
Soligard 2008 [53]	-0.342	0.189	161	215	6.7	0.71 [0.49, 1.03]
Emery 2010 [48]	-0.478	0.239	50	79	5.9	0.62 [0.39, 0.99]
McGuine 2006 [58]	-0.581	0.271	23	39	5.4	0.56 [0.33, 0.95]
Wedderkopp 1999 [42]	-1.365	0.294	14	66	5.1	0.26 [0.14, 0.45]
Longo 2012 [51]	-0.825	0.361	14	17	4.2	0.44 [0.22, 0.89]
Heidt 2000 [35]	-0.861	0.392	7	91	3.8	0.42 [0.20, 0.91]
Mandelbaum 2005 [40]	-1.707	0.426	6	67	3.5	0.18 [0.08, 0.42]
Waldén 2012 [52]	-1.021	0.439	49	47	3.3	0.36 [0.15, 0.85]
Collard 2010 [47]	-0.378	0.458	44	40	3.2	0.69 [0.28, 1.68]
Cumps 2007 [56]	-1.071	0.528	5	10	2.6	0.34 [0.12, 0.96]
Kiani 2010 [50]	-1.801	0.691	3	13	1.8	0.17 [0.04, 0.64]
Emery 2005 [57]	-1.609	0.756	2	10	1.5	0.20 [0.05, 0.88]
Hewett 1999 [36]	-1.314	0.775	2	10	1.5	0.27 [0.06, 1.23]
Pfeiffer 2006 [41]	0.767	0.816	3	3	1.3	2.15 [0.44, 10.66]
Total (95% CI)			**1074**	**1829**	**100.0%**	**0.54 [0.45, 0.67]**

Heterogeneity: Tau² = 0.12; Chi² = 67.96, df = 20 (P < 0.00001); I² = 71%
Test for overall effect: Z = 5.92 (P < 0.00001)

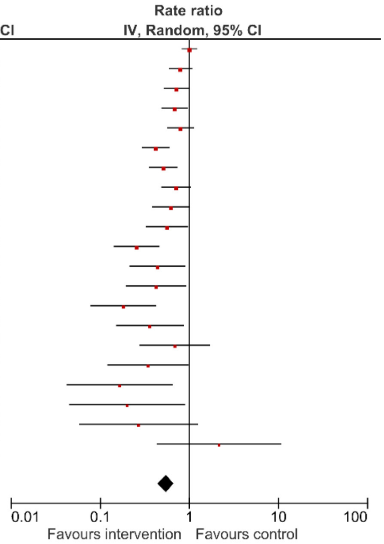

Figure 3-2: Overall effect of exercise-based sport injury prevention programs (sorted by weight). SE = standard error, IV = inverse-variance, CI = confidence interval.

Study or subgroup	log[rate ratio]	SE	Intervention Total	Control Total	Weight%	Rate ratio IV, Random, 95% CI
"global focus"						
Steffen 2008 [54]	0	0.093	242	241	8.1	1.00 [0.83, 1.20]
Junge 2002 [37]	-0.233	0.148	77	111	7.3	0.79 [0.59, 1.06]
Scase 2006 [55]	-0.332	0.161	66	330	7.1	0.72 [0.52, 0.98]
Emery 2007 [49]	-0.228	0.169	130	141	7.0	0.80 [0.57, 1.11]
Emery 2010 [48]	-0.478	0.239	50	79	5.9	0.62 [0.39, 0.99]
Wedderkopp 1999 [42]	-1.365	0.294	14	66	5.1	0.26 [0.14, 0.45]
Longo 2012 [51]	-0.825	0.361	14	17	4.2	0.44 [0.22, 0.89]
Heidt 2000 [35]	-0.861	0.392	7	91	3.8	0.42 [0.20, 0.91]
Collard 2010 [47]	-0.378	0.458	44	40	3.2	0.69 [0.28, 1.68]
Emery 2005 [57]	-1.609	0.756	2	10	1.5	0.20 [0.05, 0.88]
Subtotal (95% CI)			**646**	**1126**	**53.2**	**0.62 [0.48, 0.81]**
Heterogeneity: Tau² = 0.10; Chi² = 31.08, df = 9 (P = 0.0003); I² = 71%						
Test for overall effect: Z = 3.58 (P = 0.0003)						
focus on knee injuries						
Mandelbaum 2005 [40]	-1.707	0.426	6	67	3.5	0.18 [0.08, 0.42]
Waldén 2012 [52]	-1.021	0.439	49	47	3.3	0.36 [0.15, 0.85]
Kiani 2010 [50]	-1.801	0.691	3	13	1.8	0.17 [0.04, 0.64]
Hewett 1999 [36]	-1.314	0.775	2	10	1.5	0.27 [0.06, 1.23]
Pfeiffer 2006 [41]	0.767	0.816	3	3	1.3	2.15 [0.44, 10.66]
Subtotal (95% CI)			**63**	**140**	**1.4**	**0.32 [0.15, 0.68]**
Heterogeneity: Tau² = 0.35; Chi² = 8.16, df = 4 (P = 0.09); I² = 51%						
Test for overall effect: Z = 2.98 (P = 0.003)						
focus on ankle injuries						
McGuine 2006 [58]	-0.581	0.271	23	39	5.4	0.56 [0.33, 0.95]
Cumps 2007 [56]	-1.071	0.528	5	10	2.6	0.34 [0.12, 0.96]
Subtotal (95% CI)			**28**	**49**	**8.0**	**0.51 [0.31, 0.81]**
Heterogeneity: Tau² = 0.00; Chi² = 0.68, df = 1 (P = 0.41); I² = 0%						
Test for overall effect: Z = 2.83 (P = 0.005)						
focus on lower extrimity injuries						
Malliou 2004 [39]	-0.383	0.167	60	88	7.0	0.68 [0.49, 0.95]
LaBella 2011 [38]	-0.873	0.174	50	96	6.9	0.42 [0.30, 0.59]
Olsen 2005 [59]	-0.672	0.181	66	115	6.8	0.51 [0.36, 0.73]
Soligard 2008 [53]	-0.342	0.189	161	215	6.7	0.71 [0.49, 1.03]
Subtotal (95% CI)			**337**	**514**	**27.4**	**0.57 [0.44, 0.72]**
Heterogeneity: Tau² = 0.03; Chi² = 6.06, df = 3 (P = 0.11); I² = 50%						
Test for overall effect: Z = 4.51 (P < 0.00001)						
Total (95% CI)			**1074**	**1829**	**100.0**	**0.54 [0.45, 0.67]**
Heterogeneity: Tau² = 0.12; Chi² = 67.96, df = 20 (P < 0.00001); I² = 71%						
Test for overall effect: Z = 5.92 (P < 0.00001)						
Test for subgroup differences: Chi² = 2.97, df = 3 (P = 0.40), I² = 0%						

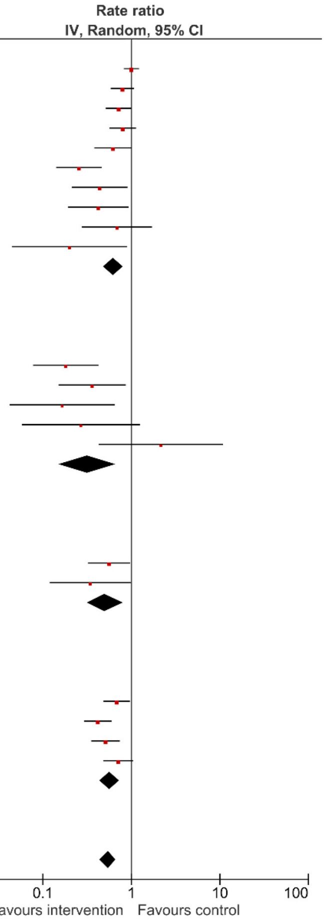

Figure 3-3: Effects of exercise-based sport injury prevention programs focusing on "all", "lower extremity", "knee", and "ankle" injuries (sorted by weight). SE = standard error, IV = inverse-variance, CI = confidence interval.

Study or subgroup	log[rate ratio]	SE	Intervention Total	Control Total	Weight%	Rate ratio IV, Random, 95% CI
Football (Soccer)						
Steffen 2008 [54]	0	0.093	242	241	11.5	1.00 [0.83, 1.20]
Junge 2002 [37]	-0.233	0.148	77	111	10.6	0.79 [0.59, 1.06]
Malliou 2004 [39]	-0.383	0.167	60	88	10.2	0.68 [0.49, 0.95]
Soligard 2008 [53]	-0.342	0.189	161	215	9.8	0.71 [0.49, 1.03]
Heidt 2000 [35]	-0.861	0.392	7	91	6.0	0.42 [0.20, 0.91]
Mandelbaum 2005 [40]	-1.707	0.426	6	67	5.5	0.18 [0.08, 0.42]
Waldén 2012 [52]	-1.021	0.439	49	47	5.3	0.36 [0.15, 0.85]
Kiani 2010 [50]	-1.801	0.691	3	13	2.9	0.17 [0.04, 0.64]
Subtotal (95% CI)			**605**	**873**	**61.6**	**0.57 [0.42, 0.79]**
Heterogeneity: Tau² = 0.14; Chi² = 30.32, df = 7 (P < 0.0001); I² = 77%						
Test for overall effect: Z = 3.35 (P = 0.0008)						
Basketball						
Emery 2007 [49]	-0.228	0.169	130	141	10.2	0.80 [0.57, 1.11]
Longo 2012 [51]	-0.825	0.361	14	17	6.5	0.44 [0.22, 0.89]
Cumps 2007 [56]	-1.071	0.528	5	10	4.2	0.34 [0.12, 0.96]
Subtotal (95% CI)			**149**	**168**	**20.8**	**0.57 [0.34, 0.97]**
Heterogeneity: Tau² = 0.11; Chi² = 4.03, df = 2 (P = 0.13); I² = 50%						
Test for overall effect: Z = 2.09 (P = 0.04)						
Handball						
Olsen 2005 [59]	-0.672	0.181	66	115	9.9	0.51 [0.36, 0.73]
Wedderkopp 1999 [42]	-1.365	0.294	14	66	7.7	0.26 [0.14, 0.45]
Subtotal (95% CI)			**80**	**181**	**17.6**	**0.38 [0.19, 0.74]**
Heterogeneity: Tau² = 0.18; Chi² = 4.03, df = 1 (P = 0.04); I² = 75%						
Test for overall effect: Z = 2.85 (P = 0.004)						
Total (95% CI)			**834**	**1222**	**100.0%**	**0.53 [0.41, 0.69]**
Heterogeneity: Tau² = 0.15; Chi² = 52.57, df = 12 (P < 0.00001); I² = 77%						
Test for overall effect: Z = 4.77 (P < 0.00001)						
Test for subgroup differences: Chi² = 1.30, df = 2 (P = 0.52), I² = 0%						

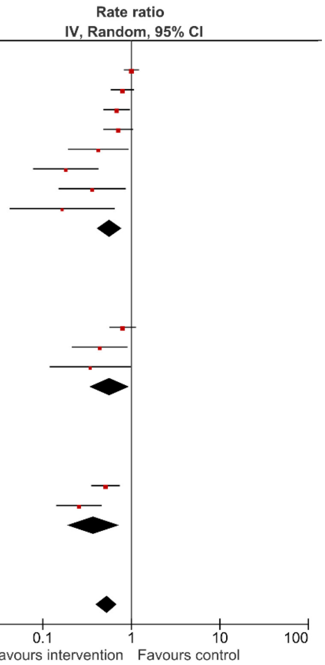

Figure 3-4: Effects of exercise-based injury prevention programs in football (outdoor only), basketball, and handball (sorted by weight). SE = standard error, IV = inverse-variance, CI = confidence interval.

Discussion

Comparison with other (systematic) reviews

To date no meta-analysis was available that specifically examines the effects of injury prevention programs in children and adolescents. Ten years ago, Emery wrote a systematic review on risk factors in child and adolescent sport.[12] Mainly based on the evidence presented in case control and cross-sectional studies she concluded that injury prevention programs targeting on potentially modifiable risk factors are warranted and proprioceptive training is recommended. She noted that there is only limited evidence from high quality studies and especially RCTs.

A key to injury prevention is the modification of intrinsic risk factors. Hereby jumping/plyometric and balance exercises seem to be of special interest in the literature. Basically these are two different approaches as one focusses on strength and the other one on proprioception. Therefore, these two concepts are compared with regard to their effects on injury reduction.[12, 36]

In 2007, a systematic review of Abernethy and Bleakley that included 7 studies, reported beneficial effects of sports injury prevention programs in adolescent sport (without providing a quantitative synthesis).[30] Currently sports injury prevention is a trending topic, and within the last six years, since the review by Abernethy and Bleakley, 10 studies of which 8 were high-quality studies have been published. Consequently we included these in our systematic review and meta-analysis. In 2009, Frisch et al systematically reviewed the effects of exercise-based injury prevention programs in youth sports.[32] Without providing a quantitative synthesis they concluded that injury prevention is effective when the compliance to the program is high. Our systematic review updates their findings, as since then six new studies, of which five are of high quality, were published.

Ladenhauf et al reviewed anterior cruciate ligament (ACL) injury prevention programs in young athletes.[29] They concluded that programs are effective in reducing injury risk and recommend age-appropriate strength and neuromuscular balance exercises. Gagnier et al also focused on ACL injuries.[60] They conducted a systematic review and meta-analysis of ACL prevention programs in adolescents and adults and found a significant reduction of injuries (RR = 0.49 [95% CI 0.30, 0.79]). Myer et al conducted a meta-analysis to investigate whether the effectiveness of ACL injury prevention programs in female athletes is age-dependent.[61] They found an age-related association between the application of injury prevention programs and reduction of ACL incidence, and recommend the implementation of ACL prevention during early adolescence. Herman et al systematically reviewed neuromuscular warm-up programs, which require no additional equipment, for preventing lower limb injuries.[62] They found beneficial effects in five different prevention programs. Six of the studies they included comprised youth athletes. Thus, we considered these studies as well.

Van Beijsterveldt et al conducted a systematic review on exercise-based injury prevention programs with a specific focus on football players.[63] Although the focus of their review was not specifically set to youth athletes, five out of six studies investigated youth football. Consequently, we included these five studies in our review as well.

Nauta and colleagues recently reviewed the effectiveness of school- and community-based injury prevention programs on risk behavior and injury risk in 8 to 12-year-old children.[64] They concluded that the results with regard to active prevention were inconclusive. This is probably due to the small number of exercise-based injury prevention studies in the school- and community-based setting.

The present systematic review is the first meta-analysis that quantifies the effects of injury prevention programs in children and adolescents in organized sports. Thus, it updates and extends the systematic reviews of Frisch et al as well as Abernethy and Bleakley, and provides a broad overview as well as cumulative and detailed subgroup analyses.[30, 32] The aim of this systematic review is to summarize the current evidence in the broadest possible way for youth sports and to clarify more specific questions in appropriate subgroup analyses.

Effectiveness of preventive programs

The cumulated overall effect size indicates an injury reduction of 46%. This value is slightly reduced to 41% when only “high-quality” studies are taken into account. However, even a moderate reduction of all sports injuries is of acute significance for the young peoples’ health and could have a short- and long-term economic impact on health care costs.[15, 65] The sensitivity analyses did not reveal significant differences with respect to study quality and type of exposure measurement.

Most of the studies involved girls, and thus, boys were highly underrepresented accounting for just one eighth of all participants. This is in contrast to the higher PA participation rates observed in boys as compared to girls.[66-68] The risk of sports injuries is similar for both sexes, except for some specific types of injuries (e.g. ACL injuries, concussions).[69-72]

The present meta-analysis revealed that girls profited significantly more from injury prevention than boys. Based on the present data it is speculative to assume that girls have a greater potential to respond to exercise-based injury prevention. As data for boys are underrepresented, further research is required to clarify underlying reasons.

Both, elite and sub-elite athletes profited significantly from prevention programs. The slightly lower effect in elite than in sub-elite athletes could be due to a ceiling effect, meaning that better trained athletes have less potential for further improvements (e.g. neuromuscular performance). To minimize the probability of ceiling effects, programs should enable the possibility of variation and progression.[32]

The comparison between programs that implemented “preseason only”, “in-season only” or “preseason and in-season” revealed very similar effects. Based on this finding, injury prevention programs can be recommended regardless of timing of their implementation.

No statistically significant difference was found between studies on football, handball, and basketball. All three subgroups showed significant preventive effects and, thus, at least in team sports the injury reduction effect seems to be independent of the sports performed.

While programs which incorporated balance exercises did not result in an increased injury reduction, programs including plyometric and jumping exercises showed a significantly greater preventive effect than programs that did not apply such exercises. A possible explanation could be the fact that injuries are often related to high-impact situations (landing, change in moving direction, opponent contact),[53, 73] and that the neuromuscular system is best prepared to resist these influences through high intensity exercises like jumps and landings.[36]

Although not significant ($P = 0.10$), a tendency towards greater preventive effects of programs focusing on knee injuries was observed. However, it has to be considered that a certain amount of injuries is not preventable through exercise-based programs (e.g. head injuries as a result of a collision). This basic amount of injuries is not considered in studies with a “specific” focus whereas studies with a “global” focus include these non-preventable injuries into their analysis. Thus, greater preventive effects are to be expected in studies with a "specific" focus. This needs to be elucidated in further research – for example by comparing the effectiveness of "global" programs when non-preventable injuries are included or excluded from analysis.

While it is of special importance to prevent severe injuries such as ACL ruptures or severe ankle sprains, it can also be argued that prevention programs should focus on the most frequent injuries. It is therefore recommended that injury prevention targets on the reduction of injuries in the broadest possible way without losing its specificity to tackle the most severe injuries. It would seem reasonable to call for multimodal approaches that consist of different exercises each one of which has a specific aim. We also have to be aware of the fact that some injuries will not be preventable through a modification of intrinsic risk factors.

Strengths and limitations

This systematic review was conducted according to the PRISMA statement.[74] To our knowledge, it is the first meta-analysis which cumulates the effects of injury prevention programs in organized child and adolescent sport. It gives a comprehensive overview of current scientific evidence. As recommended by Impellizzeri and Bizzini, no cut-off in quality score was used firstly to avoid an influence of subjective study rating and secondly to get the broadest possible perspective.[75] All subgroup analyses except of two were planned a priori. The analyses which compared mild, moderate, and severe injuries and the analysis that focused on elite and sub-elite level were defined a posteriori. Therefore, the findings of these two analyses are exploratory and hence preliminary in nature and should be carefully interpreted. A sensitivity analysis was undertaken to check for a potential bias due to study quality. The 21 studies included in the meta-analysis provided a large enough data pool for specific analysis of subgroups with different characteristics in relation to study population, characteristics of the injury prevention program and outcome variables. The available studies on the topic vary considerably in characteristics of the study population, type of intervention (content, dose, and duration), injury definition, severity classification (e.g. "severe" is defined heterogeneously as "more than two weeks" or "more than four weeks" of absence), exposure measurements, and research design. However, it can be argued that although different in nature, all programs do seem to have beneficial effects regardless of the specific setting in which preventive measures are applied. As the development of various different prevention programs seems to be not efficient and current programs show similar effects, the current evidence may be used to establish a blueprint for effective injury prevention in children and adolescents.

Injury prevention trials in children under the age of 14 are almost completely missing to date. Only one study focused solely on primary school children, and a few others included children younger than 14 years. Thus, an analysis of the effectiveness of injury prevention programs in different age groups was not possible.

Directions for future research

This meta-analysis shows promising beneficial effects of injury prevention programs in organized child and adolescent sport, but more high quality studies are required to clarify the effect of specific exercises and the influence of compliance. Studies on sports injury prevention in children under the age of 14 years and in individual sports athletes are desirable for the future.

Consistency with regard to injury definition and severity classification are key features to consolidate the evidence in the future. The success of an injury prevention program is not only based on a quantitative reduction of injuries but on a reduction in severity of injury as well. Therefore, an intervention can be beneficial, even without an absolute reduction of injury incidence, if the severity of injuries is reduced. Kiani et al explicitly reported such an effect.[50] However, this needs to be substantiated by further research.

To increase the quality of future studies, authors should report the definition of inclusion and exclusion criteria, use an intention-to-treat analysis, and assure blinding of injury assessors. As recently shown, the success of a sports injury prevention program depends essentially on the compliance.[76] A dose-response relationship of adherence to the program and injury reduction effect was found.[52, 76, 77] Therefore, it is of particular importance to assess and report the compliance with the intervention. To clarify the net effect, compliance and dose-response analyses are recommended for all future injury prevention studies. The development and application of a consensus statement on how to conduct studies on injury prevention programs in child and adolescent sports would be warranted, since homogeneity with respect to study design will enable a clearer interpretation of results.

The prevention of severe sports injuries is a major challenge of the future. Thereby, the age group of 6 to 18-year-olds is of particular interest as the proportion of sport-related injuries of all life-threatening injuries is much higher in children and adolescents (32%) compared to adults (9%).[78]

Exercise-based injury prevention should become an integral part of regular training sessions as it can improve physical fitness and technical performance.[79] There may be voices who claim a loss of practice time due to the application of injury prevention programs. However, considering injury reduction and performance enhancement effects, children, parents, coaches, sport institutions, and the society in general can benefit from exercise-based injury prevention.

Conclusion

The present systematic review and meta-analysis reveals good evidence that exercise-based injury prevention programs can result in an injury reduction of around 46% in youth sports. Multimodal programs including jumping/plyometric exercises can be recommended. There is a considerable lack of data for children (under 14 years), boys (representing only 12.7% of the overall study population), and for individual sports. More high quality studies are needed to clarify the effect of specific exercises and compliance.

Acknowledgements

OF and RR designed the study protocol. RR and TS searched the databases and checked the obtained studies regarding inclusion and exclusion criteria. OF, AJ, and EV contributed to the search. OF and RR assessed the eligibility of the studies for inclusion. RR and TS extracted the data. RR and LD assessed the quality of eligible studies. OF contributed to the study quality assessment. RR conducted the analysis and wrote the draft of the paper. All authors contributed to writing, reviewing, and revising the manuscript, agreed on the final draft, and take responsibility for the integrity of the data and accuracy of the analysis. No sources of funding were utilized in conducting this study. The authors have no potential conflicts of interest that are directly relevant to the content of this review.

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4 Publication II: Soccer Injuries in Players Aged 7 to 12 Years: A Descriptive Epidemiological Study Over 2 Seasons

Roland Rössler

Astrid Junge

Jiri Chomiak

Jiri Dvorak

Oliver Faude

Short Title: Football injuries in children

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Soccer injuries in players aged 7 to 12 years: A descriptive epidemiology study over two seasons

Roland Rössler[1], Astrid Junge[2,3], Jiri Chomiak[4], Jiri Dvorak[2,5], Oliver Faude[1]

[1]Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland

[2]FIFA-Medical Assessment and Research Centre (F-MARC)

[3]Medical School Hamburg, Germany

[4]Orthop. Dept. of 1st Faculty of Medicine, Charles University and Hospital Na Bulovce and FIFA Medical Centre of Excellence, Prague, Czech Republic

[5]Fédération Internationale de Football Association (FIFA), Zurich, Switzerland

Corresponding author:

Roland Rössler

University of Basel

Department of Sport, Exercise and Health

Birsstrasse 320B, 4052 Basel, Switzerland

email: roland.roessler@unibas.ch

phone: +41 61 377 87 39

Abstract

Background

Following a risk management approach, sound epidemiological data are needed to develop prevention programs. A recent review on soccer injuries of players under the age of 19 years concluded that prospective data concerning children are lacking.

Purpose

The aim of the present study was to analyze the incidence and characteristics of soccer injuries in children aged 7 to 12 years.

Study Design

The present survey was a prospective descriptive epidemiology study on soccer injuries over two seasons in the Czech Republic and Switzerland.

Methods

Exposure of players during training and match play (in hours), and injury data were reported by coaches via an internet-based registration system. Location, type and severity of injuries were classified according to an established consensus. Injury characteristics are presented as absolute numbers and injury incidence rates (injuries per 1000 hours of soccer exposure). An injury was defined as any physical complaint sustained during a scheduled training session or match play resulting in at least one of the following points: (a) inability to complete the current match or training session, (b) absence from subsequent training sessions or matches, (c) injury requiring medical attention.

Results

In total 6,038 player seasons with 395,295 hours of soccer exposure were recorded. Players' mean age was 9.3 (SD 1.9) years. 3.9% of participants were girls. A total of 417 injuries were reported. Most (76.3%) injuries were located at the lower limbs, and 15.6% at the upper limbs. 30.5% were joint/ligament injuries, 23.0% contusions, 22.5% muscle and tendon injuries, and 14.9% fractures and bone injuries. 23.7% of injuries led to more than 28 days of absence from sport participation. The overall injury incidence was 0.61 [95%-CI 0.53; 0.69] injuries per 1000 hours of soccer exposure during training sessions and 4.57 [4.00; 5.23] during match play. Injury incidence rates increased with increasing age.

Conclusion

The observed injury incidences were lower compared to studies in youth players. Children showed a relative high proportion of fractures and bone stress and of injuries to the upper limbs.

Clinical Relevance

The study provides an evidence base for injury incidence rates and injury characteristics in children's soccer. These data are the basis to develop an age-specific injury prevention program.

Key Terms

Football, epidemiology, injury patterns, prevention

What is known about the subject

Injury characteristics in youth and adolescent athletes are well known, but prospective epidemiological data of children's soccer are nearly completely missing. Injury incidence increases with age from youth to adulthood.

What this study adds to existing knowledge

The overall injury incidence rates increased with age in 7 to 12 year old soccer players. The overall injury incidence rates in the present study were lower than in players older than 13 years, but the distribution of mild/moderate/severe injuries, and the mean lay off time was similar as it has been reported in older players.

The proportion of fractures and bone stress (15.3%) and injuries to the upper limbs/hands (15.6%) was higher compared to players older than 13 years (about 4% and 7%, respectively). The highest amount of injuries (78.2%) occurred in high-intensity situations with high biomechanical loads.

Background/rationale

Regular physical activity and physical fitness are considered to be important prerequisites for the health of children.[1-3] Participation in organized youth sport is positively associated with higher levels of physical activity in adulthood.[4, 5] Hence, from an individual as well as from a socio-economic health-care perspective, it is important to promote sufficient amounts of physical activity during childhood.[1] Children are recommended to accumulate at least 60 minutes of moderate- to vigorous-intensity activity daily.[6, 7] Sport may serve as a suitable physical activity setting for children.[8] As soccer is the world's most popular sport with most players being younger than 18 years,[9] soccer has a great potential to induce beneficial health effects and to support a healthy lifestyle during the life span.[10]

Soccer is a high-intensity sport including frequent changes in movement velocity and direction as well as many situations in which players are involved in tacklings to keep possession or win the ball.[11, 12] Especially high-impact situations during player to player contact, cutting maneuvers, and falls result in a notable risk of injuries.[13]

Therefore, it seems inevitable to implement injury prevention programs to early counter potential injury-related risks. Exercise-based injury prevention has shown to be effective in youth athletes in different sports.[14-17] Nevertheless, studies on injury prevention in children's soccer (under 13 years of age) are lacking. Before developing prevention programs, sound prospective epidemiological data on incidence and characteristics of soccer injuries in children have to be assessed.[18-20]

Population-based descriptive data from presentations to emergency departments exist for sport-related injuries in children and players under 19 years of age in several sports[21] and specifically in soccer.[22-24] However, these data are not representative for all injuries except those medically treated. Further, these data do not allow the calculation of exposure-related incidence rates.

Whereas numerous epidemiological reports on injury characteristics in adolescents and in professional soccer already exist,[25-28] comprehensive prospective data concerning children are lacking.[11]_ENREF_16 _ENREF_16Only two relatively small prospective studies focusing on injuries in under-13-year old soccer players are available.[29, 30] A recent review on injuries in soccer players under the age of 19 years provides comprehensive knowledge of injuries in youth soccer.[11] Findings on injury incidence in children's soccer are contradictory. On the one hand injury incidence was reported to be higher compared to other sports,[31] on the other hand injury incidence was judged to be "low" in children's soccer.[22, 29]

Maturation seems to have an influence on incidence and characteristics of injury.[11] Injury incidence tends to be higher in early maturing as compared to late-maturing players. Children seem to have more fractures, fewer strains and sprains, and more injuries of the upper body than older players. Skeletal and coordinative immaturity in combination with growth-related issues may lead to specific injury characteristics in children's soccer.[11] These considerations, however, are based on limited data from methodologically inconsistent studies. Reliable data on the youngest age groups in organized soccer are needed.

Objective

The objective of the present study was to analyze the incidence and characteristics of soccer injuries in children aged 7 to 12 years. The results will serve as a basis to develop, implement and evaluate the effectiveness of injury prevention programs for these age groups.

Methods

Study Design

The STROBE guidelines were used for the reporting of this descriptive epidemiology study on soccer injuries.[32] The follow-up period covered two complete soccer seasons (August 2012 to June 2013, and August 2013 to June 2014) in the Czech Republic and Switzerland. The seasons started after the summer school holidays and lasted till the beginning of the subsequent summer holidays with short breaks during all other school holidays (in total about 10 weeks). The study was approved by the ethics committee "Ethikkommission beider Basel" (Ref. Nr. EK: 129/12).

Setting

Soccer clubs in Czech Republic (Season 1: 51; Season 2: 61) and German-speaking cantons of Switzerland (Season 1: 845; Season 2: 846) were invited to take part in the study. Information letters were sent to all responsible persons in the clubs via e-mail.

Study population

Children's soccer teams (with girls and boys aged between 7 and 12 years) of officially registered soccer clubs in Czech Republic or Switzerland were recruited from June to August 2012 and June to August 2013. The group was subdivided into three age categories (7/8 years, 9/10 years, and 11/12 years). In these age categories children play on small soccer fields with 5 to 9 children per team. Boys and girls are not separated in these age categories.

Documentation of injuries and exposure

Data acquisition was carried out according to the international consensus statement on injury definitions and procedures for epidemiological studies of soccer injuries.[33] An injury was defined as any physical complaint sustained during a scheduled training session or match play resulting in at least one of the following points: (a) inability to complete the current match or training session, (b) absence from subsequent training sessions or matches (c) injury requiring medical attention.[34, 35]

Injury location, type / diagnosis, mechanism and resulting absence from sport as well as exposure in training (under supervision of the coach) and matches (competitive or friendly against another team) were documented. Injury mechanisms were classified in four groups: "contact" (e.g. ball contact, collision with other player, duel, header duel, foul, falling), “non-contact” (e.g. change in movement direction, jumping, running), “overuse”, and “growth-related” injuries.[36] An overuse injury was defined as an injury with insidious onset and no known trauma. An injury was categorized as “growth-related” in cases the consulted physician explicitly related the origin of the injury to growth.

Implementation of data collection

Responsible contact persons in the clubs (commonly the coaches) had access to an internet-based injury registration platform (Chapter 8.5). This platform was used to record injuries, exposure in training and match play, as well as absence of players. The coaches were supplied with a detailed written instruction manual on injury definitions and examples how to complete the injury and exposure report forms within the online system (see Chapter 8.5). Alternatively, if a coach felt uncomfortable with the online registration, paper sheets for reporting exposure time and injuries were provided. These sheets were sent back via e-mail ideally weekly but at least twice a month.

Injury and exposure data (duration of training or match) for each individual player were entered weekly by the coaches into the system. In case of an injury, coaches were required to report information regarding its nature and mechanism. Coaches were directly contacted via telephone or email in case they did not enter exposure data during the last 2 weeks. In such cases coaches were asked to complete exposure and (if necessary) injury data.

After occurrence of an injury, parents and children were contacted via telephone by two of the authors to clarify open questions and to validate injury data provided by the coaches and to receive further injury specific information (e.g. time of absence from sport participation and medical diagnosis). These telephone interviews were based on a standardized injury registration form. In case of injuries requiring medical treatment, parents were instructed to receive the exact diagnosis from the respective physician (either as specific written diagnosis or a specific injury coding system, e.g. Orchard classification[37]). Baseline data (date of birth, height and weight) of the children were obtained from their parents prior to the start of the study (in conjunction with informed consent).

Bias minimization

These following measures were applied to guarantee a complete, reliable and valid injury registration. Prior to the start of the study, coaches and contact persons of the teams received standardized and detailed information to achieve a uniform documentation of all relevant data throughout the study period in all clubs. A qualified person contacted coaches, parents and injured children. To ensure sufficient compliance of the coaches, a financial compensation for full participation was provided. It could be assumed that our design neither changed injury rate, nor injury severity in training and matches.

Sample size calculation

The required number of players was estimated a priori. An effect size of 33.3% has recently been considered as relevant difference between injuries on grass and artificial turf,[38] and as overall reduction of injury risk due to a prevention program in youth female soccer players.[16, 17] Thus, the sample size calculation is based on 95% confidence limits for the overall injury incidence of at least +/-16.7%. Therefore, 160 injuries are needed per age group for assessing injury incidence with sufficient accuracy. Based on estimated overall injury incidences of 1.0 injury per 1000 training hours in 7/8, 1.5 injuries per 1000 h in 9/10, and 2.0 injuries per 1000 h in 11/12 year old players 160,000 h, 110,000 h, and 80,000 h of soccer exposure are needed to assess injury incidence in each age group.[29] When considering increasing exposure time with increasing age (7/8 years: 1.5 hours per week; 9/10 years: 2.0 hours per week; 11/12 years: 2.5 hours per week) this results in a total of 4,966 player seasons corresponding to about 167 teams needed for statistical analyses (7/8 years: n = 1368 children, 9/10 years: n = 705 children; 11/12 years: n = 410 children). Assuming a drop-out rate of about 15%,[39] 196 teams (corresponding to 5,850 player seasons) would have been initially recruited.

Statistical methods and quantitative analyses

Results are presented for the entire group and for each the three age categories. Statistical analyses were mainly of descriptive nature. Injury incidence was calculated as number of injuries per 1000 player hours ((Σ injuries/Σ exposure hours)×1000). All continuous data are described as means with standard deviation. Injury characteristics are presented (separately for training and match play) as absolute numbers with percentages, and incidences (injuries per 1000 hours of soccer exposure) with 95% confidence limits. Rate ratios (RR) of injury incidences between age groups and corresponding p-values were calculated using Stata 13 (StataCorp LP, Texas, USA).

Results

From August 2012 to June 2014, 6,038 player seasons with a total of 395,295 hours of soccer exposure were recorded (see Appendix 6 for detailed flow of participants). N = 238 (3.9%) player seasons were completed by girls, for further baseline data see Table 4-1.

A total of 417 injuries were sustained by 329 players (Table 4-2). Thus, 5.7% of the players sustained at least one injury per season. The overall injury incidence was 0.61 [95%-CI 0.53; 0.69] injuries per 1000 hours of soccer exposure during training sessions and 4.57 [4.00; 5.23] during match play. Injury rates increased with age (Figure 4-1). The RR during match play was 1.44 [95% CI 0.91; 2.28; $P = 0.06$] for 9/10 year olds and 2.47 [1.64; 3.72; $P < 0.001$] for 11/12 year olds when compared to the youngest age group. During training the RR was 1.36 [0.88; 2.13; $P = 0.09$] for 9/10 year olds and 3.55 [2.44; 5.15; $P < 0.001$] for the 11/12 year olds, again compared to the 7/8 year old players. Training and match injury incidence were similar between countries ($P > 0.21$) and between seasons ($P > 0.24$).

Injury severity and medical consultation

Almost half (48.7%) of the injuries resulted in absence from sport of less than 8 days, 27.6%, in absence of 8-28 days, and 23.7% in absence form sport of more than 28 days. Mean lay off time after injury was 18.9 days (range 0–238). If only time-loss injuries were considered mean lay off time was 21.9 days (range 1–238). In total 52.0% of all injuries led to medical consultation. The incidence rate of medical-consultation injuries increased with age. The RR of the comparison 9/10 vs 7/8 was 1.66 [95%-CI 1.07; 2.58; $P = 0.023$], for the comparison 11/12 vs 7/8 it was 3.35 [95%-CI 2.24; 5.02; $P < 0.001$], and for the comparison 11/12 vs 9/10 the RR was 2.02 [95%-CI 1.49; 2.72; $P < 0.001$].

Injury location, type and mechanism

Most (76.3%) injuries were at the lower limbs, 15.6% at the upper limbs, and 6.2% at the head (Table 4-3). Most common were joint and ligament injuries (30.5%), followed by contusions (22.5%), muscle and tendon injuries (18.5%), and bone injuries (15.4%) (Table 4-4). Contact accounted for 57.3% of all injuries, 20.9% were acute non-contact injuries, and 16.8% were growth- or overuse-related (Table 4-5). The most frequent diagnosis was ligament injury of the ankle followed by ligament injury of the knee and muscle/tendon injuries of hip/groin and thigh (Table 4-6).

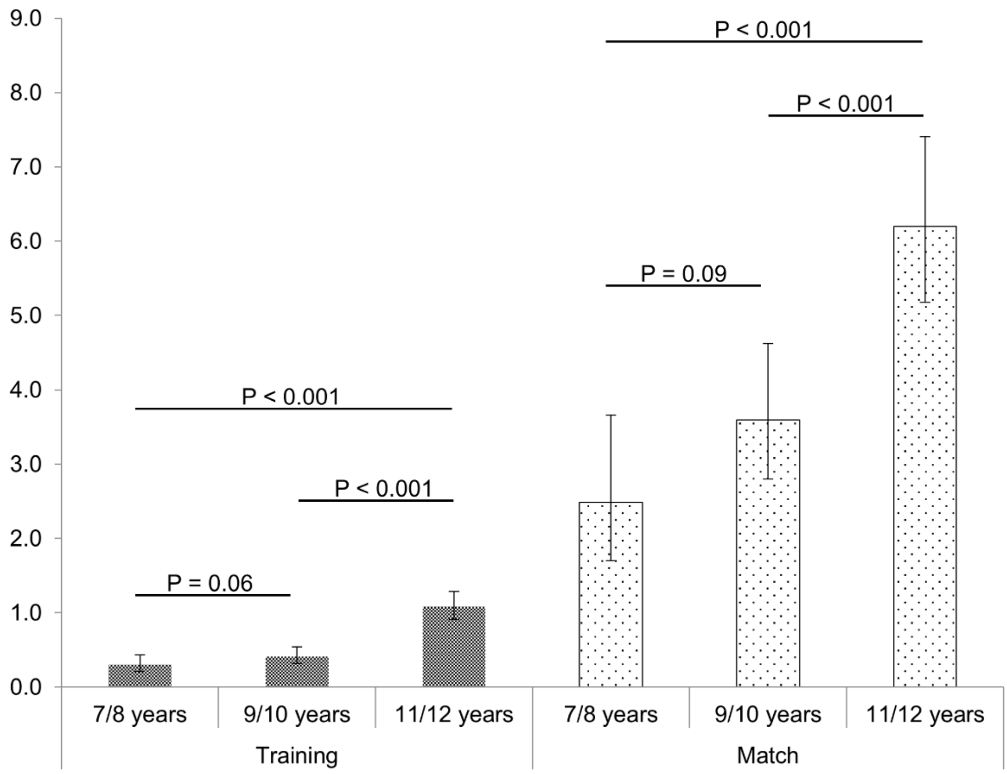

Figure 4-1: Incidence of training and match injuries with 95% CI; P-values of comparisons between incidence rates of age groups.

Table 4-1: Number of player seasons and anthropometric data (mean (SD)) for different age groups.

Age group	Player seasons [N]	Age [years]	Height [cm]	Weight [kg]	BMI [m²/kg]
7/8 yrs old	1770	7.2 (0.9)	125.8 (7.5)	24.8 (4.6)	15.6 (1.8)
9/10 yrs old	2247	9.5 (0.6)	138.3 (7.6)	31.9 (5.5)	16.6 (2.2)
11/12 yrs old	2021	11.4 (0.6)	147.7 (7.4)	38.0 (6.4)	17.4 (2.2)
Total	6038	9.3 (1.9)	136.3 (11.8)	31.0 (7.7)	16.4 (2.2)

Table 4-2: Exposure time, number and severity of injuries in training and matches.

	Age group	Exposure hours	Number of injuries (percentage)	Injuries with different duration of absence from sport (%)				
				0 days	1 to 3 days	4 to 7 days	8 to 28 days	> 28 days
Match	**7/8**	10442	26 (100.0)	3 (11.5)	6 (23.1)	7 (26.9)	6 (23.1)	4 (15.4)
	9/10	16971	61 (100.0)	12 (19.7)	11 (18.0)	10 (16.4)	14 (23.0)	14 (23.0)
	11/12	19374	119 (100.0)	14 (11.8)	21 (17.6)	21 (17.6)	39 (32.8)	24 (20.2)
	Total	46787	206 (100.0)	29 (14.1)	38 (18.4)	38 (18.4)	59 (28.6)	42 (20.4)
Training	**7/8**	99261	30 (100.0)	4 (13.3)	3 (10.0)	8 (26.7)	7 (23.3)	8 (26.7)
	9/10	130914	54 (100.0)	3 (5.6)	14 (25.9)	11 (20.4)	8 (14.8)	18 (33.3)
	11/12	118334	127 (100.0)	6 (4.7)	22 (17.3)	27 (21.3)	41 (32.3)	31 (24.4)
	Total	348508	211 (100.0)	13 (6.2)	39 (18.5)	46 (21.8)	56 (26.5)	57 (27.0)
	Overall	395295	417 (100.0)	42 (10.1)	77 (18.5)	84 (20.1)	115 (27.6)	99 (23.7)

Table 4-3: Location of injury and related comparison of incidence in different age groups.

Location	Total		7/8 y		9/10 y		11/12 y		9/10 y vs 7/8 y	11/12 y vs 9/10 y	11/12 y vs 7/8 y
	N	(%)	N	(%)	N	(%)	N	(%)	RR [95%-CI]	RR [95%-CI]	RR [95%-CI]
Head/face	26	(6.2)	5	(8.9)	11	(9.6)	10	(4.1)	1.63 [0.57; 4.70]	0.98 [0.41; 2.30]	1.59 [0.54; 4.66]
Shoulder/clavicle	10	(2.4)	1	(1.8)	1	(0.9)	8	(3.3)	0.74 [0.05; 11.86]	8.59 [1.07; 68.69]	6.37 [0.80; 50.95]
Upper arm	2	(0.5)	1	(1.8)	1	(0.9)	0		0.74 [0.05; 11.86]		
Elbow	4	(1.0)	0		1	(0.9)	3	(1.2)		3.22 [0.34; 30.97]	
Forearm	5	(1.2)	0		2	(1.7)	3	(1.2)		1.61 [0.27; 9.64]	
Wrist	18	(4.3)	2	(3.6)	3	(2.6)	13	(5.3)	1.11 [0.19; 6.66]	4.65 [1.33; 16.33]	5.18 [1.17; 22.95]
Hand/finger/thumb	26	(6.2)	4	(7.1)	6	(5.2)	16	(6.5)	1.11 [0.31; 3.94]	2.86 [1.12; 7.32]	3.19 [1.07; 9.53]
Sternum/ribs/upper back	4	(1.0)	0		1	(0.9)	3	(1.2)		3.22 [0.34; 30.97]	
Lower back/pelvis/sacrum	4	(1.0)	0		1	(0.9)	3	(1.2)		3.22 [0.34; 30.97]	
Hip/groin	41	(9.8)	5	(8.9)	8	(7.0)	28	(11.4)	1.19 [0.39; 3.63]	3.76 [1.71; 8.25]*	4.46 [1.72; 11.55]
Thigh	41	(9.8)	4	(7.1)	7	(6.1)	30	(12.2)	1.30 [0.38; 4.43]	4.60 [2.02; 10.48]*	5.97 [2.10; 16.96]*
Knee	68	(16.3)	6	(10.7)	19	(16.5)	43	(17.5)	2.35 [0.94; 5.88]	2.43 [1.42; 4.17]	5.71 [2.43; 13.41]*
Lower leg/Achilles tendon	29	(7.0)	2	(3.6)	10	(8.7)	17	(6.9)	3.71 [0.81; 16.93]	1.83 [0.84; 3.99]	6.77 [1.56; 29.31]
Ankle	87	(20.9)	19	(33.9)	28	(24.3)	40	(16.3)	1.09 [0.61; 1.96]	1.53 [0.95; 2.49]	1.68 [0.97; 2.90]
Foot/toe	52	(12.5)	7	(12.5)	16	(13.9)	29	(11.8)	1.70 [0.70; 4.12]	1.95 [1.06; 3.58]	3.30 [1.45; 7.53]
Total	417	(100.0)	56	(100.0)	115	(100.0)	246	(100.0)	1.52 [1.11; 2.10]	2.30 [1.84; 2.87]*	3.50 [2.62; 4.68]*

* p < .001

Table 4-4: Type of injury and related comparison of incidence in different age groups.

Category	**Total**		**7/8 y**		**9/10 y**		**11/12 y**		**9/10 y vs 7/8 y**	**11/12 y vs 9/10 y**	**11/12 y vs 7/8 y**
	N	**(%)**	**N**	**(%)**	**N**	**(%)**	**N**	**(%)**	**RR [95%-CI]**	**RR [95%-CI]**	**RR [95%-CI]**
Fracture	42	(10.1)	6	(10.7)	12	(10.4)	24	(9.8)	1.48 [0.56; 3.95]	2.15 [1.07; 4.29]	3.19 [1.30; 7.80]
Other bone injuries	22	(5.3)	1	(1.8)	4	(3.5)	17	(6.9)	2.97 [0.33; 26.55]	4.56 [1.54; 13.56]	13.54 [1.80; 101.76]
Dislocation/subluxation	12	(2.9)	3	(5.4)	3	(2.6)	6	(2.4)	0.74 [0.15; 3.68]	2.15 [0.54; 8.59]	1.59 [0.40; 6.37]
Sprain/ligament injury	86	(20.6)	14	(25.0)	25	(21.7)	47	(19.1)	1.32 [0.69; 2.55]	2.02 [1.24; 3.28]	2.67 [1.47; 4.86]
Inflammation/overuse of joint	27	(6.5)	3	(5.4)	9	(7.8)	15	(6.1)	2.23 [0.60; 8.22]	1.79 [0.78; 4.09]	3.98 [1.15; 13.76]
Lesion of meniscus or cartilage	2	(0.5)	0		2	(1.7)	0				
Muscle rupture/tear/strain/cramps	70	(16.8)	7	(12.5)	11	(9.6)	52	(21.1)	1.17 [0.45; 3.01]	5.08 [2.65; 9.73]*	5.92 [2.69; 13.03]*
Tendon injury/rupture/ tendinosis/bursitis	7	(1.7)	1	(1.8)	2	(1.7)	4	(1.6)	1.48 [0.13; 16.36]	2.15 [0.39; 11.73]	3.19 [0.36; 28.51]
Haematoma/contusion/bruise	94	(22.5)	12	(21.4)	27	(23.5)	55	(22.4)	1.67 [0.85; 3.29]	2.19 [1.38; 3.47]*	3.65 [1.96; 6.82]*
Abrasion	6	(1.4)	2	(3.6)	1	(0.9)	3	(1.2)	0.37 [0.03; 4.09]	3.22 [0.34; 30.97]	1.19 [0.20; 7.15]
Laceration	3	(0.7)	1	(1.8)	1	(0.9)	1	(0.4)	0.74 [0.05; 11.86]	1.07 [0.07; 17.17]	0.80 [0.05; 12.74]
Concussion	8	(1.9)	0		5	(4.3)	3	(1.2)		0.64 [0.15; 2.70]	
Other injuries	38	(9.1)	6	(10.7)	13	(11.3)	19	(7.7)	1.61 [0.61; 4.23]	1.57 [0.78; 3.18]	2.52 [1.01; 6.32]
Total	417	(100.0)	56	(100.0)	115	(100.0)	246	(100.0)	1.52 [1.11; 2.10]	2.30 [1.84; 2.87]*	3.50 [2.62; 4.68]*

* $p < .001$

Table 4-5: Injury mechanisms and related comparison of incidence in different age groups.

Category	**Total**		**7/8 y**		**9/10 y**		**11/12 y**		**9/10 y vs 7/8 y**	**11/12 y vs 9/10 y**	**11/12 y vs 7/8 y**
	N	**(%)**	**N**	**(%)**	**N**	**(%)**	**N**	**(%)**	**RR [95%-CI]**	**RR [95%-CI]**	**RR [95%-CI]**
Contact											
Ball	31	(7.4)	3	(5.4)	12	(10.4)	16	(6.5)	2.97 [0.84; 10.51]	1.43 [0.68; 3.03]	4.25 [1.24; 14.58]
Collision with other player	36	(8.6)	10	(17.9)	14	(12.2)	12	(4.9)	1.04 [0.46; 2.34]	0.92 [0.43; 1.99]	0.96 [0.41; 2.21]
Duel	67	(16.1)	8	(14.3)	20	(17.4)	39	(15.9)	1.85 [0.82; 4.21]	2.09 [1.22; 3.59]	3.88 [1.81; 8.31]*
Header duel	25	(6.0)	2	(3.6)	6	(5.2)	17	(6.9)	2.23 [0.45; 11.03]	3.04 [1.20; 7.72]	6.77 [1.56; 29.31]
Foul	49	(11.8)	4	(7.1)	13	(11.3)	32	(13.0)	2.41 [0.79; 7.39]	2.64 [1.39; 5.04]	6.37 [2.25; 18.02]*
Falling	31	(7.4)	6	(10.7)	9	(7.8)	16	(6.5)	1.11 [0.40; 3.13]	1.91 [0.84; 4.32]	2.12 [0.83; 5.43]
Non-contact											
Change in moving direction	35	(8.4)	4	(7.1)	10	(8.7)	21	(8.5)	1.85 [0.58; 5.91]	2.26 [1.06; 4.79]	4.18 [1.44; 12.18]
Jumping	10	(2.4)	1	(1.8)	4	(3.5)	5	(2.0)	2.97 [0.33; 26.55]	1.34 [0.36; 5.00]	3.98 [0.47; 34.09]
Running	42	(10.1)	4	(7.1)	5	(4.3)	33	(13.4)	0.93 [0.25; 3.45]	7.09 [2.77; 18.16]*	6.57 [2.33; 18.55]*
Overuse	50	(12.0)	8	(14.3)	16	(13.9)	26	(10.6)	1.48 [0.63; 3.47]	1.75 [0.94; 3.25]	2.59 [1.17; 5.72]
Growth-related	21	(5.0)	1	(1.8)	2	(1.7)	18	(7.3)	1.48 [0.13; 16.36]	9.67 [2.24; 41.65]	14.34 [1.91; 107.41]
Other	20	(4.8)	5	(8.9)	4	(3.5)	11	(4.5)	0.59 [0.16; 2.21]	2.95 [0.94; 9.27]	1.75 [0.61; 5.04]
Total	417	(100.0)	56	(100.0)	115	(100.0)	246	(100.0)	1.52 [1.11; 2.10]	2.30 [1.84; 2.87]*	3.50 [2.62; 4.68]*

* p < .001

Table 4-6: Injury location and injury type.

	Fractures and bone stress	Joint (non-bone) and ligament	Muscle and tendon	Haematoma/ contusion/bruise	Laceration and skin lesion	Concussion	Other	Total
Head/face				6	6	8	6	26
Shoulder/clavicle	3	3		3			1	10
Upper arm	2							2
Elbow	1			3				4
Forearm	5							5
Wrist	8	8		2				18
Hand/finger/thumb	9	12		4			1	26
Sternum/ribs/upper back	1			2			1	4
Lower back/pelvis/sacrum				2			2	4
Hip/groin		4	33	1			3	41
Thigh			31	8	1		1	41
Knee	5	34		18	2		9	68
Lower leg/Achilles tendon	2		12	10			5	29
Ankle	4	61		20			2	87
Foot/toe	24	5	1	15			7	52
Total	**64**	**127**	**77**	**94**	**9**	**8**	**38**	**417**

Fractures and bone stress

Of acute fractures 62.5% were located at the upper limbs (of which more than half affected hand, finger, or wrist), 35.0% at the lower limbs and 2.5% at the trunk (ribs). Acute fractures led to a mean lay off time of 44.9 (11-163) days. 42.5% of fractures occurred after contact with another player and 35.0% as a direct consequence of falling and another 17.5% were due to contact with the ball. 30.5% of all upper extremity injuries were fractures with a mean lay off time of 37.6 (14-65) days. Nearly half of those upper extremity fractures occurred as a direct consequence of falling. Regarding non-acute bone stress 63.6% was growth-induced and mainly affected knee (N = 8 Osgood-Schlatter syndrome; mean lay off time 52.4 days; range 21-99) or foot (N = 6 Sever's disease; mean lay off time 47.5 days; range 24-93). Further, 22.7% of non-acute bone injuries were overuse-related injuries and solely affected the foot. Non-acute bone stress led to a mean lay off time of 43.4 (3-180) days.

Acute ligament injuries (sprains)

55.1% of sprains were located at the ankle and 16.3% at the knee. Mean lay off time of all sprains was 16.4 (0-169) days. The lay off time of ankle sprains was 15.7 (0-91) and of knee sprains (including 2 ACL avulsions from tibial spine) 27.9 (0-169) days. 44.8% of sprains occurred after contact with another player, 32.6% during change in moving direction, running, or jumping, 11.2% occurred after contact with the ball, and 9.2% after falling.

Contusions

76.6% of contusions were located at the lower and 12.8% at the upper limbs (Table 4-6). 81.9% occurred after contact with another player, 7.4% after falling and 6.4% after contact with the ball. Mean lay off time following a contusion was 8.4 (0-110) days. The long lay off time (110 days) of one 12 year old girl was due to long lasting pain in the metatarsal after an opponent stepped on her foot.

Comparisons of age groups

Location of injury

The ankle was the most frequent injury location in all three age groups, and its percentage decreased with age (Table 4-3). In all age categories the second and third most frequently injured body parts were knee and foot, and the percentage and incidence rate of knee injuries increased with age. The fifth and sixth most frequent injury locations were hip/groin and thigh injuries, whereby both injury locations were more frequent in older players. The incidence rate of wrist injuries was higher in 11/12 year old children than in 7 to 10 year old children. Although injury incidence rates of head/face injuries did not differ between the three age groups, it should be mentioned that the percentage of head/face injuries was twice as high in 7 to 10 year old children compared to the oldest age group.

Type of injury

Haematoma/contusion/bruise, sprain/ligament, and muscle injuries were the most frequent types of injury in all three age categories, and its incidence rates increased with age (Table 4-4). Acute fractures showed equal percentages but increasing incidence rates from younger to older players. The incidence rates of inflammation/overuse of joints, and of non-acute bone stress were higher in older players.

Mechanism of injury

Duel, overuse, foul play (opinion of the coach), and running were the most common injury mechanisms, and incidence rates increased with age (Table 4-5). The percentages of injuries resulting from collisions and falling were higher in younger players but the incidence rates did not differ between age groups. The incidence rates of injuries resulting from change in moving direction and header duels increased with age. The 11/12 age category showed by far the highest percentage and incidence rate of growth-related injuries.

Discussion/Conclusion

Key results

This is the first prospective large-scale epidemiological study on soccer injuries in players younger than 13 years. 5.7% of the players sustained at least one injury per season. The overall injury incidence rates increased with increasing age, and were lower in the present study than in players older than 13 years.[11] However, the distribution of mild/moderate/severe injuries and the mean lay off time was similar as it has been reported in older players.[11]

The observed incidence rate of fractures was 0.11 [95%-CI 0.08; 0.14] per 1000 hours of exposure, and thus 2.41 [95%-CI 1.68; 3.46; $P < 0.001$] times higher compared to the roughly estimated fracture rate in children's soccer based on registry data.[40] Further, the proportion of fractures and bone stress (15.3%) and injuries to the upper limbs (15.6%) was higher compared to players older than 13 years (about 4% and 7%, respectively).[11] Most injuries (78.2%) occurred in high-intensity situations with high biomechanical loads (e.g. tackling, falls, jumping/landing, ball contact or change in direction of movement).

Most common were contusions to the lower extremities (N = 74). The mean lay off time was 6.5 (range 0-110) days. Second most common were ankle sprains (N = 61) with a mean lay off time of 16.1 (0-91) days.

Two players (nine and ten years old) suffered from avulsion of ACL with a minimally displaced fracture of the tibial spine (grade 1). One happened during change in moving direction and led to 169 days of absence and the other one during running (110 days of absence). A torn Achilles tendon (with avulsion fracture) of a 12 year old player led to 150 days of absence. Long lasting exercise-induced knee pain led to a lay off time of 238 days in an 11 year old player.

Interpretation

The observed incidence rate of acute injuries was comparable with existing data for these age groups (RR = 1.12 [0.60; 2.10; $P = 0.73$]).[29] Another study reported much higher (approximately times 10) incidence rates in 7 to 13 year old soccer players. However, the comparability to these data is limited, as the exposure was measured in number of athlete exposures rather than hours and injury definition was very broad ("A reportable injury was defined as an injury that brought a coach onto the field to check the condition of a player…").[30]

Uncontrolled contact with the ball accounted for 19.5%, header duels for 14.6%, and collisions with other players for 14.6% of injuries. The percentage of upper extremity injuries and acute fractures was higher in our study compared to older youth players.[11] Children seem to be at specific risk when falling as 26.8% of fractures were caused by falling. Teaching correct falling techniques may help to reduce peak landing force when touching the ground and hence may reduce the risk of injury. The high amount of fractures to the upper extremities underlines the need of implementing falling techniques into training regimens. The training of landing skills in young athletes is well known from martial arts and has been shown to reduce fall-related injuries in adolescent Australian football players.[41] Specific training scenarios to enhance spatial orientation skills and attendance on the field may reduce unwanted player to player contact.[42]

Overuse injuries are caused by repetitive micro trauma. If not accurately appreciated and treated such injuries can cause functional impairment, become chronic, and even lead to permanent disability.[43] Injuries to the growing skeleton are unique for young athletes. Special consideration has to be made for such growth-related injuries.[44] Specific characteristics and contributing risk factors have been described for these types of injury.[45] There was a distinct increase in non-acute bone stress from the youngest to the oldest age group in our study. More than half of the cases were growth-related and another fifth was overuse-induced. Complaints like Sever's disease (calcaneal apophysitis) or Osgood-Schlatter syndrome (apophysitis of the tibial tubercle) require players to rest for a longer period of time. Due to a gradual progression, such complaints may be diagnosed late. It might be reasonably assumed that the actual number of growth/overuse induced injuries was even higher in our study, as we further registered nine knee, one Achilles tendon, and seven foot/toe injuries with a non-acute onset and without clear medical diagnoses. Of these unspecified injuries around 30% were severe, whereby one led to the longest lay of time of all recorded injuries. Hence, coaches need to be aware of age/growth-specific complaints of children. Medical consultation is recommended when chronic pain is present.[46]

Within our sample the youngest players showed a high percentage of ankle injuries. Suitable exercises may help to prepare and strengthen children's lower extremities to withstand the soccer-specific demands in high impact situations. It seems reasonable to start this preparation from very young age, as it is known that a former ankle sprain increases the risk to sustain further ankle injuries.[47] Plyometric exercises have proven particularly suitable to reduce injuries.[17] Balance exercises are specifically used to target ankle sprains.[48, 49] Hence, jumping exercise and unilateral stability exercises may be combined to reduce injuries in children's soccer.

The observation that injury incidence rates increase with age was confirmed by data for the youngest players.[11] The implementation of specific exercises to prepare children's musculoskeletal system for the soccer-specific demands seems necessary. Furthermore, to reduce fall-related injuries (especially fractures of the upper limbs) falling techniques may be a reasonable part of children's injury prevention. Taking these age-specific injury patterns into account, injury prevention must be adapted for the youngest players. Based on these findings we developed the injury prevention program "FIFA 11+ Kids" for children's soccer. We are currently testing its effectiveness to prevent injuries in a randomized controlled trial.

Limitations

Although the percentage of girls in our sample is representative for soccer in Switzerland and Czech Republic this could be a limitation. The transferability of results may be reduced for countries with higher rates of female participation in soccer. Future studies from countries with a higher percentage of girls are desirable.

The dropout rate was higher than expected and hence, the recruitment process had to be extended to reach the necessary sample size. Injury rates might be underestimated because coaches who are willing to participate in such a study might be more aware of the relevance of prevention and thus, more cautious in planning their training (e.g. importance of fair play, specific exercises, and general cautiousness).

Although we used a tighter monitoring schedule compared to other studies (coaches were advised to report exposure and injury data weekly and were personally contacted if they did not) minor injuries and especially such injuries that did not lead to any lay off time (N = 42) may be underrepresented compared to severe injuries leading to an absence of 28 days or more (N = 99).

Low weekly training and match frequency could be an underlying reason for a potential underreporting. Further, injuries were not reported by medical staff of the soccer clubs (which is possible in professional clubs only). Around the half of all injuries did not lead to medical consultation and hence data of these injuries are only based on coaches', parents' and children's opinion. However, standardized interviews were conducted by two of the authors with all involved persons to minimize the chance of incorrect reporting.

Within the scope of the study it was not possible to measure physical activity exposure time aside from organized soccer. These data would have been valuable to evaluate the occurrence of overuse-induced injuries.

Conclusion and perspective

As there is a remarkable lack of information on soccer injuries and injury prevention for players younger than 13 years, this study is a useful step towards an evidence base. These data serve as a basis for subsequent projects. Further analyses regarding specific risk factors should be considered. The effectiveness of injury prevention in older players is promising.[17] Therefore target-aimed and effective injury-prevention programs for children's soccer may be developed and evaluated in future.[11, 18, 20]

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5 Publication III: Risk factors for soccer injuries in players aged 7 to 12 years

Roland Rössler

Astrid Junge

Jiri Chomiak

Karel Nemec

Jiri Dvorak

Eric Lichtenstein

Oliver Faude

Short Title: Risk factors for football injuries

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Risk factors for football injuries in young players aged 7 to 12 years

Roland Rössler[1], Astrid Junge[2,3], Jiri Chomiak[4], Karel Nemec[4], Jiri Dvorak[2,5], Eric Lichtenstein[1], Oliver Faude[1]

[1]Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland

[2]FIFA-Medical Assessment and Research Centre (F-MARC)

[3]Medical School Hamburg, Germany

[4]Orthop. Dept. of 1st Faculty of Medicine, Charles University and Hospital Na Bulovce and FIFA Medical Centre of Excellence, Prague, Czech Republic

[5]Fédération Internationale de Football Association (FIFA), Zurich, Switzerland

Corresponding author:

Roland Rössler

University of Basel

Department of Sport, Exercise and Health

Birsstrasse 320B, 4052 Basel, Switzerland

email: roland.roessler@unibas.ch

phone: +41 61 377 87 39

Abstract

Objectives

Football (soccer) is very popular amongst children. Little is known about risk factors for football injuries in children. The aim was to analyse potential injury risk factors in 7 to 12 year old players.

Design

Prospective epidemiological study.

Methods

We collected prospective data in Switzerland and the Czech Republic over two seasons. Coaches reported exposure of players (in hours), absence, and injury data via an internet-based registration system. We analysed time-to-injury data with extended Cox models accounting for correlations on team- and intra-person-level. We analysed injury risk in relation to age, sex, playing position, preferred foot, and regarding age-independent body height, body mass, and BMI. Further, we analysed injury risk in relation to playing surface.

Results

In total, 6,038 player seasons with 395,295 hours of football exposure were recorded and 417 injuries occurred. Injury risk increased by 46% ($P<0.001$) per year of life. Left-footed players had a higher injury risk (53%; $P=0.02$) for training injuries compared to right-footed players. Injury risk was increased in age-adjusted taller players (higher percentile-rank). Higher match-training-ratios were associated with a lower risk of match injuries. Injury risk was increased on artificial turf (39%; $P<0.001$) and lower during indoor sessions (32%; $P<0.001$) compared to natural grass.

Conclusions

Age is known as a risk factor in older players and was confirmed to be a risk factor in children’s football. Playing surface and leg dominance have also been discussed previously as risk factors. Differences in injury risks in relation to sex should be investigated in the future.

Background

Physical activity positively affects physical and psychological health, as well as mental, cardiorespiratory and neuromuscular fitness in children and adolescents.[1] Hence, football may serve as a suitable physical activity setting for children.[2] Football is the world's most popular sport with 270 million active players of which the majority is younger than 18 years.[3] Therefore, football has a great potential to induce positive health effects in children.

However, participation in sport always entails a certain injury risk. Sport and recreational activities are the leading cause of injury in youth.[4, 5] Injuries may lead to a reduction in physical activity levels which in turn may have a considerable impact on future health and quality of life.[6]

The implementation of injury prevention programmes is necessary to counter potential injury-related risks in children's sport. Exercise-based injury prevention programmes have shown to be effective in youth/adolescent sport.[7] There is a lack of studies focusing on injury prevention in children's football (under 13 years of age). Following a risk management approach, sound epidemiological data of football injuries in children have to be assessed prior to the development of a prevention programme.[8] Epidemiological data concerning children have been lacking. Therefore, we conducted a prospective epidemiological study on injuries in children's football and observed that injury characteristics partly differ from those of older players.[9, 10] Several studies have investigated risk factors in adult and adolescent football players. However, injury risk factors in children's football have not been described.

The objective of the present study was the analysis of risk factors for football injuries in children aged 7 to 12 years.

Methods

The manuscript was written following the STROBE guidelines to ensure comprehensive reporting of this prospective observational cohort study.[11] The follow-up period covered two football seasons (August 2012 to June 2014) in Switzerland and the Czech Republic. The study was approved by the ethics committee (Ethikkommission beider Basel; Ref. No.: 129/12). The general epidemiological data of this project are described in a separate publication.[10]

Football clubs in Switzerland (season 1, n = 845; season 2, n = 846), and the Czech Republic (season 1, n = 51; season 2, n = 61) were invited to participate in the study. Responsible persons in the clubs were contacted via e-mail and/or telephone.

Football teams (age categories under-9, under-11 and under-13) of officially registered football clubs were recruited. Children play on small football fields with 5 to 9 players per team, boys and girls together.

Anthropometric data were assessed at the beginning of each season. Some children took part in both seasons and were handled as separate cases in each season to use the most recent anthropometric data. Extended Cox models were used for statistical analysis to account for multiple injuries of a child during the same season.

A physical complaint sustained during a scheduled training session or match play was recorded as an injury if the player (a) was unable to complete the current match or training session, and/or (b) was as a consequence absent from subsequent training sessions or matches, and/or (c) sought medical attention.[12, 13]

The international consensus statement on injury definitions and procedures for epidemiological studies of football injuries was followed for data collection.[14] Injuries were classified as "acute" (e.g. collision with another player, jumping), or "chronic" (gradual onset).[15]

Data collection was accomplished using an internet-based injury registration platform which was developed for this study (Chapter 8.5). Contact persons in the clubs (commonly the coaches) had access to the platform and entered injuries, exposures (training and match play), and absences of players. Prior to the start of the study coaches were supplied with detailed instructions on injury definition and usage of the online registration platform (see Chapter 8.5).

Every week, coaches entered exposure data (e.g. duration, training or match, surface of the pitch) into the system. In case a player got injured, coaches entered corresponding information (e.g. mechanism and circumstance) into the platform. The study coordinators in each country (R.R. and J.C.) were instantly informed about injury events and contacted parents and injured children via telephone to clarify open questions (e.g. time of absence from sport participation, medical diagnosis and treatment). To ensure a comprehensive and uniform data collection, telephone interviews were based on a standardised injury registration form. In case of a medically treated injury, parents were asked to forward the exact diagnosis from the physician either as a specific written diagnosis or a diagnosis code. Birth date, player specific data (playing position and preferred foot), and anthropometric baseline data were obtained from the parents and coaches. Players and parents signed an informed consent prior to the start of the study.

In order to achieve a uniform documentation procedure in all clubs, coaches and contact persons were provided with detailed and standardised information. To enhance compliance and improve the quality of data entry a financial compensation for full participation was dispensed to the clubs.

Sample size estimation of the prospective cohort study was based on the main outcome injury incidence during match and training as described earlier.[10] The study was sized to detect a (hypothetical) 33% reduction of injuries by a future injury prevention programme and not originally powered for the analyses completed in the present study.

However, a posteriori evaluation revealed that the sample size was sufficient. To detect a hypothetical hazard ratio (HR) of 0.66 with a power of 0.95 and an alpha level of 0.01, a total of 1638 children would have been needed for the analyses.[16] The effective sample size of our study (with respect to a design effect (variance inflation factor) of 2.86 and an average team size of 15 children per team) was 2111 children and therefore large enough.[17]

We analysed the time-to-event data using three different statistical models and followed a stepwise increase in model complexity. (1) We used the “classic” Cox regression which analyses time to the first injury.[18] However, some of the children sustained more than one injury during the study period, which the “classic” Cox regression cannot handle.

(2) Hence, we used “frailty” models to analyse all injuries (including multiple injuries of single players), while accounting for potential correlations on intra-person-level.[19]

(3) Finally, we fit extended Cox models containing mixed (random and fixed) effects while assuming a Gaussian distribution for the random effects. These models account for clustering effects on team level and allow to analyse multiple injuries of players while accounting for potential correlations on intra-person-level.[20]

Most children did not sustain an injury during the study period. Hence, these children contributed their right censored “survival times” which are statistically exploited in the analyses.

We tested the proportional hazard assumption and potential multi-collinearity between predictor variables during model building.[21] Variables which had $p < 0.2$ in the univariate analysis were entered into multivariate models.[22] Sex was included into the multivariate model regardless of its p-value. Playing position and leg dominance were generally not included into the multivariate analyses. In cases of multi-collinearity between variables with a p-value < 0.2 we included the one with the smaller p-value into the multivariate analysis.

Time to event data were analysed using R (version 3.2.2). We used the coxph function of the “survival” package (version 2.38.3) to fit standard Cox models. The extended Cox models were fitted with the “frailtypack” (version 2.7.6.1) and the “coxme” package (version 2.2-5).

We plotted Kaplan-Meier curves for the variables split by their median. As dichotomisation of continuous data is not recommended for explanatory variables, we only used this approach to improve visualisation in the plots.[23]

Finally, to compare injury risk with regard to playing surface (e.g. natural grass, artificial turf) we calculated injury incidence rates (injuries per 1000 hours of football exposure) with 95% confidence limits. We calculated rate ratios, 95% confidence limits, and corresponding p-values using Stata 13 (StataCorp LP, Texas, USA). Thereby, natural grass was set as the reference category.

We calculated player-specific exposure time in hours until injury (if applicable also from 1^{st} to 2^{nd} injury, from 2^{nd} to 3^{rd} injury, etc.) based on attendance lists and duration of the respective sessions. In cases of non-injured players, total exposure time until the end of the study was used for the analyses.

We calculated chronological age of the children to analyse injury risk in relation to age utilising the start of the study as the reference date. We used sex as a dichotomous variable to compare injury risks between girls and boys. We categorised children in six percentile groups (<P3; P3 to P10; P10 to P50; P50 to P90; P90 to P97; >P97) to analyse injury risk in relation to body height and body mass independent of age. To analyse BMI, we categorised children according to eight percentile-ranges (<P3; P3 to P10; P10 to P25; P25 to P50; P50 to P75; P75 to P90; P90 to P97; >P97).[24]

We investigated the influence of the four common playing positions in children's football (defense (as reference category), attack, goal, and midfield) on injury risk. We analysed the effect of leg dominance on injury risk.[12] Players were split according to three categories (right foot preferred to kick the ball (as reference category), left foot preferred, or no preference). Furthermore, we calculated the match-training-ratio for each player by dividing the number of hours during match play by the number of hours during training and analysed its effect on injury risk. We calculated injury incidence rates on natural grass, artificial turf, indoors and sand to compare injury risk with regard to playing surface.

All analyses were performed for 1) overall injuries, 2) training injuries, 3) match injuries, 4) acute injuries, 5) overuse/growth-related injuries, and 6) severe injuries.

Results

From August 2012 to June 2014, we recorded 395,295 hours of football exposure during 6,038 player seasons of which 3.9% were completed by girls. Mean age of players was 9.3 (SD 1.9) years. Players' mean height was 1.36 m (SD 0.12), players' body mass was 31.0 kg (SD 7.7), and mean BMI was 16.4 kg/m^2 (SD 2.2). In total, 417 injuries, of which 18 (4.3%) affected girls, were sustained by 329 players during the study period. For further information please refer to the publication that covers the general epidemiology.[10]

We mainly refer to the results of the Cox mixed effects model (model 3, see Table 5-1 and Table 5-2). Most results were consistent throughout the three models. The results from model 1 and 2 are presented as supplemental material (Appendix 7, Appendix 8, Appendix 9, and Appendix 10). As player age showed non-proportional hazards we stratified the data according to the age categories in the mixed effects Cox model.

Injury risk increased with age by 34% during match play and by 55% during training per year of life (Figure 5-1 A; $p < 0.001$). Risk for overall injuries did not differ between girls and boys (Figure 5-1 B and Table 5-1). However, girls tended to show an increased injury risk during training (Table 5-1). Age-adjusted taller players (higher percentile rank) had a higher injury risk (Figure 5-1 C, Table 5-1, and Table 5-2; $p < 0.001$). Players with a higher percentile rank of body mass suffered from higher injury risk during training ($p = 0.04$).

The match-training-ratio of non-injured and injured players was 0.16 (SD 0.09) and 0.13 (SD 0.08), respectively with $p < 0.001$. Otherwise, higher match-training-ratios were associated with a lower injury risk during matches (Table 5-1; $p < 0.001$). Left-footed players had a higher injury risk for training injuries (Table 5-1; $p = 0.02$).

Injury risk was increased by 39% ($p < 0.001$) on artificial turf compared to natural grass. In contrast, injury risk was 32% ($p < 0.001$) lower during indoor sessions compared to natural grass (Table 5-3).

Table 5-1: Cox mixed effects model stratified by age group (accounting for recurrent injuries and team-clustering). Hazard ratios (HR) with 95%-confidence intervals and corresponding p-values of overall, match, and training injuries.

		Overall Injuries		Match Injuries		Training Injuries	
		HR [95%-CI]	p	HR [95%-CI]	p	HR [95%-CI]	p
Univariate	Age	1.07 [0.91; 1.26]	0.485	0.94 [0.75; 1.17]	0.556	1.25 [1.00; 1.55]	0.058
	Sex	1.12 [0.61; 2.06]	0.714	0.52 [0.16; 1.72]	0.277	1.75 [0.95; 3.25]	0.076
	Body height percentile cat.	1.22 [1.09; 1.37]	0.002	1.21 [1.02; 1.44]	0.028	1.37 [1.10; 1.70]	0.005
	Body mass percentile cat.	1.15 [0.98; 1.33]	0.076	1.04 [0.83; 1.30]	0.747	1.19 [1.00; 1.40]	0.044
	BMI percentile cat.	1.02 [0.94; 1.11]	0.733	0.91 [0.80; 1.03]	0.139	1.13 [0.99; 1.28]	0.070
	MTR	0.94 [0.75; 1.16]	0.440	0.32 [0.23; 0.46]	<0.001	1.29 [0.94; 1.79]	0.095
	Defense*	1	-	1	-	1	-
	Attack	1.08 [0.79; 1.47]	0.657	1.34 [0.88; 2.04]	0.182	0.76 [0.46; 1.24]	0.263
	Goal	1.02 [0.67; 1.57]	0.853	1.06 [0.62; 1.88]	0.892	0.93 [0.54; 1.66]	0.645
	Midfield	1.17 [0.87; 1.58]	0.303	1.10 [0.70; 1.71]	0.697	1.43 [0.94; 2.19]	0.098
	Right foot preferred*	1	-	1	-	1	-
	Left foot preferred	1.22 [0.94; 1.60]	0.159	0.97 [0.63; 1.49]	0.872	1.53 [1.07; 2.19]	0.021
	No preference	1.14 [0.72; 1.85]	0.889	1.13 [0.56; 2.25]	0.737	1.14 [0.54; 2.40]	0.727
Multivariate	Age	-	-	-	-	1.27 [0.92; 1.75]	0.150
	Sex	1.08 [0.49; 2.38]	0.848	0.66 [0.19; 2.32]	0.515	1.89 [0.72; 4.98]	0.200
	Body height percentile cat.	1.04 [1.02; 1.06]	<0.001	1.04 [1.02; 1.07]	<0.001	1.03 [1.01; 1.06]	0.010
	MTR	-	-	0.32 [0.22; 0.48]	<0.001	1.01 [0.70; 1.44]	0.970

Abbreviations: cat. = Category; BMI = Body Mass Index; MTR = Match-Training-Ratio; * = Reference Category

Table 5-2: Cox mixed effects model stratified by age group (accounting for recurrent injuries and team-clustering). Hazard ratios (HR) with 95%-confidence intervals and corresponding p-values of acute, overuse, and severe injuries.

		Acute Injuries		Overuse Injuries		Severe Injuries	
		HR [95%-CI]	**p**	**HR [95%-CI]**	**p**	**HR [95%-CI]**	**p**
Univariate	**Age**	1.09 [0.92; 1.30]	0.293	1.09 [0.85; 1.40]	0.495	1.14 [0.89; 1.46]	0.323
	Sex	0.88 [0.44; 1.78]	0.723	1.75 [0.75; 4.12]	0.198	0.79 [0.24; 2.65]	0.694
	Body height percentile cat.	1.16 [1.02; 1.32]	0.019	1.21 [1.03; 1.42]	0.026	1.17 [0.98; 1.39]	0.077
	Body mass percentile cat.	1.08 [0.92; 1.27]	0.364	1.23 [1.01; 1.51]	0.053	1.22 [0.97; 1.54]	0.091
	BMI percentile cat.	0.98 [0.90; 1.07]	0.644	1.03 [0.92; 1.16]	0.654	1.00 [0.88; 1.13]	0.902
	MTR	0.91 [0.71; 1.17]	0.480	0.74 [0.52; 1.06]	0.100	1.17 [0.81; 1.71]	0.400
	Defense*	1	-	1	-	1	-
	Attack	1.10 [0.79; 1.52]	0.636	0.83 [0.56; 1.24]	0.374	0.98 [0.64; 1.50]	0.949
	Goal	1.07 [0.69; 1.67]	0.773	0.60 [0.33; 1.11]	0.109	0.61 [0.32; 1.19]	0.139
	Midfield	1.18 [0.86; 1.62]	0.333	1.01 [0.69; 1.46]	1.000	1.01 [0.67; 1.53]	0.980
	Right foot preferred*	1	-	1	-	1	-
	Left foot preferred	1.14 [0.85; 1.54]	0.386	1.19 [0.83; 1.72]	0.347	1.27 [0.85; 1.90]	0.248
	No preference	1.12 [0.65; 1.92]	0.687	0.47 [0.16; 1.43]	0.182	0.98 [0.40; 2.36]	0.970
Multivariate	**Sex**	0.80 [0.31; 2.02]	0.636	2.45 [0.89; 6.72]	0.083	1.30 [0.35; 4.83]	0.707
	Body height percentile cat.	1.04 [1.02; 1.05]	<0.001	1.03 [1.01; 1.06]	0.001	1.04 [1.02; 1.06]	0.001
	MTR	-	-	0.76 [0.51; 1.12]	0.160	-	-

Abbreviations: cat. = Category; BMI = Body Mass Index; MTR = Match-Training-Ratio; * = Reference Category

Table 5-3: Exposure time, number of injuries, injury incidence rate [injuries/1000h], and rate ratio with corresponding p-value. Natural grass is the reference category.

Playing surface	Exposure [h]	Injuries [N]	Incidence	RR 95%-CI	p
Natural grass	156011	161	1.03 [0.88; 1.20]	1	-
Artificial turf	115711	166	1.43 [1.23; 1.67]	1.39 [1.12; 1.73]	<0.001
Indoor	119760	84	0.70 [0.57; 0.87]	0.68 [0.52; 0.88]	<0.001
Sand	3810	6	1.57 [0.71; 3.50]	1.53 [0.68; 3.45]	0.310

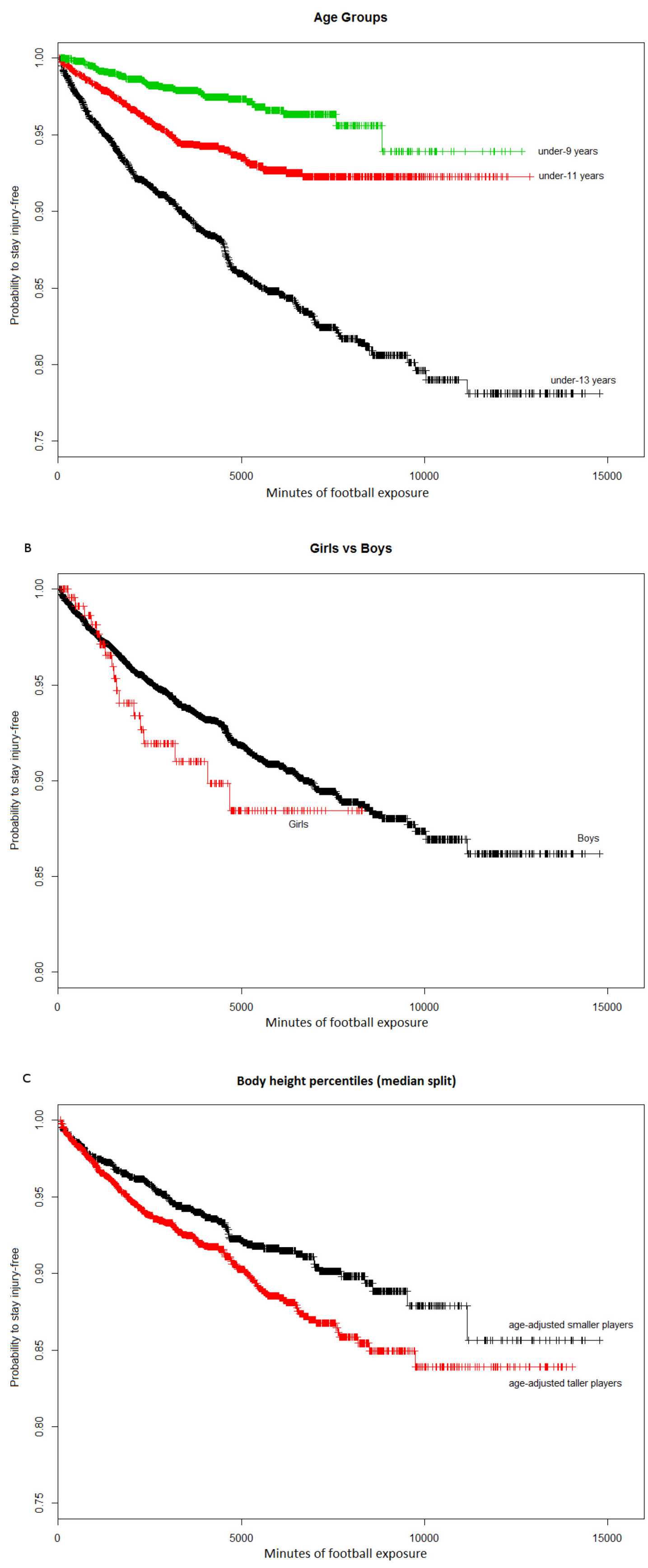

Figure 5-1: Kaplan-Meier curves for overall injuries of (A) age categories (under-9, under-11 and under-13 years of age); (B) girls and boys; (C) age-adjusted body height (body height percentiles split by median).

Discussion

In 7 to 12 year old players, injury risk was increased by one third for match play and by one half for training per year of life (Appendix 7 and Appendix 9). This finding is in line with other studies reporting higher injury rates with increasing age in youth football players.[9] Rising levels of competition and body contact have been discussed as underlying reasons.[6]

Girls tended to show an increased injury risk during training in the univariate analysis, but this effect diminished in the multivariate model. A higher injury risk in girls has been shown in high school football.[25] However, the comparability might be limited as girls and boys are playing together in children's football teams, in contrast to high school sports, where they play in separate teams.

A higher age-adjusted percentile category of body height was associated with an increased injury risk. Higher biomechanical loads of soft tissue and joints have been discussed in the literature as an underlying reason why taller and heavier athletes show higher injury rates.[6] However, the percentile-adjusted body mass only affected training injury risk. Overuse and severe injury risk tended to be increased for players with a higher percentile-adjusted body mass category. Assuming that body height and mass reflect the maturity status of the children, this could be carefully interpreted as an increased risk with increased biological age.[26] An increased injury risk during growth spurts in talented young football players has been shown recently.[27] Further research might help to clarify the relation of maturity status and injury risk in children's football.

Non-injured players had a match-training-ratio of 1:7 whereas injured players had 1:5. In adolescent football players it has been shown earlier that those who had relatively more training exposure suffered from less injuries.[28] Higher match-training-ratios were associated with a lower risk for match injuries and a tendency towards a higher risk for training injuries. On the one hand, it might be assumed that players who are used to playing games suffer from less match injuries. On the other hand, those players who were frequently selected by coaches to play games, also might have higher training intensities and hence, are more prone to sustain injuries during training. Future studies might be indicated to clarify underlying reasons.

Except for a tendency towards higher injury risk during training in midfielders, similar injury risks have been found in our statistical model (3) for defense, attack, goal, and midfield positions. However, in the less complex models (1 and 2; see Appendix 7, Appendix 8, Appendix 9, and Appendix 10) the midfield position showed an increased injury risk in nearly all outcomes. To the best of our knowledge, injury risks in relation to playing position have not been described in children's football. It has to be considered that official guidelines advise against fixed playing positions in children's football to enable the broadest possible development.

We found a higher injury risk during training for players who preferred their left leg to shoot the ball. Leg dominance has been previously discussed in the context of injuries. In under 14 to under 18 football players left leg-dominant players tended to be at an increased risk of injury compared with right leg-dominant players.[12] Reasons for these findings remain speculative.

Injury risk was clearly increased on artificial turf compared to natural grass. This finding is in contrast with data from youth female and young adult football players where the risk of injury did not differ between artificial turf and natural grass.[15, 29] It might be speculated that most low level amateur football clubs do not play on artificial surfaces of the latest, high-quality generation. This circumstance may contribute to an increased risk of injury. Playing indoors showed a lower injury risk. A threefold lower injury risk during indoor sessions compared to outdoor sessions have been shown in high level football players of the age groups under 14 to under 18.[13]

A limitation of this study is that some of the risk factors analysed were non-modifiable (i.e. age, sex, and age-adjusted body height). Nonetheless, knowledge about these risk factors might sensitise coaches allowing identification of individuals or groups at risk. In any case, these risk factors should be considered as control variables in future injury prevention studies. Future investigations of further modifiable risk factors (e.g. balance performance) are highly warranted. To measure respective parameters, however, it might require complex large-scale intervention studies including many motor performance-tests. But, the necessary sample size of such studies might limit their feasibility. Therefore, biomechanical analyses may be indicated to understand injury mechanisms and to (indirectly) identify additional modifiable risk factors in young football players.[30]

The low proportion of girls (and the low number of injuries sustained by girls) limits the interpretation of sex-specific injury risks. However, the percentage of girls in this study was representative for the respective national football associations.

Anthropometric data were assessed once at the beginning of each season, rather than multiple times during the season. In fact, using anthropometric data as time varying factors would have been the better option. However, regarding the sample size of the study, a tighter monitoring schedule was impractical.

The results of the comparisons between different playing surfaces are limited due to the fact that the statistical method of this specific analysis does not account for potential team cluster effects and correlations on within person level.

Conclusion

This is the first study to investigate potential risk factors for injuries in children's football. We analysed the data using different statistical models improving comparability with other studies and allowing the reader to compare between different approaches. To our knowledge, this is the first study to analyse risk factors for sport injuries, utilising player-specific exposure time and accounting for injury recurrence. We used extended Cox models to take individual hazards (frailties) and potential team clustering effects into account.

Injury risk increased with age. Age-adjusted taller players (higher percentile rank) showed a higher injury risk. It could be speculated that this relates to an increased risk with increased biological age. Girls tended to show an increased injury risk during training. Injury risk was higher on artificial turf and lower during indoor sessions compared to natural grass. Future studies on injuries in children's football should consider these findings and control for the above described risk factors. Specifically tailored studies may be conducted to investigate the underlying causes for increased injury risks in relation to maturity status, sex, match-training-ratio, and leg dominance.

Based on our epidemiological data we developed the injury prevention programme "FIFA 11+ Kids".[10, 31] The programme is currently tested in a randomised controlled trial to assess its effectiveness regarding injury prevention.

Practical implications

- Coaches should consider age-adjusted taller players, girls, and/or left-footed players as individuals with an increased risk of injury.
- Players' match-training ratio should be noted as a potentially modifiable risk factor.
- The playing surface should be taken into account as a potentially modifiable risk factor in children's football.
- The reported risk factors should be considered as confounding variables in future analysis.
- Early and age-specific injury prevention seems indicated to counter the increase in injury risk with increasing age.

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6 Publication IV: A new injury prevention programme for children's football – FIFA 11+ Kids – can improve motor performance: a cluster-randomised controlled trial

Roland Rössler

Lars Donath

Mario Bizzini

Oliver Faude

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A new injury prevention programme for children’s football – FIFA 11+ Kids – can improve motor performance: a cluster-randomised controlled trial

Roland Rössler[1], Lars Donath[1], Mario Bizzini[2], Oliver Faude[1]

[1]Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland

[2]FIFA-Medical Assessment and Research Centre (F-MARC) and Schulthess Clinic, Switzerland

Corresponding author:
Roland Rössler
University of Basel
Department of Sport, Exercise and Health
Birsstrasse 320B, 4052 Basel, Switzerland
email: roland.roessler@unibas.ch
phone: +41 61 377 87 39

Abstract

The present study evaluated the effects of a newly developed injury prevention programme for children’s football (“FIFA 11+ Kids”) on motor performance in 7 to 12 years old children.

We stratified 12 football teams (under-9/-11/-13 age categories) into intervention (INT, N = 56 players) and control groups (CON, N = 67). INT conducted the 15-min warm-up programme “FIFA 11+ Kids” twice a week for 10 weeks. CON followed a standard warm-up (sham treatment). Pre- and post-tests were conducted using: Single leg stance; Y-balance test; drop and countermovement jump; standing long jump; 20-m sprint; agility run; slalom dribble; and wall volley test. We used magnitude-based inferences and linear mixed-effects models to analyse performance test results.

We observed likely beneficial effects favouring INT in Y-balance (right leg; +3.2%; standardised mean difference (SMD) = 0.34; *P* = 0.58) and agility run (+3.6%; SMD = 0.45; *P* = 0.008). Possibly beneficial effects were found in Y-balance, drop jump reactive strength index, drop jump height, countermovement jump, standing long jump, slalom dribble and wall volley test.

At least possibly beneficial improvements in favour of “FIFA 11+ Kids” were observed in nearly all parameters. Most effects were small, but slight improvements in motor performance may potentially contribute to a reduction of injury risk.

Keywords**:** Soccer, sprint, balance, agility, youth athletes, juniors

Background/rationale

Football is a high-intensity and high-impact team sport entailing a notable risk of injury. The highest proportion of football players is younger than 18 years.[1] Whereas injury prevention programmes already exist for adolescent players as young as 14 years old, no such programme exists for younger children to date.[2]

Injury prevention strategies generally focus on risk factors. These risk factors can be classified as intrinsic versus extrinsic and further into potentially modifiable and non-modifiable risk factors.[3, 4] Multimodal approaches aim at altering these modifiable intrinsic risk factors (e.g. poor motor performance in strength, power, proprioception and balance).[2] Therefore, it seems reasonable to evaluate a newly developed programme with regard to its effects on motor performance. “FIFA 11+” has been shown to induce meaningful motor performance improvements in strength, sprint and power in youth male futsal players after 12 weeks of intervention compared to the control group (CON).[5] Further, “FIFA 11+” was tested in adolescent female players. High player adherence to the injury prevention programme resulted in improvements in functional balance and reduced injury risk.[6]

The previous version of the programme, “The 11”, did not improve motor performance in adolescent female football players after a 10-week intervention period regarding strength-, power-, speed- and football-specific tests. The authors suggested that the training volume and intensity of the exercises were too low to result in performance improvements.[7]

The established injury prevention programme “FIFA 11+” was designed for players 14 years and older and has been shown to be effective in reducing football injuries in female and male players.[8, 9] An injury prevention programme for children’s football could not be found in the literature.[2] Based on our epidemiological data [10] and following an international expert’s cooperation, we developed an appropriate injury prevention programme specifically tailored to younger children. “FIFA 11+ Kids” takes age-specific injury characteristics and physical maturity into account and focuses on (1) spatial orientation, anticipation and attention, particularly while dual-tasking (to avoid unintended contact with other players or objects) (2) body stability and movement coordination (more general than specific neuromuscular or proprioceptive training); and (3) learning appropriate fall techniques (to minimize the consequences of unavoidable falls).

The present pilot study evaluated “FIFA 11+ Kids” with regard to possible adaptations in movement skills and motor performance. We hypothesized that the new programme shows beneficial effects on neuromuscular performance and motor coordination as compared to a standard warm-up programme.

Methods

Study design

The reporting of this study is presented according to the CONSORT statement.[11, 12] We designed the study as a two-armed, pre-post cluster-randomised trial with an intervention period of 10 weeks. We used an official invitation letter and a mailing list generated from the database of the Swiss Football Association for the recruitment of the teams. We stratified the teams according to their age category. We used the “lottery method” for cluster randomisation to either an intervention group (INT) or a CON. A blinded researcher, who was not involved in any aspect of the study, conducted the randomisation. Players and coaches of the CON were blinded for group allocation. Due to organisational reasons, it was not possible to blind the outcome assessors. The study was approved by the local ethics committee “Ethikkommission beider Basel” (Ref. Nr. EK: 150/13).

Participants

Twelve children’s football teams (in total 157 children from the following age categories: under-9, -11 and -13 years) took part in this study. The inclusion criteria were: (1) playing in an officially registered football club in North-Western Switzerland (2) conducting at least two regular training sessions per week. The flow of participants is presented in Figure 6-1. We informed the participants and their parents about the study procedures as well as risks and harms associated with participation and both signed an informed consent prior to the start of the study.

Sample size

Sample size estimation was based on the traditional null-hypothesis testing. We additionally used the approach of magnitude-based inferences and calculated confidence intervals. We expected small to moderate training effects ($f = 0.10$ to $f = 0.25$) of neuromuscular measures and motor coordination skills for the intervention.[13] We estimated the sample size on the basis of a small effect size ($f = 0.10$, $P = 0.05$, statistical power = 0.80) for the relevant within-between interaction effect. Sample size estimation revealed a required total sample size of 82 children for final analysis. Assuming a dropout rate of about 35% and aiming at achieving two teams per age group we initially recruited about 130 children (6 teams with 11 children per group).

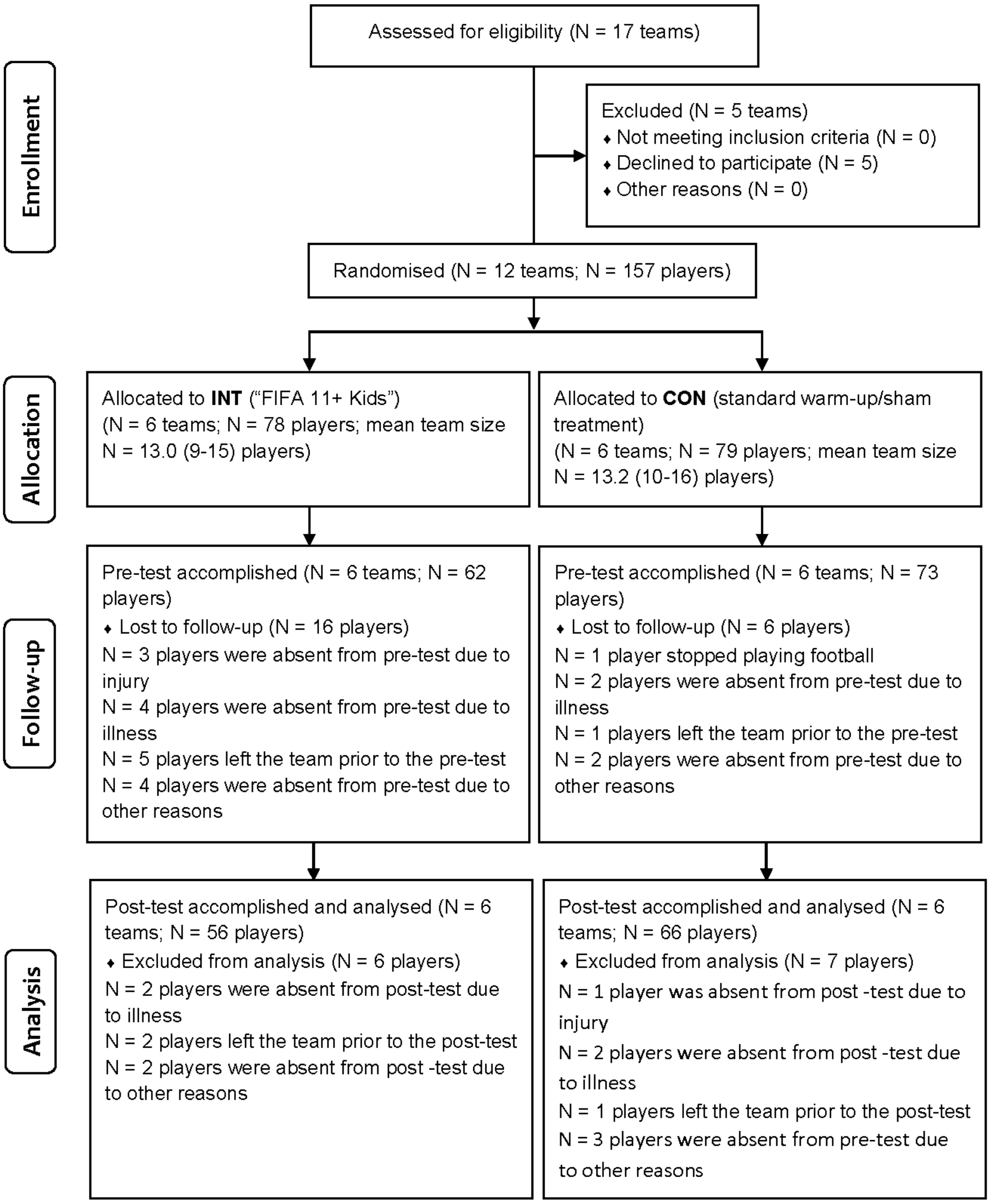

Figure 6-1: CONSORT Flow Diagram.

Treatments

Each treatment session of INT and CON was led by a trained study assistant (sport scientist) in order to ensure comparability and to control for compliance and contamination. The treatments replaced the regular warm-up routine for both INT and CON. Thus, no extra time to the regular training schedule was expended by coaches or players.

FIFA 11+ Kids

INT conducted the 15-min warm-up programme "FIFA 11+ Kids" twice a week (Table 6-1). The programme consisted of 7 different exercises: A running game, two jumping exercises, a balance/coordination task, two exercises targeting body stability and an exercise to improve falling technique. The content of the "FIFA 11+ Kids" programme was adapted (based on "FIFA 11+") by an international group of experts based on the findings of an epidemiological study on injury incidence and characteristics in children's football.[10] Coaches received a printed version of the "FIFA 11+ Kids" manual in which all exercises were described. The programme has a modular structure and consists of three skill levels with progressive load. All teams started at level 1. The study assistants decided when a team would enter the next level of an exercise. This was the case when all players were able to perform the exercise according to the description in the manual. Specific attention was set on the biomechanical axes during the exercises (e.g. leg alignment during single leg jumps).

Control treatment

CON received a 15-min standard warm-up programme (sham treatment) twice a week. It consisted of three different combinations of games (5 min) and technical drills (10 min). The three warm-up combinations were systematically alternated from training session to training session to minimize the risk of decreasing motivation. Programme 1 consisted of a catching game (many catchers) played in the penalty area followed by a dribble/pass exercise, which had different difficulty levels. Players were separated into two rows facing each other and dribbled towards each other. A pass was played after reaching the cone. Programme 2 consisted of a catching game (one catcher) followed by a dribble-task with different difficulty levels. During the dribble exercise, all players moved freely in an area of 8 times 8 meter while dribbling a ball. Programme 3 consisted of a robber game followed by a relay game with different exercises and difficulty levels.

Prior to the development of the CON-training, we interviewed several football coaches in order to assess which types of exercises and games are commonly used as a warm-up in the respective age categories. Hence, we assume that the selected exercises reflect a usual warm-up procedure. The CON-treatment explicitly should not contain specific tasks that are part of the INT-protocol (aiming at stability, strengthening and balance).

Table 6-1: The “FIFA 11+ Kids” exercises.

Exercise	Level 1	Level 2	Level 3
1) Running Game	In the starting position players are at the goal line with sufficient space between each other (like in all other exercises). Players run into the direction of the coach after an acoustical command. Players stop and stand still and stable on one leg after the coach gives the stop signal. Players who move after the stop signal go back to the starting line. The one who is first at the finish line wins. Three heats with about 5 stop commandos each	Like Level 1 but with a ball in one hand.	Like Level 1 but with dribbling the ball (stand still and stop the ball on command).
2) Skating jumps	Players jump slanted forward and land on the free leg. After landing players stand still on one leg until the next jump. The coach gives an acoustical signal for the timing and a visual sign with his arm to show the direction in which players have to jump. Three series with 6 jumps each	Like Level 1 but with a ball in both hands.	Like Level 1 but with a ball balancing on one hand.
3) Single leg jumps	Players jump forward and land on the jumping leg. After landing, players stand still on one leg until the next jump. The coach gives an acoustical signal for the timing of the jumps. Two series with 10 jumps (5 per leg)	Like Level 1 but players jump forwards or backwards. The coach gives a visual sign to show the direction in which players have to jump.	Like Level 1 but players jump forwards in a zig-zag manner.
4) Ball passing	Two players face each other while standing on one leg 3-5m apart. One player throws the ball to his partner, who catches the ball with his hands and throws it back. Variations in throwing technique are allowed. Two series (1 per leg) with 10 passes each (5 per player)	Like Level 1 but one player returns the ball volley with his foot. After 5 repetitions, players change rolls. Four series (1 per leg and player) with 5 passes each	Two players face each other while standing on one leg in reach distance. Both hold a ball in front of their chest. Players press their own ball against the partner’s ball and try to perturb his/her balance. Two repetitions (1 per leg) with a duration of 20 s each
5) Spiderman	Players are on all four legs with the back towards the ground. While keeping the hip elevated, players “walk” forwards. Three heats (distance depending on player’s abilities)	Like Level 1. Additionally players carry a ball on their belly	Like Level 1 but now the feet are on the ball. Players have to keep their feet on the ball while rolling it forwards.
6) Push-up	Players are in the push-up position and roll a ball 8-shaped around their hands. Two repetitions with a duration of 20 s each	Like Level 1 but players roll the ball from their right hand to the left foot, then to the right hand and so on.	Like Level 1 but player’s hands are leaning on a ball. Players walk backwards with tiny steps as far as possible while holding the tension. Three repetitions with a duration of 15 s each
7) Falling techniques	Players do the judoka falling technique “Mae-Maware-Ukemi” starting at a crouching position. Five to seven rolls per side	Like Level 1 but players start the movement from the standing position.	Like Level 1 but players do the falling technique while walking forward.

Outcome measures

Pre- and post-tests were conducted within the time frame of a regular training session at the same time of the day (in the late afternoon or early evening, depending on the team’s training schedule). As the study started in late summer it had to be expected that weather conditions would be increasingly unstable. Hence, by conducting jump and balance tests indoors and the running tests on artificial turf, we controlled for environmental influences in the best possible way. Tests were intra-individually performed at the same place and surface and with the same group of examiners (with few exceptions due to organizational and time constraints). The total testing procedure lasted approximately 2 h for one team. Tests were performed to assess locomotor skills (e.g., standing, running, jumping) and object control skills (e.g., controlling the ball, dribbling, passing).[13] Children were instructed prior to each test in a standardised way. Prior to the test each child was asked whether it suffers from pain or discomfort.

Single leg stance on the dominant leg

Static balance performance (path length of centre of pressure, COP) was measured using the GKS® balance system (Medi Tech Electronic GmbH, Wedenmark, Germany). Children accomplished a familiarisation test and then 3 times 20 s of single leg stance on their dominant leg.[14] The dominant leg was determined using a laterality questionnaire prior to the test.[15] The aggregated path length of the COP (in [mm]) served as the outcome measure. Smaller values represent better balance performance. Reliability was reported to be high with ICC = 0.76.[16]

Y-balance test

For testing dynamic balance, children performed the Y-balance test (Functional Movement Systems, Chatham, USA), which is a simplified version of the star excursion balance test using a Y-shaped plastic device. All players conducted a familiarization test on each leg prior to the 2 tests. The composite score – which is a measure for the reaching distance in relation to the leg length – was used for the statistical analysis. Player’s leg length was measured in centimetres from the anterior superior iliac spine to the distal portion of the medial malleolus with a flexible tape measure.[17, 18] Reliability was reported to be high, with ICC = 0.85 (95%-CI 0.62–0.95) and 0.89 (95%-CI 0.69–0.96).[17]

Drop jump

After 2 familiarization tests, children accomplished 3 bilateral drop jumps (drop height = 0.30 m) using the “OptoGait” system (Microgate Slr, Bolzano, Italy). The OptoGait system is an optoelectronic bar-shaped device that is placed on the floor.[19] Ground contact time and flight time were measured.[20] Jump height was calculated according to the flight time method.[21] In addition, the reactive strength index (jump height per contact time) was calculated.[22] The drop jumps were performed in the akimbo-position. This position reduces the impact of arm movement on jumping height. Children were instructed to perform the drop jump with minimum contact time and maximum jumping height.

Countermovement jump

After 2 familiarization tests children conducted 3 bilateral countermovement jumps using the “OptoGait” system.[20] The jumps were performed in the akimbo-position and children were instructed to jump as high as possible after dipping from a standing position. Flight time was measured and jump height calculated and used for the analysis. Reliability was reported to be high with ICC = 0.99 (95%-CI 0.97–0.99).[19]

Standing long jump

Bilateral standing long jump was measured using the “OptoGait” system. After 2 familiarization tests, children accomplished 3 repetitions.[23] Children were positioned between the two bars of the “OptoGait” system, which were 3 m in length. Players were instructed to jump as far as possible. The arms should be used in order to acquire an adequate momentum. Players had to land on both feet in the 3 x 1 m corridor between the bars of the measuring system. The outcome was the smallest orthogonal distance between the tiptoes (prior to the jump) and the heels of the feet (after landing). Reliability of manually assessed standing long jump performance was reported to be high with ICC = 0.94 (95%-CI 0.93–0.95).[24]

20-m sprint

The 20-m straight sprint was accomplished using 2 photoelectric timing gates (Witty, Microgate Slr, Bolzano, Italy). Temporal resolution was 1/100 s. To eliminate the influence of reaction time, the stopwatch was triggered by a timing gate placed at the starting line. Children started 0.3 m in front of the starting line and performed 2 repetitions.[23] A standardised starting signal was given anyway to enhance motivation. Reliability was reported to be high (ICC = 0.96).[25]

Agility run

The agility run was 20 m in length, including several sharp turns around 6 cones. The run time was measured using 2 photoelectric timing gates ("Witty"). Children completed 2 repetitions with slow speed prior to the tests to get familiar with the course. Players started 0.3 m in front of the starting line and performed 2 repetitions.[26] A standardised starting signal was given to enhance motivation.

Slalom dribble

The slalom dribble course was 20 m in length. Players ran with the ball in a zig-zag fashion around five cones placed in a straight line 4.5 m away from one another. The run time was measured using 2 photoelectric timing gates ("Witty"). Children started 0.3 m in front of the starting line and performed 2 repetitions.[27] A standardised starting signal was given to enhance motivation. Reliability was reported to be between ICC = 0.92 and 0.95.[27]

Wall volley test

The wall volley test required players to pass the ball through the air against a wall, control the rebound and make as many direct air-borne passes against the wall as possible, within a time limit of 30 s. The outcome was the absolute number of correct rebounds.[27] The player was placed in a field which was 2 m wide and 0.5 m away from the wall. Only rebounds accomplished while standing in the sector were counted. After 2 familiarization tests, children accomplished 2 repetitions. Reliability of the wall volley test was reported to be between ICC = 0.97 and 0.98.[27]

Statistical procedures

Anthropometric data and attendance rates of INT and CON players were analysed using the independent samples t-test. Player's best performance of each test was used for statistical analysis. Magnitude-based inferences of differences between groups were calculated with an open-source spread sheet.[28] For each outcome measure, the absolute differences, the log-transformed percentage differences and SMDs between INT and CON in the change scores from pre- to post-test were calculated together with 90% confidence intervals. The analysis was adjusted for pre-test values to take potential baseline differences into account.

This approach of data analysis uses confidence intervals to calculate the probability that a difference is of practical relevance. A difference score of at least 0.2 of the betweenparticipant standard deviation (representing a small effect) was considered to be practically worthwhile.[29] Qualitative descriptors were assigned to quantitative chances of performance effects as follows: 0.5-5 %: "very unlikely"; >5-25 %: "unlikely"; >25-75 %: "possibly"; >75-95 % "likely"; >95-99.5 %: "very likely"; >99.5 %: "almost certainly".[30]

Moreover, we used linear mixed-effects models after log-transformation to analyse performance test results. The covariance structure was selected using the "smaller-is-better-approach" with the -2 Log Likelihood and the Akaike Information Criterion.[31] Differences between INT and CON were calculated after adjustment for baseline data and covariates. In case of a substantial correlation with the performance test ($r > 0.30$), potential confounders (body height, body weight) were used as a covariate.[32] Linear regression was used to evaluate the effect of player attendance in INT players on performance adaptations.

Results

Initially, 157 players were recruited, of which N = 22 did not accomplish the pre-test. Of the remaining 135 players N = 122 accomplished the post-test, which equals a dropout rate of 9.6%. These 122 players did not report physical complaints prior to the test. Data of these players were analysed (INT, N = 56 and CON, N = 66). The flow of participants is shown in Figure 6-1. In total, 4.9% of the participating players were girls.

Anthropometric data are presented in Table 6-2. Groups did not differ in age, body height, weight and BMI ($P > 0.32$). Growth and weight gain between pre- and post-test was higher in CON ($P \leq 0.04$).

Likely beneficial effects favouring INT were observed in Y-balance test (right leg) and agility run. Possibly beneficial effects in favour of INT were observed in Y-balance test (left leg), drop jump reactive strength index, drop jump height, countermovement jump height and standing long jump. The two technical tests, slalom dribble and wall volley test, also showed possibly beneficial effects. Likely trivial effects were found for single leg stance and for the 20-m sprint performance (Table 6-3 and Figure 6-2) In the mixed model analysis, INT showed better performance in agility run and countermovement jump height compared to CON (Table 6-3).

Attendance rate during scheduled training sessions was higher ($P = 0.009$) in CON (89.5%) compared to INT (85.3%; Table 6-2). CON accomplished 1.7 sessions per player and week whereas INT accomplished 1.5. Player attendance rate of INT had no influence on performance test results ($P = 0.11$).

Table 6-2: Number of players, number of athlete sessions and anthropometric pre and post data (mean (SD)).

Group	Players [N]	Planned athlete sessions [N]	Completed athlete sessions [N]	Age [years]	Height pre [cm]	Height post [cm]	Weight pre [kg]	Weight post [kg]	BMI pre [m^2/kg]	BMI post [m^2/kg]
INT	56	974	831	10.0 (1.8)	138.1 (12.3)	139.6 (12.2)	33.0 (9.7)	33.9 (9.5)	16.9 (2.4)	17.1 (2.3)
CON	66	1290	1154	10.1 (1.6)	139.2 (11.5)	140.9 (11.2)	34.6 (10.0)	35.7 (10.1)	17.5 (2.7)	17.7 (2.7)

Table 6-3: Mean values of test results (SD), differences between intervention and control group (90%-CI), and P-values of mixed modelling.

	Mean values				Change differences between INT and CON (90% CI)		
	CON		INT				
	pre	post	pre	post	absolute	percentage	*P*
COP dom [mm]*	491 (199)	459 (126)	516 (118)	479 (86)	-8 [-36, 21]	-0.5 [-6.3, 5.0] %	0.81
Y-B CS right [cm]	107 (10)	106 (8)	109 (10)	110 (9)	3.5 [0.8, 6.2]	3.2 [0.7, 5.8] %	0.58
Y-B CS left [cm]	108 (12)	108 (7)	108 (12)	111 (8)	2.8 [0.5, 5.1]	2.6 [0.4, 4.8] %	0.28
DJ Contact Time [ms]*	248 (63)	218 (55)	256 (75)	207 (35)	-13.6 [-26.1, -1.1]	-4.4 [-9.6, 1.1] %	0.29
DJ Height [cm]	17.7 (5.2)	19.0 (4.3)	18.7 (5.7)	20.3 (5.3)	0.8 [-0.5, 2.1]	4.3 [-3.6, 12.8] %	0.35
DJ RSI [cm/s]	75.3 (29.0)	92.4 (29.4)	77.8 (29.3)	100.7 (29.4)	6.8 [-0.6, 14.3]	9.1 [-0.5, 19.7] %	0.34
CMJ Height [cm]	22.7 (3.6)	22.9 (3.2)	23.0 (4.1)	24.0 (4.3)	0.9 [0.1, 1.8]	3.7 [0.0, 7.6] %	0.03
SLJ [cm]	159 (15)	167 (17)	163 (20)	173 (18)	2.8 [-1.3, 1.9]	1.9 [-0.5, 4.5] %	0.56
20 m Sprint [s]*	4.04 (0.27)	4.02 (0.27)	3.99 (0.28)	3.97 (0.25)	0.00 [-0.04 , 0.04]	-0.1 [-1.1, 0.9] %	0.34
Agility Run [s]*	8.83 (0.82)	9.48 (0.50)	9.23 (0.40)	9.29 (0.46)	-0.31 [-0.47, -0.16]	-3.6 [-5.1, -2.0] %	0.008
Slalom Dribble [s]*	6.00 (1.11)	6.11 (1.23)	5.78 (0.76)	5.74 (0.88)	-0.18 [-0.38, 0.03]	-2.9 [-6.0, 0.3] %	0.66
Wall Volley [n]	14.1 (6.9)	14.0 (7.3)	10.4 (5.1)	11.6 (4.8)	1.2 [-0.2, 2.7]	23.2 [6.7, 41.1] %	0.23

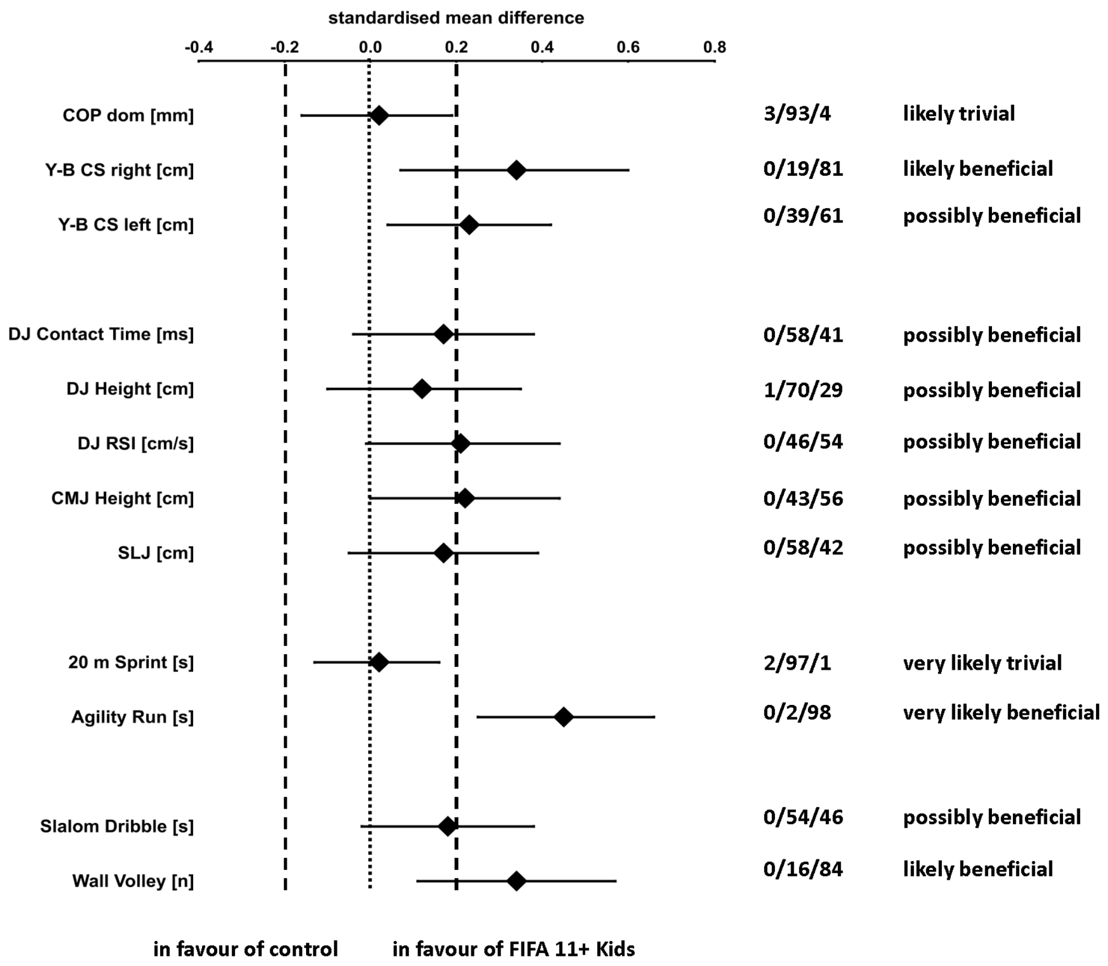

Figure 6-2: Outcomes in standardised (Cohen) units with 90% confidence intervals. The probabilities of an effect being harmful/trivial/beneficial are expressed as percentage values. Clinical inference is provided. Abbreviations: COP dom = centre of pressure path length during single leg stance on the dominant leg; Y-B CS = Y-balance-test composite score; DJ = drop jump; RSI = reactive strength index; CMJ = counter movement jump; SLJ = standing long jump; Wall volley = wall volley test.

Discussion

Our study demonstrated that “FIFA 11+ Kids” can improve motor performance in children and hence can be considered superior compared to a standard warm-up programme. In general, at least possibly beneficial improvements were observed in nearly all performance tests. To our knowledge, no cut-off values of performance parameters exist to estimate if an effect might lead to a reduction in injury risk. Most observed effects were small, but considering the short intervention period of 10 weeks, such slight improvements in motor performance may contribute to a reduction of injury risk in the long-term application. To clarify the latter question, “FIFA 11+ Kids” is currently evaluated regarding its potential to reduce injuries in a large-scale cluster-randomised controlled trial.

Several studies showed that successful injury prevention programmes can induce motor performance enhancement.[5, 6, 32-37] Performance improvements of youth futsal players have been reported after conducting “FIFA 11+” twice a week for 12 weeks with SMDs mostly ranging between 0.5 and 1.1. Players improved especially in isokinetic hamstring and quadriceps strength. These SMDs were higher compared to our study, where we observed SMDs between 0.2 and 0.5. The percentage differences between INT and CON in the change scores from pre- to post-test mostly ranged between 7% and 27 % and hence somewhat higher than the differences in our study (0–23% with most changes lying between 1% and 9%).[5] Several studies in female high school athletes used balance and plyometric exercises to enhance performance and influence risk factors for knee and specifically anterior cruciate ligament injury. Players improved their postural stability as well as neuromuscular power and control.[34-37] The authors suggested that a combination of plyometric and balance exercises may maximize the effectiveness of such preseason training programmes.[35-37] This suggestion was confirmed by a recent meta-analysis on exercise-based injury prevention in youth sport.[2] Eccentric overload strength training of the hamstring muscles was investigated in adult male high level football players. The authors reported improvements in isokinetic hamstring strength and sprint performance (flying 30-m-time) and a reduction in injury rate.[33]

The relevance of performance enhancement effects comprises two aspects: First, it might positively affect injury risk factors that are associated with a lack in balance, power and stability.[3, 38] And second, sport specific performance enhancement might be a key argument for the real-life implementation of the injury prevention programme and for compliance. The latter point is relevant, as it has been shown that compliance is essential for the success of injury prevention programmes.[6, 39]

It has to be stated that CON accomplished more training sessions throughout the observation period compared to the “FIFA 11+ Kids” group. But, although the CON-treatment involved games with many changes in movement direction, dribbling and ball handling exercises, players of the “FIFA 11+ Kids” group showed greater improvements in agility, dribbling and ball handling. It has to be noted that the CON-treatment was not progressive in its nature, whereas “FIFA 11+ Kids” consists of several levels with progressive difficulty. To our experience the chosen CON-treatment reflected a “standard warm-up routine” in the best possible way.

Growth and weight gain was higher in CON, which might indicate a higher physical development rate during the study period. As maturity and growth rate are crucial for physical performance it might be hypothesised that the latter point led to performance improvements in favour of CON which in turn would underline the observed effects in favour of INT.[40] All players were free of physical complaints prior to and during the tests. Hence, it can be assumed that none of the players were limited in their performance due to pain or discomfort – which might have been relevant in cases of growth-related complaints or injury.

Player adherence has been reported to be crucial for the success of injury prevention.[6] However, within the scope of our study, the “FIFA 11+ Kids”-attendance rate of players did not influence the performance test results. Nevertheless, it has to be stated that the results of the attendance analysis are somehow limited due to homogeneous attendance rates throughout the sample. When applying a median split, low-attending players had 77% (SD 8.3) and high-attending players 93% (SD 5.1) of sessions accomplished. With regard to the sample size, this difference might be too small to reveal a potential effect of attendance rate on performance improvements.

Limitations

The dropout rate was smaller than expected, which as a consequence led to a higher number of players in the analysis. In contrast, observed effects were smaller than expected which might go in line with the higher player attendance rates in CON compared to INT and the aforementioned higher growth rate in CON players. It was not possible to blind assessors against group allocation. Clustering was not accounted for within the sample size estimation. No index of maturity was assessed within the study.

Conclusions

The newly developed injury prevention programme “FIFA 11 + Kids” can be considered appropriate, as it seems to be adequate for inducing slight performance enhancements when compared to a traditional warm-up programme. Dynamic balance and agility were clearly improved. Further, jumping performance and slalom dribbling were slightly enhanced. No negative side effects of “FIFA 11+ Kids” were observed. Potential risk factors can be positively influenced.[3] Hence, “FIFA 11+ Kids” fulfils the requirements for being capable of reducing football injuries in children.

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7 Synthesis, discussion, and perspectives

The overall aim of the PhD project was to develop an evidence-based injury prevention programme for children's football.

One key finding of our review article on injuries in young football players was the paucity of data regarding children younger than 14 years of age.[1]

Alongside our original studies, we conducted a systematic review and meta-analysis on injury prevention programmes in young athletes to assess the current state of the art of such programmes and to identify their structure and content. Thereby, we found that no injury prevention programme for organised children's sport existed (Chapter 3).[2]

As described earlier, the first step towards injury prevention is to gather prospective epidemiological data (Chapter 1.6). For that reason, we collected epidemiological data on injuries in children's football in a large-scale prospective study (Chapter 4 and 5).[3]

Based on the cumulative knowledge of our previous work we developed "FIFA 11+ Kids", which is an age-specific warm-up programme to prevent football-related injuries in children. In a next step, we tested "FIFA 11+ Kids" in a pilot study regarding feasibility and possible adaptations in motor performance (Chapter 6).[4]

Beyond the scope of the PhD project we updated "FIFA 11+ Kids" after the aforementioned pilot study and tested its efficacy to reduce injury incidence rates in an international multicentre cluster-RCT (Chapter 7.5).

7.1 Summary of the main results

Injury prevention meta-analysis

The aim of our injury prevention meta-analysis was to quantify the efficacy of exercise-based injury prevention in children and adolescents in organised sport. We analysed (cluster-) RCTs and controlled intervention studies. We intended to describe the characteristics of the study population and the intervention, to calculate cumulative effects, to analyse effects for specific subgroups, and to provide recommendations for future research.

We systematically searched all relevant databases. We included studies published in English in peer-reviewed journals, analysing the effects of exercise-based injury prevention programmes in athletes younger than 19 years of age. The main outcome was the overall injury reduction.

These criteria were fulfilled by 21 relevant trials, including a total of 27,561 athletes. The cumulative effect showed an overall injury reduction of 46%. Based on our findings, multimodal programmes utilising jumping/plyometric and balance exercises can be recommended. The beneficial effects were independent of whether the programme was implemented during pre- or in-season. An important finding was the fact, that there is a considerable lack of data concerning children under 14 years of age and that no injury prevention programme for organised children's sport existed.[2]

Football injuries in children

The second PhD-relevant project was our epidemiological study on the incidence and characteristics of football injuries in children aged 7 to 12 years.[3] Exposure time of players during training and match play (in hours) was collected prospectively over two seasons. Injury data (e.g. location, type, mechanism, and severity of injuries) were reported by coaches via an internet-based registration system. Based on these data, we calculated injury incidence rates (injuries per 1,000 hours of football exposure).

This was the first prospective large-scale epidemiological study on football injuries in players younger than 13 years of age. The mean age of the players was 9.3 (SD 1.9) years, and 4% of participants were girls. In total, we recorded 6,038 player-seasons with 395,295 hours of football exposure. A total of 417 injuries were reported. The overall injury incidence was 0.61 (95%-CI 0.53, 0.69) injuries per 1,000 hours of football exposure during training sessions and 4.57 (95%-CI 4.00, 5.23) during match play. The overall injury incidence rate increased with increasing age. About half of all injuries led to medical consultation. The majority of all injuries (76%) were located in the lower limbs. Joint and ligament injuries comprised 31%, contusions 23%, muscle and tendon injuries 19%, and fractures and bone injuries 15% of all injuries. Regarding injury severity, nearly one quarter (24%) of all injuries was classified as severe, i.e. led to more than 28 days of absence from sport participation. Children showed a relatively high proportion of fractures and injuries to the upper limbs. Our study provides an evidence base for injury incidence rates and injury characteristics in children's football.[3] These data built the basis for the development of an age-specific injury-prevention programme.

Risk factors for football injuries

The third PhD-relevant paper investigated time-to-injury data of our epidemiological study to analyse risk factors of football injuries in children aged 7 to 12 years. We used sophisticated extended Cox models to account for correlations on team- and intra-person-level. We analysed injury risk in relation to age, sex, playing position, preferred foot (to kick the ball), and regarding age-independent body height, body mass, and body mass index. Further, we analysed injury risk in relation to the playing surface.

Injury risk was increased by 46% ($P < 0.001$) per year of life. Age-adjusted taller players (higher percentile-rank) had a higher risk for injury. Injury rates were higher on artificial turf (39%; $P < 0.001$) and lower during indoor sessions (32%; $P < 0.001$), compared to natural grass. Girls tended to show an increased injury risk during training sessions compared to boys.

Development of "FIFA 11+ Kids"

In an international and interdisciplinary group of experts (names and affiliation of the project group members see Chapter 8.1) we developed an age-specific football injury prevention programme called "FIFA 11+ Kids". As planned, the findings of our epidemiological study served as a sound basis to detect age-specific injury patterns. "FIFA 11+ Kids" is a 15-minute warm-up programme. In its first version it consisted of 7 different exercises with 3 levels of difficulty. The programme focuses on (1) spatial orientation, anticipation, and attention especially while dual-tasking (to avoid unintended contact with players or objects) (2) neuromuscular performance, body stability and movement coordination (to prepare the body for the physical demands of playing football and to reduce the number of falls) and (3) appropriate falling techniques (to minimise the injury risk of falling).

“FIFA 11+ Kids” – motor performance (pilot study)

The fourth PhD-relevant study was a pilot project to evaluate the “FIFA 11+ Kids” programme regarding possible adaptations in motor performance (Chapter 6) and feasibility (Chapter 7.2.5). Improvements in motor performance are relevant, as effective exercise-based injury prevention programmes need to influence modifiable risk factors (e.g. lack in balance or strength). We stratified 12 football teams (with players aged 7 to 12 years) into intervention (N = 56 players) and control groups (N = 67). The intervention group conducted the 15-min warm-up programme “FIFA 11+ Kids” twice a week for 10 weeks. The control group followed a standard warm-up (as a sham treatment). During pre- and post-tests we assessed parameters to determine motor performance during different tasks. The results showed beneficial effects in nearly all parameters favouring the intervention group in dynamic balance, agility, technique, and jumping performance.[4] We modified “FIFA 11+ Kids” after the practical experiences during the pilot study (modified version of “FIFA 11+ Kids” see Chapter 8.6). The main changes were 2 additional levels for each of the 7 exercises, taking the large differences in children’s performance due to chronological age, maturity, and level of play into account.

7.2 Synthesis and general discussion

7.2.1 Injury prevention in youth sport

Prior to our publication, no meta-analysis examined the effects of injury prevention programmes in children and adolescent sport. About ten years earlier, a systematic review on injury risk factors in children's and adolescent's sport had been published.[5] The authors concluded that injury prevention programmes should target potentially modifiable risk factors through proprioceptive training and that further high-quality studies are necessary.[5] The modification of intrinsic risk factors is regarded as a key to injury prevention. Jumping (e.g. plyometrics) and balance exercises have been discussed as the methods of choice to prevent different types of injury.[5, 6]

Earlier systematic reviews reported beneficial effects of injury prevention programmes in different sports,[7-9] as well as in football.[10] Participants of the included original studies were mostly youth and adolescent athletes. However, the authors did not perform a quantitative synthesis (meta-analysis).

Several reviews and/or meta-analyses investigating different populations focused specifically on anterior cruciate ligament (ACL) injury prevention programmes.[11-13] The authors concluded that programmes were effective in reducing ACL injuries by about 40% to 50% and recommended age-appropriate strength and neuromuscular balance exercises.

Our publication was the first meta-analysis that quantified the effects of injury prevention programmes in children and adolescents in organised sport. Thus, it updated and extended previous systematic reviews which did not include a quantitative synthesis.[7, 8] It does provide a broad overview as well as detailed subgroup analyses.

In 2015 (after publication of our meta-analysis), two further meta-analyses with the same scope were published. One of these meta-analyses additionally included one single original study that was published after our meta-analysis – all other original studies had already been included in our analysis. Therefore, the added value of these two meta-analyses might be regarded as limited.[14-16]

Our meta-analysis revealed an impressive 46% of injury reduction. A subgroup analysis (sensitivity analysis) including only "high-quality" studies still showed a large effect of 41% injury reduction. Nevertheless, we used a more conservative hypothetical effect of

33% as a basis for the sample size estimation of our subsequent multicentre cluster-RCT. We decided to use this conservative value because of two reasons: firstly, to consider the fact that even a moderate reduction of sport injuries has been indicated to be of acute relevance for children's health as well as of short- and long-term economic impact for health care costs;[17, 18] secondly, we did not want to underpower our study due to a too optimistic estimation of the anticipated intervention effect.

The clear vast majority of participants of sport injury prevention studies in young athletes were girls (87%). Boys have been highly underrepresented – accounting for just one eighth of participants.[2] This is surprising, given higher sport participation rates in boys.[19-21] Some studies reported similar overall risks for sport injuries in girls and boys. However, specific injury patterns have been shown for some types of injuries with higher incidence rates in girls (e.g. ACL injuries, concussions).[1, 22-26]

Our meta-analysis showed that girls profited more from injury prevention than boys. However, the causes remain speculative. We concluded that in any case further research is required to clarify the underlying reasons especially because data for boys are underrepresented. Our subsequent multicentre cluster-RCT included mostly boys (about 96%), which is representative for the children's football in the corresponding countries (Chapter 7.5). Therefore, our subsequent study helps to equalise the imbalance of injury prevention data between girls and boys.

Both, elite as well as sub-elite athletes profited from prevention programmes, whereby sub-elite athletes benefited more than elite athletes. It could be assumed, that this relates to a ceiling effect in the elite group as better trained athletes may have less potential for further improvements regarding neuromuscular performance.[5, 27] We acknowledged this finding and developed multiple levels per exercise for "FIFA 11+ Kids". The variation and progressive difficulty might help to minimise ceiling effects.[7]

We compared studies that implemented injury prevention during "pre-season only", "in-season only" or "pre-season and in-season". All three settings led to very similar effects which is valuable information for practice. As in children's football there are generally no pre-season phases like in higher age groups and more professional settings, we designed "FIFA 11+ Kids" to be conducted throughout the entire season.

Programmes that included plyometric and jumping exercises showed a greater preventive effect than programmes that did not entail such exercises. This might be related to the fact that injuries often occur during high-impact situations (e.g. landing, change in moving direction, opponent contact).[28, 29] In this regard, players' neuromuscular system might be best prepared to resist such impacts through specific high-intensity exercises like jumps and landings.[6] Taking these findings into account, we set a specific focus on jumping and landing exercises in "FIFA 11+ Kids". Biomechanical axes have been shown to be relevant in relation to lower extremity injuries (especially knee injuries).[6, 30-32] "FIFA 11+ Kids" aims at sensitising the coaches regarding biomechanical axes, especially leg alignment. Therefore, we provided respective explanations and pictures in the manual (Figure 7-1 and Chapter 8.6).

Figure 7-1: Typical errors occurring during exercise number 1 of the "FIFA 11+ Kids" programme. Left: Inappropriate leg alignment and hip axes during single leg stance; Middle: Internal rotation of the foot; Right: External rotation of the foot.

We observed a tendency towards lower rate ratios in studies focusing specifically on knee injuries. However, it has to be considered that a comparison of scopes (e.g. "aiming at overall injury rate" versus "aiming at a reduction of lower extremity injuries") is limited. This is due to the fact, that a certain amount of injuries (e.g. head collision during a header duel) might not be directly preventable through exercise-based programmes. Regarding data analysis, this "basic amount" of non-preventable injuries is not considered in studies with a "specific" focus, whereas studies with an "overall" focus include these. Therefore, greater preventive effects (expressed by lower rate ratios) are to be expected in studies with a "specific" focus.

On the one hand, it can be argued that it is of utmost importance to prevent specific types of severe injuries such as ACL ruptures or severe ankle sprains. On the other hand, it can also be argued that prevention programmes should focus on the most frequent injuries to achieve the greatest possible outreach. Based on these thoughts, "FIFA 11+ Kids" aims at the reduction of injuries in the broadest possible way without losing its specificity to reduce the most severe injuries. In line with the findings of our meta-analysis, we designed “FIFA 11+ Kids” as a multimodal programme consisting of different exercises each one having a specific goal (manual see Chapter 8.6).

7.2.2 General epidemiology of injuries in children’s football

We conducted the first prospective large-scale epidemiological study on football injuries in children (Chapter 4). The observed overall injury incidence rate was comparable with one of the – very limited – available studies on these age groups.[33] However, another study reported about 10 times higher incidence rates in 7- to 13-year-old football players. The latter study used a very broad injury definition and assessed exposure as the number of athlete sessions rather than hours.[34] As mentioned in the introduction, the comparability between studies is limited because of different injury and/or exposure definitions (Chapter 1.4).

Compared with studies in older players the observed injury incidence rates in our epidemiological study in children were lower. However, the distribution of mild/moderate/severe injuries and of mean layoff time was similar to older players.[1, 3]

Acute fractures were the most frequent type of severe injuries. Their observed incidence rate was about 2.5 times higher compared to the estimated fracture rates in children’s football based on registry data.[35] Compared to prospective data from players older than 13 years, the proportion of fractures and bone stress as well as injuries to the upper extremities was 2 to 3 times higher.[1, 3] Young players seem to be at specific risk when falling as one quarter of fractures was caused by falling. We concluded that an age-specific injury prevention programme should consider these findings. Appropriate falling minimises the risk of injury by reducing the peak landing force during ground contact.[36] The importance of so called “landing skills” is well known from martial arts and has been shown to be efficacious in reducing fall-related injuries in adolescent Australian rules football players.[37] Therefore, we included exercises to learn proper falling techniques into “FIFA 11+ Kids” to reduce fractures of the upper limbs.

We observed a relative high proportion of injuries related to unintended contact with players or objects. For that reason, we included exercises into “FIFA 11+ Kids” to enhance spatial orientation and attention on the field. This may help to reduce unintended body contact with objects or other players.[38]

The most frequent diagnosis was ligament injury of the ankle, which on average led to more than two weeks of absence from football participation. Especially the youngest players showed a high proportion of ankle injuries. Balance exercises have successfully been used to target ankle sprains.[39-41] From a prevention perspective it seems necessary to start with appropriate exercises from a very young age as it is known that a previous ankle sprain clearly increases the risk to sustain further ankle injuries.[39] Consequently, different tasks of "FIFA 11+ Kids" aim at improving the stabilisation of the ankle.

Most injuries by far occurred in high-intensity situations with high biomechanical loads like tackling, falling, jumping/landing, or ball contact. Such impacts can for example lead to ligament injury of the knee which was the second most common diagnosis in our study. These knee injuries led to a mean layoff time of about one month. To reduce these injuries we included balance tasks into "FIFA 11+ Kids" to improve dynamic stability and proprioception. Further, the included plyometric exercises (e.g. single leg jumps) aim specifically at improving neuromuscular control of joints of children's lower extremities,[42] and prepare the musculoskeletal system for football-specific demands. To stay injury free it is crucial to withstand situations with high biomechanical loads. In this regard, plyometric exercises have been proven particularly suitable to reduce injuries – specifically ligament injuries to the lower extremities.[2, 43]

Non-acute injuries accounted for one sixth of all injuries. Such overuse injuries are mostly induced by repetitive micro traumata.[44] The absence of a clear traumatic event might be a problem regarding the correct behaviour of athletes, coaches, and parents. Due to the insidious onset of the complaints such injuries may be diagnosed late and the beginning of treatment might be delayed.[44] If not accurately treated, such injuries can cause functional impairment, become chronic, and even lead to permanent disability. Therefore, it is important that coaches, parents and players themselves attend the (early) signs of sport-related overuse symptoms and consider respective actions.[45] In some cases, such overuse-induced conditions are difficult to distinguish from "growth-related" conditions. The latter complaints are unique for young athletes as they affect the growing skeleton of the child.[46] Characteristics and related risk factors have been described for these types of conditions.[47, 48] In our study the amount of non-acute bone stress conditions increased from the youngest to the oldest age group. Growth-related conditions like Sever's disease (calcaneal apophysitis) and Osgood-Schlatter syndrome (apophysitis of the tibial tubercle) are most common among 9- to 12- and 11- to 14-year-olds, respectively. Both conditions often require a long time of rest or at least a reduction in training load.[49] However, there is still limited evidence on how to treat calcaneal apophysitis best.[50, 51] As we further registered nine knee, one Achilles tendon, and seven foot/toe injuries with non-acute onsets and without (clear) medical diagnoses it could be reasonably assumed that the actual number of growth/overuse-induced injuries was even higher. About one third of these unspecified injuries were categorised as severe, whereby one led to the longest layoff time of all injuries. Therefore, we recommend that coaches should be aware of age/growth-specific complaints of children. Medical consultation is strongly indicated if chronic pain is present.[52]

7.2.3 Risk factors for football injuries

Many studies covered the topic of risk factors for football injuries [53-75] and other sport-related injuries.[5, 7, 25, 76-88] However, there is a paucity of data regarding injury risk factors in children's football. Our study was the first to investigate potential risk factors for injuries in children's football. Further, to our knowledge, this was the first study to analyse risk factors for sport injuries, utilising player-specific exposure time and accounting for injury recurrence. We used extended Cox models to account for individual hazards (frailties) and potential team clustering effects.[89-92]

In our sample of child footballers, the injury risk was increased with each year of life by one third during match play and by half during training. These findings are generally in line with studies on older players as we also found higher injury rates with increasing age in our review article.[1] Increasing competitiveness and body contact have been discussed as underlying reasons.[5] Consequently, we used age as a covariate in our analysis of the subsequent multicentre cluster-RCT.

In the univariate analysis girls tended to show an increased injury risk during training compared to boys. Increased injury rates have been reported for female high school football players.[86] The comparability is, however, limited due to two reasons: Firstly, in our study girls and boys were playing together which is normal for children's football teams in Switzerland and the Czech Republic, whereas in high school sports, they generally play in separate teams. Secondly, our players were prepubescent compared to high school sport in which athletes are pubescent. It might be assumed that sex-specific injury patterns establish after childhood.[62, 93]

We analysed body height, body mass, and body mass index independently of age using percentile categories.[94] We found that a higher age-adjusted percentile category of body height was associated with an increased injury risk. Previous data showed that taller and heavier athletes had higher injury rates.[5, 67] The authors related this to higher biomechanical loads of soft tissue and joints.[5] In our sample, a higher age-adjusted body mass led to an increased injury risk during training. Further, we found a tendency towards an increased risk for overuse and severe injuries in players with a higher age-adjusted body mass. Increased sport-related injury rates have been reported for overweight/obese school children (11 to 15 years of age) compared to peers with normal body mass.[95]

It could be reasonably assumed that body height and mass reflect the maturity status of the children.[96] Therefore, our findings could be interpreted as an increased risk with increased biological age. This would be in line with recently published data that showed an increased injury risk during growth spurts in young talented football players.[72] Consequently, we controlled for anthropometric parameters in our multicentre cluster-RCT.

A simple comparison of injured and non-injured players revealed a difference in the match-training-ratio (1:5 compared to 1:7) in our sample. This finding is in line with data from adolescent football players. It has been shown that those who had relatively more match exposure suffered from more injuries.[55] However, the results of our time-to-injury analysis with extended Cox models was less clear: Here we found higher match-training-ratios to be associated with a lower risk for match and a tendency towards a higher risk for training injuries. We suggested that players who are used to playing games suffer from less match injuries (per unit of exposure) and further, that those players who were frequently selected by coaches to playing games, might have higher training intensities which in turn could be a reason for the increased injury risk during training. As this interpretation is speculative, future studies are indicated to investigate underlying mechanisms. In any case, prescribing the appropriate workload is challenging – especially on an individual level. A recently published model called "Training-Injury Prevention Paradox" suggests that harder and/or more training might contribute to well-developed physical qualities and therefore provides a protective effect against injury. For the foregoing reasons, it is crucial that the training load is increased slowly: Too fast increases in training intensity or volume may lead to pronounced fatigue and, in turn increase the risk of injury.[97, 98] We acknowledged a potential influence of the match-training-ratio in the analysis of our multicentre cluster-RCT.

Official guidelines voice their opposition against fixed playing positions in children's football to allow the broadest possible development. Nevertheless, we analysed injury risk in relation to playing position. Differences in injury incidence rates and injury patterns in relation to playing positions have been described in football,[99, 100], rugby,[101] and handball.[102] However, except for a tendency towards higher injury risk during training in midfielders, we found similar injury risks in our statistical model for the defence, attack, goal keeper, and midfield position. It has to be stated that this analysis is of explorative manner as players under 16 years of age are mostly not settled on a particular position, yet.[100] A comparison to other data was not possible as no other study in children's sport investigated injury risk in relation to playing positions.

Leg dominance has been previously discussed in the context of injuries. An increased risk of injury in left leg-dominant players compared with right leg-dominant players has been reported in youth football.[58] At least during training we also found a higher injury risk in players who preferred their left leg to shoot the ball. The reasons for these findings remain speculative. Further research seems indicated to clarify underlying mechanisms.

Whilst older generations of artificial turf were suspected to cause higher injury rates, the latest third generation turfs did not induce increased injury incidence rates compared to natural grass in several studies.[61, 71, 103-108] However, some evidence suggests that playing on artificial turf leads to a change in playing style.[104] Few studies have shown an increased risk for ankle sprains in elite male players and higher rates of back pain in youth players on modern (third generation) artificial turf.[53, 56] These data relate to youth/adult populations mainly of elite level. Therefore, the transferability of the findings to a child population might be limited. In our study injury risk was clearly higher on artificial turf compared to natural grass. It could be speculated that most low-level amateur football clubs do not play on artificial surfaces of the latest generation. This circumstance may contribute to the increased risk of injury on artificial turf in our study.

In our sample, playing indoors showed a lower injury risk. This is in line with data from high-level football players of the age groups under-14 to under-18, in which a threefold lower injury risk during indoor sessions compared to outdoor sessions has been reported.[57] Consequently, we acknowledged a potential influence of the playing surface in the analysis of our large scale cluster-RCT

7.2.4 “FIFA 11+ Kids” and motor performance

The ability of “FIFA 11+ Kids” to improve motor performance is important because of different reasons: To target the injury risk associated with deficits in balance, power, and stability,[5, 109] to provide a strong argument for the real-life implementation of the injury prevention programme, and to improve compliance.[110, 111] Compliance is specifically relevant, as it is essential for an injury prevention programme to be efficacious/effective.[112-114]

Several studies have shown that successful injury prevention programmes induce motor performance enhancement.[6, 31, 113, 115-119] In our study, “FIFA 11+ Kids” showed to be superior compared to a standard warm-up programme as improvements were observed in nearly all performance tests (Chapter 6). In fact, most of these effects were small, but no cut-off values of performance parameters are available to estimate whether an effect might lead to a reduction in injuries. The intervention period of our pilot study was “only” 10 weeks. We assume that the improvements in motor performance may increase in the long-term application (e.g. throughout an entire season) – and that these improvements might contribute to a reduction of injuries. It could be speculated that already small improvements in motor performance may lead to relevant benefits regarding injury prevention on a population level.

7.2.5 Feasibility of “FIFA 11+ Kids” – unpublished results

Aside from the motor performance aspect, we aimed with our pilot study at assessing the feasibility of “FIFA 11+ Kids”. Therefore, participating coaches (N = 9) and children (N = 60) of the intervention arm of our pilot study evaluated “FIFA 11+ Kids” using standardised questionnaires. The questionnaire for the coaches consisted of eight open questions and the one for the players of nine closed questions (Table 7-1 and Table 7-2).

We asked coaches and children to answer the questionnaires honestly. As the phenomenon of social desirability is a potential source of bias in survey research,[120] we emphasised that it is very important to tell us any negative points. They were explained that this information is needed to improve the programme. Hence, we expect that coaches and children did not hold back negative comments and that we got a reasonable assessment of their impressions related to “FIFA 11+ Kids”. As these data have not been published, the findings are provided here.

Table 7-1: Questionnaire for the coaches with corresponding answers. In case of equal answers those were summarised and ordered by their frequency (top down). Positive answers are symbolised with a "+", negative answers with a "–", and general statements with a "o".

Q 1: *How do you evaluate the practicability of "FIFA 11+ Kids" and the integration into your training routine?*

+ children had fun doing the exercises
+ exercises were diversified
+ it was a good alternative to the normal warm-up
+ the exercises are useful for the regular training routine
+ the progressive nature of the programme integrated well in our training and increased motivation, however, more levels would be useful (better differentiation between age groups and skill levels)
– I was sceptical at the beginning, but doubts disappeared over time
– the highest level (level 3) of several exercises was too difficult for some of our players (7- and 8-year-olds)

Q 2: *How do you evaluate the space requirement for the exercises?*

+ it was very positive that we needed just a quarter of the pitch
+ there were no conflicts with other teams playing close beside us
+ the programme was also suitable for indoor training

Q 3: *How do you evaluate the time requirement of the warm-up programme?*

+ the programme was well manageable within a 15 to 20 minute time frame
+ it was comparable with the time requirement of our standard warm-up
+ it was ideal in its length
+ after our players got used to the programme, it took about 15 minutes
– it took too much time at the beginning (20 to 25 min), which is too much in relation to our total training time (90 min)

Q 4: *What are potential difficulties and how do you evaluate these?*

+ the higher levels of the exercises were challenging (which, however, increased motivation of most players)
+ "no difficulties" were present also with the youngest age group (7- to 8-year-olds)
– some exercises were too easy for the older players
– falling exercises were difficult for most children

Q 5: *How do you evaluate the quality of the manual?*

+ it was very well understandable and structured
+ easy to handle
+ it provided complete and valuable information
+ the combination of the full manual (to read at home) and the short version (for the pitch) was ideal

Q 6: *Do you feel your players are warmed-up enough after "FIFA 11+ Kids" to start with the regular training?*

+ the young players (under 11 years of age) were warmed-up enough
– at the beginning (when players were not used to the exercises and the programme took longer), players were not warmed-up enough

– older players should do some running exercises afterwards to get ready for the training

Q 7: *Do you have any suggestions to optimise the programme?*

- running exercises should be added
- an internet page containing video material might be helpful

Q 8: *Do you have any other comments?*

- I will continue doing these exercises
- I was very thankful for the diversification of our regular training – I never did such exercises before
- I started to be aware of biomechanical axes and leg alignment (which I never thought about before)
- our players seem to be more stable in different situations

The response rate was 100% of coaches and children. Based on the answers, we concluded that "FIFA 11+ Kids" in general was feasible for children's football players and that slight adaptations seem to be indicated. The key points of coaches and children were a valuable input for further improvements of "FIFA 11+ Kids". In addition, we received feedback from our study assistants who accompanied every single training session of every participating team. We used all this information as a basis to develop the second version of "FIFA 11+ Kids" (manual see Chapter 8.6) which we then tested in the subsequent large-scale cluster-RCT regarding its potential to prevent injuries (Chapter 7.5). The main adaptations were two further skill levels. Therefore, the new version consists of seven exercises with five different skill levels. In some cases, we added easier exercises to make the entry level feasible for the youngest/less skilled players. In other cases, we extended the range by adding more difficult exercises – providing challenges also for skilled players. Further, we reordered exercises three to six. In the first version, two lower-extremity exercises were followed by two core strength exercises. In the updated version, lower-extremity exercises alternate with core strength exercises. This allows for a longer recovery phase for the specific muscle groups. In turn, longer rest theoretically allows higher training intensities which is essential especially for plyometric exercises.[121-123]

One exercise was removed from the programme due to inadequateness: In the second level of the "Spiderman" exercise (exercise 5 of the initial "FIFA 11+ Kids" version) players had to carry a ball on their belly while they were walking on all fours with their back facing the ground. This task however, often led to wrong body alignment, lowering the belly and buttocks too much in order to control the ball (Figure 7-2). This might have led to a reduction of tension on the hamstring muscles. Therefore, we assumed that the exercise did not train the hamstrings as much as intended. Consequently, we replaced this exercise with a modified version of the "Spiderman" exercise where players have to dribble the ball (manual see Chapter 8.6; exercise 6).

Figure 7-2: Player performing level 2 of the exercise "Spiderman" of the first "FIFA 11+ Kids" version. A clear hip flexion is visible which leads to a reduction in hamstring activation.

Table 7-2: Questionnaire for the children and corresponding answers.

Question	Answer	
Q 1: Are the exercises fun?	95.2%	Yes
Q 2: Are the exercises easy enough for you?	87.1%	Yes
Q 3: Did you improve over time?	85.5%	Yes
Q 4: Do you want to continue with the exercises?	83.9%	Yes
Q 5: Are the exercises exhausting for you?	22.6%	Yes
Q 6: Are the exercises boring?	6.5%	Yes
Q 7: Do the exercises need too much time?	14.5%	Yes
Q 8: Which was your favourite exercise?	43.5%	Falling techniques
	29.0%	Watchman
	17.7%	Spiderman
	4.8%	Ball passing single leg stance
	4.8%	Skating jumps
	0%	Single leg jumps
	0%	Pushup-eight
Q 9: Which was the most challenging exercise?	53.2%	Spiderman
	16.1%	Falling techniques
	12.9%	Single leg jumps
	8.1%	Pushup-eight
	4.8%	Skating jumps
	3.2%	Ball passing single leg stance
	0%	Watchman

7.3 Methodological considerations

7.3.1 Methodological framework

The PhD project is based on three different studies each one of which utilised the state of the art methodology for answering the respective study questions.

Systematic review and meta-analysis

Systematic reviews and meta-analyses build the very top of the “levels of evidence”.[124] The aim is a systematic synthesis of all relevant studies on a specific topic. Thereby the systematic process limits potential biases in the assembly and supports a critical appraisal of the original studies. Systematic reviews generally focus on peer-reviewed publications about a specific problem and use strict and standardised methods for selecting original studies and the assessment of their results. A meta-analysis – which is not necessarily part of a systematic review – provides a quantitative summary of the results for all included studies (overall effect) or part of the studies (subgroup analyses). The handbook for systematic reviews of interventions from the Cochrane Collaboration provides complete and sound information on how to conduct a systematic review and meta-analysis.[125] The PRISMA statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses) describes how to report methodological aspects and study findings.[126]

Observational prospective cohort study

This epidemiological study type allows assessing the extent of a health problem in a population (or subsets of the population). Based on such data it can be identified who is or has been exposed or not exposed, to a (risk) factor or factors assumed to influence the incidence of a health outcome. Cohort studies generally require the observation of large numbers of participants over a long period of time (commonly years). The data allow measuring the extent of a health problem in the population (based on the incidence rate) and allow comparisons between groups. The STROBE guideline (Strengthening the Reporting of OBservational studies in Epidemiology) provides a framework on how to report this type of study in a publication.[127]

(Cluster-) randomised controlled trial

An RCT is an experiment in which participants in a population are randomly allocated into groups (e.g. intervention group or control group), to receive or not receive an experimental preventive/therapeutic intervention. The comparison of outcome (e.g. incidence rate, measure of performance) between the intervention group and the control group provides the intervention effect. The CONSORT statement (CONsolidated Standards Of Reporting Trials) was developed to improve and standardise the reporting of RCTs.[128]

Cluster-RCTs are characterised by their multilevel structure. Most often two levels are involved: Firstly the cluster and secondly the individual members within the cluster. This for example could be football players (individuals) within football teams (clusters). As the name implies, in cluster-RCTs groups of individuals (rather than individuals themselves) are allocated to the intervention or control condition. This hierarchical data structure increases complexity in design and especially in statistical analysis. Since data from individuals of the same cluster might be correlated, these should not be treated as independent observations. This increases the necessary sample size to obtain the same statistical power as a non-clustered trial. The above mentioned CONSORT statement is extended by a statement which focuses specifically on cluster-RCTs.[129]

7.3.2 Potential limitations

For our systematic review and meta-analysis, we strictly followed the according guideline (PRISMA) to ensure the highest possible quality.[126] Potential limitations regarding methodological issues (e.g. heterogeneity of the primary studies) are discussed in the publication in detail.[2] One important rationale of the meta-analysis was to assess the typical effect of sport injury prevention programmes which then could be used for the estimation of the expected effect of our subsequent original study. In this regard one further limitation has to be discussed: Just about 13% of the included 27,561 participants in the meta-analysis were boys, whereas in our studies about 95% and 96% of the participants were boys. Differences in sport injury patterns between girls and boys have been discussed in the literature which might relate to biomechanics, anatomical constitution, timing of maturation, strength parameters, and risk taking behaviour.[6, 11, 24, 62, 86, 130-134] Although it could be speculated that most sex-specific injury patterns establish after childhood, our findings might not be representative for girl’s football.[3, 62, 93] Therefore, further studies specifically aiming at football injuries in young girls seem indicated.

Data from children were lacking in our meta-analysis. Thus, the transferability of the observed injury prevention effects to a child population was uncertain. In consequence, we applied a more conservative expected preventive effect (33% of injury reduction) in the sample size estimation of our subsequent cluster-RCT.

Our epidemiological cohort study was the largest prospective study to investigate sport-related injuries in organised child sport. Given the size of the study we focussed on the most important data to record. However, different additional parameters would have been interesting to assess and analyse. The weather conditions,[84, 135, 136] the constitution of natural grass,[85] and the generation of artificial turf [61, 103-105] would have added further insights into possible injury risk factors in children's football.

Information on injuries in the past (prior to the start of the study) was self-reported by the parents via a baseline questionnaire. As previous injuries have been described as one of the main injury risk factors, we intended to use these data to analyse the risk for injury recurrence.[1, 5, 54, 55, 58-60, 62-64, 66, 67, 77, 137-140] However, we were concerned about the validity as the provided information was relatively inconsistent. Some parents reported every detail and some did not provide any information about injuries in the past. This issue is related to the recall bias which has been discussed as being a relevant problem.[54, 141-144] Therefore, we refrained from using these data for our analysis.

Information about the timing of the injury (e.g. beginning/mid/end of match or training) might have been interesting information as it is known from professional level team sport that injury risk is increased towards the end of a half time and in the second half of a match.[145-147] A possible explanation for this phenomenon is a decrease in eccentric strength when fatigue increases.[148]

Like all other study data, also the information whether an injury was related to "foul play" was reported by coaches, children, and by the parents of injured children. We did not get information on the actual referees' decision. However, this relates to a general problem in studies relying on self-reported data. To minimise this limitation, we asked children, parents, and coaches to answer all our questions honestly. We explained them explicitly that only true data allow us to draw the right conclusions from the study – which only then could be beneficial for children's football in the end.

In retrospect, information on the level of coach education might have been worth to analyse as it has been shown to have an impact on injury rates in competitive athletes.[87] Also the level of play of the teams would have been interesting to analyse.[144, 149, 150] However, the latter point is critical as the structure of children's football differs a lot between regions of the same country and even more between countries.

The ways of recruitment were not the same in Switzerland and the Czech Republic – at least in terms of the first contact. In Switzerland we set up a mailing list including representatives (club presidents, coaches, youth managers) of nearly all clubs in the German speaking cantons (> 4,000 contacted persons in the first season; > 6,000 contacted persons in the second season) to invite clubs and teams to participate in the study. In contrast, in the Czech Republic recruitment was accomplished "top down": The football association informed clubs about the study and put them into contact to the study administrators. It could be speculated that this might have influenced the recruitment as the "top down strategy" might have put more pressure on the clubs to participate. Clubs in Switzerland might have had more freedom to decide whether to participate or not. Therefore, it might be assumed that injury rates in Switzerland could be underestimated because coaches who were willing to participate in a study like this might be more aware of the risk of injury and, thus, more cautious in planning their training (e.g. importance of fair play, specific exercises, and general cautiousness). However, statistical testing of injury incidence rates between countries did not reveal a relevant difference.

It could be criticised that some of the risk factors analysed (i.e. age, sex, and age-independent body height) are non-modifiable. However, it was neither in the scope of the study nor possible in this setting to accomplish (several thousands of) screening tests to assess typical intrinsic and modifiable risk factors (like deficits in strength, power, or balance) described in the literature.[5, 59, 69, 80, 151] We rather aimed at detecting risk factors which need to be controlled for in future analyses. As such we used these factors as control variables in the analysis of our subsequent multicentre cluster-RCT.

The relatively short intervention period of 10 weeks might be regarded as a potential limitation of our pilot study on motor performance effects of "FIFA 11+ Kids". However, we used the longest period without interruptions by school holidays. As during holidays generally no training takes place in children's football such an interruption (detraining phase) might have had a relevant influence on the intervention effects.[152, 153]

We observed a higher growth rate from pre- to post-test in players of the control group in our pilot study. In retrospect it would have been interesting to assess an index of maturity within the study, as maturity and growth rate have an impact on physical performance.[154] Such a procedure would have allowed us to adjust our analysis with respect to maturity status. It could be speculated that such an adjustment might have led to clearer effects (in favour of the intervention group).

7.4 Importance of the project and perspectives

Football is played on an amateur or recreational level by over 270 million people all over the world. The highest proportion of players (58%) is younger than 18 years.[155] For instance, in the German football association, the largest national football association world-wide, nearly three quarters of these young players are under 14 years of age.[156] Football is the most important team sport in Switzerland as well and many children (N = 58,622 players aged 7 to 12 years, relating to one quarter of all registered players in the season 2014/2015) are playing in registered clubs.[157]

Playing football can induce considerable beneficial health effects. Thus, football has a great potential to support a healthy lifestyle (see Chapter 1.2).[158-168] According to our data, between 4% and 12% (depending on the age-group) of 7- to 12-year-old players get injured every year.[3] Half of these injuries require medical care and a quarter is categorised as severe (with a layoff time of more than one month). Negative health consequences are not only limited to the short term but may also increase the risk of early development of osteoarthritis.[169-171]

Although injury prevention programmes have shown to be efficacious to reduce football injuries in adult and adolescent, female and male football players,[6, 27, 28, 113, 172-183] no study has investigated football injury prevention in children under the age of 13 years.[2] However, from an individual and societal as well as from a socio-economic perspective it is necessary to implement preventive measures starting from a young age to reduce the risk of injury and to early and consequently support the health benefits associated with playing football.[2]

As outlined in chapter 1.6, comprehensive epidemiological data on football injuries have to be assessed prior to the development of a tailored injury prevention programme.[137, 184] In the past 25 years a large number of studies on female and male, youth and adult, elite and non-elite footballers have investigated rates of injury and enlarged the knowledge about risk factors and mechanism of injuries.[54, 55, 57, 59, 61, 66-68, 71, 73, 103, 105, 150, 185-193] Our epidemiological study is the first large-scale prospective study that focused on injury epidemiology in children's football (Chapter 4 and 5).

As injury characteristics differ between children and older players, preventive programmes proven to be efficacious in late adolescent or adult players had to be adapted to accommodate for the specific injury profile and maturational status of children.[1, 3]

Based on our topical review,[1] the findings of our meta-analysis,[2] and our epidemiological study on football injuries in players aged 7 to 12 years,[3] we were able to develop the age-specific injury prevention programme "FIFA 11+ Kids" focusing on players younger than 13 years. We successfully tested a preliminary version of "FIFA 11+ Kids" in a pilot study regarding feasibility and effects on motor performance. Possibly beneficial improvements were observed in nearly all performance tests.[4] The above mentioned research efforts built the basis for our subsequent multicentre intervention study on injury prevention in children's football to assess the efficacy of "FIFA 11+ Kids" regarding injury reduction (publication under review).

As "FIFA 11+ Kids" has proven to be efficacious in reducing injuries (Chapter 7.5) we intend to analyse the cost-effectiveness of the programme in a future study. Financial saving might be a key argument for a wide implementation of injury prevention programmes.[18, 194-199] As a result of a broad implementation of "FIFA 11+ Kids", many young football players will profit from a reduced injury risk with according positive short- and long-term effects. This is beneficial for public health and will help to slow down the growth of medical spending. In this regard, football might serve as a role model for other sports, as it is the most important sport in Europe.

Our meta-analytical findings demonstrated that further high-quality studies aiming at children under the age of 14 years (especially boys) are warranted. These studies should also investigate the compliance because a dose-response relationship of exercise-based injury prevention programmes has been found.[112, 113, 200] Further studies may be conducted to investigate injury risk in relation to maturity status, match-training-ratio, and leg dominance in children's football – as well as in other sports.

Homogeneity with respect to study design enables a clear interpretation of results and improves the ability for meta-analytical assessments in the future. Therefore, a consensus statement on how to conduct studies on injury prevention in children's and adolescent's sports might be indicated.

Especially the prevention of severe sport injuries is of importance. Thereby, children and adolescents should be of particular interest as one third of all life-threatening injuries in these age groups are sport-related. In comparison, in adults only 9% of life-threatening injuries are sport-related.[201]

Injury prevention as well as the promotion of fair play should become an integral part of regular training sessions.[27, 118, 202] Some critical voices may claim a loss of valuable practice time due to regular application of injury prevention programmes. However, this argument is not tenable considering the benefits of such programmes with respect to injury reduction (Chapter 3 and Chapter 7.5), performance enhancement (Chapter 6), and potential long-lasting layoff from sport participation or even dropout from sport after injury.[203-205] In summary, it can be stated that children, parents, coaches, and sport institutions can benefit from exercise-based injury prevention. Regarding the large number of football playing children, injury prevention in these age-groups is relevant from a public health perspective.

7.5 Outlook: Results of the "FIFA 11+ Kids" cluster RCT

A (subsequent) large-scale study was designed to assess the efficacy of "FIFA 11+ Kids" regarding injury prevention. "FIFA 11+ Kids" is tailored for the youngest players (7 to 12 years of age) and was further adapted after the pilot study.[4] The structure of the programme is based on the established "FIFA 11+" programme which has been shown to be efficacious in players older than 13 years.[28, 113, 172, 173, 183] We hypothesised that the overall injury incidence rate would be reduced by at least one third in the intervention group compared to a control group.[2]

Children's football teams (under-9, under-11, and under-13 age groups) from Switzerland, Czech Republic, The Netherlands, and Germany were recruited. Clubs were randomised to an intervention and a control group and followed for one season (August 2014 to August 2015). The intervention group performed "FIFA 11+ Kids" during their warm-up whilst the control group warmed-up as usually.

The methods (e.g. recruitment of teams, injury definition, data collection procedure) were essentially identical to our epidemiological cohort study. Time-to-injury data were analysed, and hazard ratios (HR) calculated using extended Cox models to account for correlations on team- and intra-person-level.

In total, 3,895 player seasons and 292,749 hours of football exposure were recorded. During the study period 374 injuries occurred. The overall injury rate in the intervention group was reduced by 48% compared to the control group (HR 0.52; 95%-CI 0.32, 0.86; P = 0.01). Further reductions of injury rates were found regarding severe (74%, (HR 0.26; 95%-CI 0.10, 0.64), P = 0.003), and lower extremity injuries (55%, (HR 0.45; 95%-CI 0.24, 0.84), (P = 0.01). We conclude that "FIFA 11+ Kids" is efficacious in reducing injuries in children's football. Considerable effects were found for overall, match, training, lower extremity, and specifically severe injuries. The observed overall injury reduction is comparable to studies in older youth football players.[2] The reduction of injury incidence might be due to improved motor performance.[4] A broad implementation may help to reduce injuries and to support the health benefits of playing football in the long term. The corresponding publication is currently under review.

7.6 Summarising the history of "FIFA 11+"

A former version of "FIFA 11+" called "The 11" was a warm-up programme to prevent injuries in amateur football players. In 2003 it was developed by the FIFA Medical Assessment and Research Centre (F-MARC) in cooperation with international experts to reduce the most frequent and most severe types of football injury. "The 11" comprised ten physical exercises and included the promotion of "Fair Play". The effectiveness of "The 11" has been proven in Switzerland. A nationwide implementation (2004 to 2008) led to a decrease in football injuries during matches and training.[196] However, the study has some methodological weaknesses as it was lacking a control group and data were collected by interviews, which might be associated with reporting bias and memory effects.[206]

"The 11" failed to prove efficacious in reducing injuries in a randomised setting.[207] Therefore, in 2006 it has been further developed into a more comprehensive programme called "FIFA 11+" in cooperation with the Santa Monica Sports Medicine Foundation and the Oslo Sports Trauma and Research Centre.[208] The new version is a complete warm-up programme to reduce injuries among male and female football players aged 14 years and older.

Several studies investigated "FIFA 11+" in RCTs in different populations and showed a clear reduction in injuries.[28, 113, 172, 173, 183] A recently published RCT evaluated "FIFA 11+" in veteran male football players (mean age over 40 years) and found only a small injury preventive effect. However, low training frequency and compliance to the programme have been discussed as important limiting factors.[209] Compliance appears to be important as beneficial effects were greater in players with higher adherence to the programme.[112, 113] "FIFA 11+" has also shown to be efficacious in reducing injuries in male elite basketball players.[210] Several systematic reviews provide further evidence of the preventive effects of "FIFA 11+" especially in youth amateur football.[9, 211, 212]

Many studies investigated whether "FIFA 11+" is suitable to induce performance improvements. Beneficial effects regarding general physical fitness and technical performance, agility, vertical jumping, and proprioception performance, static as well as dynamic balance, concentric hamstring strength as well as isokinetic strength of the knee extensor and flexor muscles, and improvements in the hamstring to quadriceps ratio have been reported. Further, the programme showed to be superior regarding different motor performance outcomes compared to an alternative injury prevention programme (namely “HarmoKnee”).[113, 118, 213-219]

“FIFA 11+” has also been investigated regarding short term effects to evaluate whether the programme suits as a proper warm-up – and proved efficacious.[220-223] Longitudinal studies investigated the effects of “FIFA 11+” regarding muscle activation as well as structural changes of relevant muscles. An increased muscle activity, but no structural changes have been reported. Therefore, it is suggested that beneficial adaptations mostly appear on a neuromuscular rather than on a structural level.[119, 224-226]

Our newly developed “FIFA 11+ Kids” programme is a valuable complement of the existing “FIFA 11+”. “FIFA 11+ Kids” extends the age-range towards the lower bound with its tailored, age-specific exercises and enables injury prevention in children’s football (Chapter 7.5 and Chapter 8.6).

7.7 Conclusion

Our meta-analysis showed very promising effects of exercise-based injury prevention programmes across several studies in different youth sports. Especially multimodal programmes including jumping/plyometric exercises proved efficacious. We found a considerable lack of injury prevention research for children (under 14 years of age), and particularly for boys. The two major aims of the PhD project were the prospective assessment of injury characteristics in children's football and the development of an age-specific injury prevention programme.

We found differences in the relative prevalence of certain injuries in child football players compared to older youth players, which clearly underlines the necessity of a specific injury prevention programme for children's football. Therefore, we developed the tailored injury prevention programme called "FIFA 11+ Kids" based on our research. It is designed as a warm-up programme and takes age-specific injury patterns of the youngest players into account.

"FIFA 11+ Kids" can induce performance enhancements compared to a traditional warm-up programme with clear improvements of dynamic balance and agility. Further improvements of jumping performance and slalom dribbling indicate that "FIFA 11+ Kids" positively influences several intrinsic risk factors. Importantly, no negative side effects of the programme were observed. Coaches' as well as players' feedback regarding the feasibility of the programme were positive.

In our subsequent study (that goes beyond the scope of the PhD project) "FIFA 11+ Kids" has proven to be efficacious in reducing injuries in children's football in an international multicentre cluster-RCT. Considerable effects were found for overall, match, training, lower extremity, and specifically severe injuries. The observed overall injury reduction is comparable to studies in youth football players in our meta-analysis. Based on these findings a broad implementation of "FIFA 11+ Kids" can be recommended to reduce injuries and to support the health benefits of playing football in the long term.

7.8 References

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8 Appendix/Supplemental material

8.1 Contribution to the PhD project

04/2012 – 12/2015 "Football injuries in players aged 7 to 12 years: a descriptive epidemiological study over 2 seasons"

- Contribution:
  - Overall study coordination (both countries)
  - Recruitment of football clubs and teams in Switzerland (e.g. sending over 10,000 emails to club presidents and coaches of all registered football clubs in the German-speaking part of Switzerland; countless telephone calls)
  - Involved in the development of an internet-based injury recoding system ("TeamRec")
  - Writing user-manual for "TeamRec"
  - Providing technical support for coaches using "TeamRec"
  - Recording of study data in Switzerland over two football seasons (e.g. regular telephone interviews in cases of injuries; reminding coaches to enter data)
  - Processing of data
  - Statistical analyses
  - Writing publications as first author
- Collaborators:
  - PD Dr. Oliver Faude (Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland): Head of study group and guarantor of the project
  - Prof. Jiri Chomiak (Member FIFA Medical Committee, Charles University and Teaching Hospital Bulovce, Prag)
  - Prof. Astrid Junge (FIFA-Medical Assessment and Research Centre (F-MARC) and Schulthess Clinic, Zürich, Switzerland and Medical School Hamburg, Germany)
  - Prof. Jiri Dvorak (FIFA-Medical Assessment and Research Centre (F-MARC) and Schulthess Clinic, Zürich, Switzerland)
  - Master students Christoph Beeler, Patrik Bieli, Michael Meier (Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland)
  - Study assistant Karel Nemec (Charles University and Teaching Hospital Bulovce, Prag)

10/2012 – 06/2014 “Exercise-based injury prevention in child and adolescent sport: a systematic review and meta-analysis”

- Contribution:
  - Overall study coordination
  - Planning of the study
  - Systematic literature search and screening
  - Data extraction
  - Statistical analyses
  - Publication as first author
- Collaborators:
  - PD Dr. Oliver Faude (Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland): Head of study group and guarantor of the project
  - Prof. Astrid Junge (FIFA-Medical Assessment and Research Centre (F-MARC) and Schulthess Clinic, Zürich, Switzerland and Medical School Hamburg, Germany)
  - Prof. Evert Verhagen (Amsterdam Collaboration on Health and Safety in Sports, Department of Public and Occupational Health & Amsterdam Movement Sciences, VU University Medical Center, Amsterdam, Netherlands)
  - Dr. Lars Donath (Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland)
  - Master student Thomas Schweizer (Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland)

03/2013 – 01/2016 “Development of “FIFA 11+ Kids”: The injury prevention programme for children’s football”

- Contribution:
  - Active participation in several meetings at the “Home of FIFA” in Zürich with an international group of experts
  - Preparation of epidemiological data and several interim analyses
  - Presentation of the preliminary study data
  - Co-worker of an international team of developers
  - Involved in the organisation of photo shootings
  - Writing and design of the manual and short version (version 1) for the coaches
  - Revision of the manual and short version (version 2) based on results of our pilot study
- Collaborators:
  - PD Dr. Oliver Faude (Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland): Head of study group; guarantor of the project

  - Prof. Astrid Junge (FIFA-Medical Assessment and Research Centre (F-MARC) and Schulthess Clinic, Zürich, Switzerland and Medical School Hamburg, Germany)
  - Dr. Mario Bizzini (FIFA-Medical Assessment and Research Centre (F-MARC) and Schulthess Clinic, Zürich, Switzerland)
  - Prof. Jiri Dvorak (FIFA-Medical Assessment and Research Centre (F-MARC) and Schulthess Clinic, Zürich, Switzerland)
  - Prof. Evert Verhagen (Amsterdam Collaboration on Health and Safety in Sports, Department of Public and Occupational Health & Amsterdam Movement Sciences, VU University Medical Center, Amsterdam, Netherlands)
  - Prof. Tim Hewett (University of Cincinnati, U.S.A.)
  - Prof. Jiri Chomiak (Member FIFA Medical Committee, Charles University and Teaching Hospital Bulovce, Prag)
  - MSc Nicolas Mathieu (PT, HES-SO Valais, University of Applied Sciences, Sion, PT of Swiss National Team U-21)
  - Dr. Karen aus der Fünten (Institute for Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany)

05/2013 – 09/2015 “A pilot project on injury prevention in children’s football (FIFA 11+ Kids): Feasibility and training effects”

- Contribution:
  - Overall study coordination
  - Planning of the study
  - Writing draft of research proposal
  - Writing ethical approval
  - Recruitment of football clubs and teams
  - Recording und processing of data
  - Statistical analyses
  - Publication as first author
- Collaborators:
  - PD Dr. Oliver Faude (Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland): Head of study group and guarantor of the project
  - Dr. Mario Bizzini (FIFA-Medical Assessment and Research Centre (F-MARC) and Schulthess Clinic, Zürich, Switzerland)
  - Dr. Lars Donath (Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland)
  - Master students and study assistants Marie-Andrea Egli, Mauro Vivian, Eric Lichtenstein, Michael Meier, Patrik Bieli, Kevin Suter, Yannik Hohn, and Patrik Breton (Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland)

03/2014 – present “Injury prevention in children’s football (“FIFA 11+ Kids”): an international multicentre cluster-randomised controlled trial”

- Contribution:
  - Planning of the study
  - Writing draft of research proposal
  - Writing ethical approval
  - Overall study coordination (all four countries)
  - Recruitment and coordination of study assistants
  - Recruitment of football clubs and teams in Switzerland
  - Processing of data
  - Planning and conducting statistical analyses (e.g. writing the programming code for the statistical analyses in “R”)
  - Publications as first author (under review)
- Collaborators:
  - PD Dr. Oliver Faude (Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland): Head of study group and guarantor of the project
  - Prof. Jiri Chomiak (Member FIFA Medical Committee, Charles University and Teaching Hospital Bulovce, Prag)
  - Prof. Evert Verhagen (Amsterdam Collaboration on Health and Safety in Sports, Department of Public and Occupational Health & Amsterdam Movement Sciences, VU University Medical Center, Amsterdam, Netherlands)
  - Dr. Karen aus der Fünten (Institute for Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany)
  - Prof. Astrid Junge (FIFA-Medical Assessment and Research Centre (F-MARC) and Schulthess Clinic, Zürich, Switzerland and Medical School Hamburg, Germany)
  - Dr. Mario Bizzini (FIFA-Medical Assessment and Research Centre (F-MARC) and Schulthess Clinic, Zürich, Switzerland)
  - Prof. Jiri Dvorak (FIFA-Medical Assessment and Research Centre (F-MARC) and Schulthess Clinic, Zürich, Switzerland)
  - Master students and study assistants from Switzerland: Marie-Andrea Egli, Mauro Vivian, Eric Lichtenstein, Michael Meier, Patrik Bieli, Kevin Suter, Yannik Hohn, and Patrik Breton (Department of Sport, Exercise and Health, University of Basel); study assistant from the Czech Republic Karel Nemec (Charles University and Teaching Hospital Bulovce, Prag); study assistants from Germany: Florian Bohr, Tobias Tröss, and Florian Beaudouin (Saarland University, Saarbrücken); and study assistants from the Netherlands: Dr. Joske Nauta and Hanneke Wind (VU University of Amsterdam)

8.2 Supplemental material related to Publication I

Appendix 1: Literature search strategy and searched databases.

	searches		
database	**#1**	**#2**	**#3, screened titles**
PubMed [a]	1178	243	56
Cochrane [b]	912	337	147
ISI Web of Science [c]	14341	3402	752
SPORTDiscus [d]	8770	1963	229
EMBASE [e]	16263	3486	521
CINAHL [f]	1149	324	57
sum	42613	9755	1762

Search #1 sport injur* OR athletic injur* OR sport accident*

Search #2 #1 AND (prevent* OR prophylaxis OR avoidance)

Search #3 #2 AND (child* OR adolescent OR youth)

a Search restricted to ”Title/Abstract“

b Search restricted to ”Title, Abstract or Keywords“

c Search restricted to ”Topic“

d Search restricted to ”Title OR Abstract“

e Search restricted to ”Title OR Abstract“

f Search restricted to ”Title OR Abstract“

Appendix 2: Study quality score key according to Abernethy and Bleakley (2007).

Item number	Item
1	How was allocation to the intervention group done? 2 = random 1 = cluster random 0 = historical comparison/volunteer or convenience group
2	Was the assigned intervention concealed before allocation? 2 = adequate 1 = unclear 0 = inadequate/impossible
3	Were the outcomes of participants who withdrew described and included in the analysis (intention to treat/effect of compliance)? 2 = withdrawals well described and accounted for in analysis 1 = withdrawals described and analysis not possible 0 = no mention, inadequate mention, or obvious differences and no adjustment
4	Were the outcome assessors blinded to treatment status? 2 = effective action taken to blind assessors 1 = small or moderate chance of unblinding of assessors 0 = not mentioned or not possible
5	Were the inclusion and exclusion criteria (age, previous injury, sport) clearly defined? 2 = clearly defined 1 = inadequately defined 0 = not defined
6	Were the intervention and control group comparable at entry? 2 = good comparability of groups, or confounding adjusted for in analysis 1 = confounding small, mentioned but not adjusted for 0 = large potential for confounding, or not discussed
7	Were the interventions clearly defined? 2 = clearly defined interventions are applied 1 = clearly defined interventions are applied but the application is not standardized 0 = intervention and/or application are poorly or not defined
8	Were the outcome measures used clearly defined? (injury: self-reported injury/medically confirmed/severity defined) 2 = clearly defined 1 = adequately defined/recorded 0 = not adequately defined/recorded
9	Was the surveillance period active and of clinically appropriate duration? 2 = active surveillance and appropriate duration 1 = active surveillance, but inadequate duration 0 = surveillance not active or not defined

Appendix 3: Statistical procedures.

Analyses were conducted using the random effects model. The Cochrane Review Manager Software (RevMan 5.1, Cochrane Collaboration, Oxford, UK) was used to run the inverse-variance method according to Deeks and Higgins 2010. In the following formulas the intervention effect estimate describes the study's natural logarithm transformed RR. Each individual RR was weighted in accordance to the reciprocal of their variance (given as the square of the standard error). The particular weight of a study is:

$$w_i = \frac{1}{(SE\{\hat{\theta}_i\})^2}$$

The summary estimate of the weights is given by:

$$\hat{\theta}_{IV} = \frac{\sum w_i \hat{\theta}_i}{\sum w_i}$$

And the corresponding standard error is:

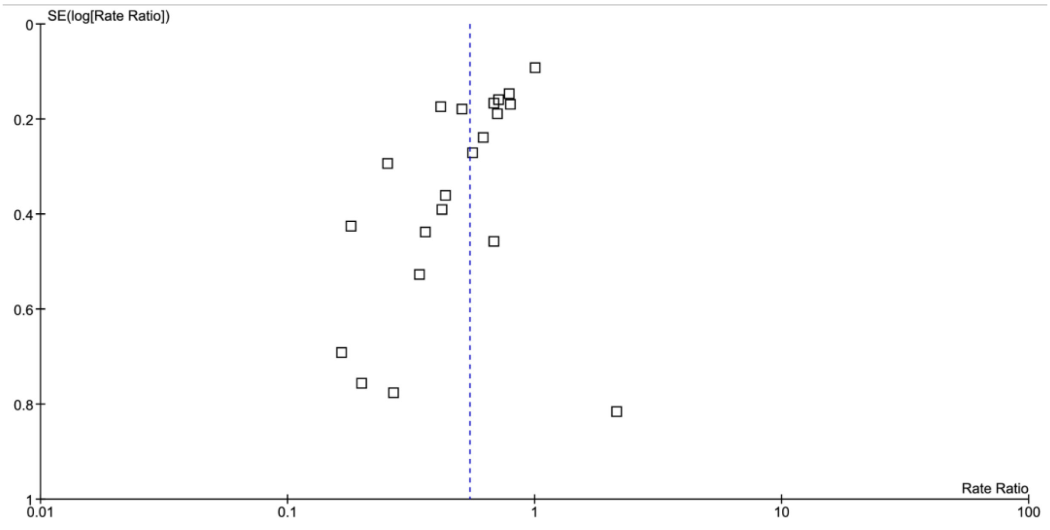
$$SE\{\hat{\theta}_{IV}\} = \frac{1}{\sqrt{\sum w_i}}$$

Heterogeneity is calculated by:

$$Q_{IV} = \sum w_i \, (\hat{\theta}_i - \hat{\theta}_{IV})^2$$

The inconsistency statistic I^2 is given by the following formula. Thereby k is the number of studies included in the meta-analysis:

$$I^2 = \max \left[100\% * \frac{Q_{IV} - (k-1)}{Q_{IV}}, 0\right]$$

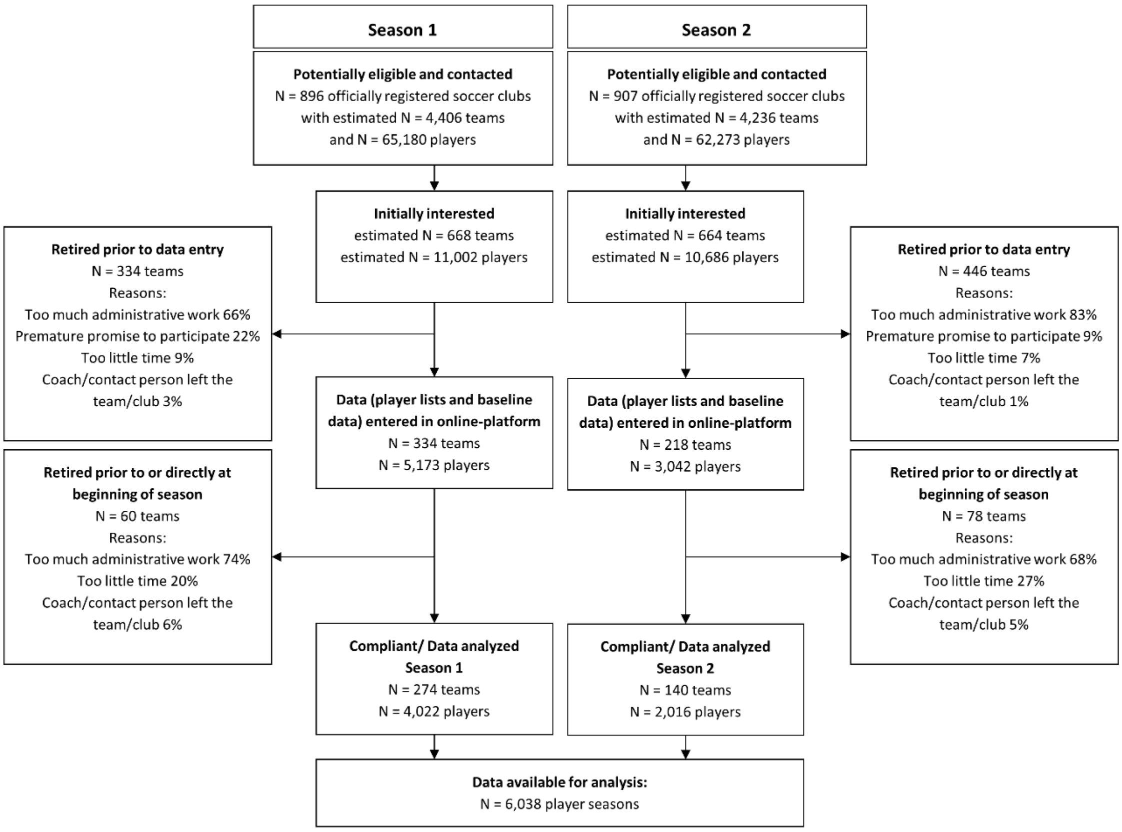


Appendix 4: Funnel plot showing effect estimates of all studies plotted against their standard error (dashed line represents the mean effect estimate over all studies RR = 0.54 [0.45, 0.67]).

Appendix 5: Detailed results of study quality assessment.

Study	Total score	1. How was allocation to the intervention group done?	2. Intervention concealed before allocation?	3. Participants who withdrew described and included in the analysis?	4. Outcome assessors blinded to treatment status?	5. Inclusion and exclusion criteria clearly defined?	6. Intervention and control group comparable at entry?	7. Interventions clearly defined?	8. Outcome measures used clearly defined?	9. Surveillance period active and of clinically appropriate duration?
Olsen 2005	16	1	1	2	2	2	2	2	2	2
Soligard 2008	16	1	1	2	2	2	2	2	2	2
Steffen 2007	16	1	1	2	2	2	2	2	2	2
Waldén 2012	16	1	1	2	2	2	2	2	2	2
Emery 2007	15	1	1	2	1	2	2	2	2	2
Emery 2010	15	1	1	2	1	2	2	2	2	2
Collard 2010	14	1	1	2	0	2	2	2	2	2
McGuine 2006	14	1	1	2	0	2	2	2	2	2
Emery 2005	13	1	1	1	0	2	2	2	2	2
LaBella 2011	13	1	1	0	2	1	2	2	2	2
Longo 2012	13	1	1	2	1	2	0	2	2	2
Scase 2006	11	0	1	0	2	0	2	2	2	2
Cumps 2007	10	0	1	1	0	0	2	2	2	2
Heidt 2000	10	2	1	0	1	0	0	2	2	2
Junge 2002	9	0	1	1	0	0	1	2	2	2
Kiani 2010	9	0	0	0	0	1	2	2	2	2
Mandelbaum 2005	9	0	1	0	0	0	2	2	2	2
Malliou 2004	8	0	1	0	0	0	2	1	2	2
Wedderkopp 1999	8	1	1	0	0	0	0	2	2	2
Hewett 1999	6	0	0	0	0	0	0	2	2	2
Pfeiffer 2006	6	0	0	0	0	0	0	2	2	2
total sum	**247**	**14**	**18**	**21**	**16**	**22**	**31**	**41**	**42**	**42**
sum good studies	**161**	**11**	**11**	**19**	**13**	**21**	**20**	**22**	**22**	**22**
sum poor studies	**86**	**3**	**7**	**2**	**3**	**1**	**11**	**19**	**20**	**20**
% (poor/good)	**53.4**	**30.0**	**70.0**	**11.6**	**25.4**	**5.2**	**60.5**	**95.0**	**100.0**	**100.0**

8.3 Supplemental material related to Publication II



Appendix 6: Flow of study participants.

8.4 Supplemental material related to Publication III

Appendix 7: Standard Cox model. Hazard ratios with 95%-confidence intervals and corresponding P-values of overall, match, and training injuries.

		Overall Injuries		Match Injuries		Training Injuries	
		HR [95%-CI]	**P**	**HR [95%-CI]**	**P**	**HR [95%-CI]**	**P**
Univariate	**Age**	1.41 [1.32; 1.50]	< .001	1.29 [1.17; 1.42]	< .001	1.45 [1.32; 1.58]	< .001
	Sex	1.25 [0.72; 2.17]	.435	0.44 [0.11; 1.78]	.249	1.88 [1.00; 3.55]	.053
	Body height percentile cat.	1.18 [1.05; 1.33]	.005	1.19 [1.00; 1.41]	.052	1.17 [0.99; 1.38]	.060
	Body mass percentile cat.	1.02 [0.88; 1.18]	.783	0.94 [0.75; 1.17]	.604	1.14 [0.92; 1.40]	.218
	BMI percentile cat.	0.98 [0.90; 1.07]	.580	0.89 [0.79; 1.01]	.082	1.08 [0.96; 1.22]	.226
	MTR	1.69 [1.44; 2.00]	< .001	0.75 [0.58; 0.98]	.034	2.06 [1.62; 2.62]	< .001
	Defense*	1	-	1	-	1	-
	Attack	1.03 [0.73; 1.44]	.886	1.21 [0.77; 1.92]	.422	0.76 [0.44; 1.32]	.335
	Goal	1.34 [0.84; 2.10]	.098	1.40 [0.76; 2.58]	.282	1.20 [0.61; 2.36]	.594
	Midfield	1.68 [1.22; 2.31]	.002	1.40 [0.87; 2.27]	.174	2.15 [1.37; 3.36]	.001
	Right foot preferred*	1	-	1	-	1	-
	Left foot preferred	1.24 [0.93; 1.65]	.156	0.94 [0.60; 1.50]	.800	1.50 [1.02; 2.21]	.039
	No preference	1.23 [0.78; 1.97]	.380	1.34 [0.70; 2.55]	.380	1.22 [0.62; 2.40]	.562
Multivariate	**Age**	1.56 [1.44; 1.70]	< .001	1.49 [1.33; 1.67]	< .001	1.69 [1.49; 1.90]	< .001
	Sex	1.34 [0.75; 2.39]	.327	0.74 [0.24; 2.33]	.611	1.79 [0.91; 3.54]	.091
	Body height percentile cat.	1.31 [1.16; 1.47]	< .001	1.28 [1.09; 1.51]	.002	1.36 [1.15; 1.60]	.004
	MTR	1.33 [1.08; 1.64]	.007	0.66 [0.48; 0.91]	.011	1.50 [1.11; 2.02]	.008

Abbreviations: cat. = Category; BMI = Body Mass Index; MTR = Match-Training-Ratio; * = Reference Category

Appendix 8: Standard Cox model. Hazard ratios with 95%-confidence intervals and corresponding P-values of acute, overuse, and severe injuries.

		Acute Injuries		Overuse Injuries		Severe Injuries	
		HR [95%-CI]	**P**	**HR [95%-CI]**	**P**	**HR [95%-CI]**	**P**
Univariate	**Age**	1.45 [1.36; 1.54]	< .001	1.64 [1.50; 1.80]	< .001	1.53 [1.39; 1.69]	< .001
	Sex	1.32 [0.81; 2.15]	.255	1.43 [0.73; 2.78]	.295	0.57 [0.19; 1.77]	.323
	Body height percentile cat.	1.17 [1.05; 1.30]	.003	1.20 [1.04; 1.38]	.018	1.20 [1.03; 1.41]	.021
	Body mass percentile cat.	1.02 [0.89; 1.16]	.829	1.03 [0.86; 1.23]	.836	1.06 [0.87; 1.30]	.534
	BMI percentile cat.	0.98 [0.91; 1.05]	.494	0.98 [0.88; 1.09]	.613	0.97 [0.86; 1.09]	.526
	MTR	1.76 [1.47; 2.10]	< .001	1.88 [1.48; 2.39]	< .001	2.22 [1.71; 2.89]	< .001
	Defense*	1	-	1	-	1	-
	Attack	1.02 [0.76; 1.37]	.938	0.93 [0.63; 1.37]	.712	1.08 [0.71; 1.64]	.727
	Goal	1.15 [0.77; 1.72]	.510	0.79 [0.44; 1.45]	.454	0.85 [0.44; 1.63]	.612
	Midfield	1.65 [1.25; 2.17]	< .001	1.62 [1.13; 2.31]	.009	1.65 [1.11; 2.45]	.014
	Right foot preferred*	1	-	1	-	1	-
	Left foot preferred	1.26 [0.98; 1.63]	.080	1.26 [0.89; 1.80]	.197	1.24 [0.84; 1.84]	.276
	No preference	0.99 [0.62; 1.57]	.986	0.42 [0.16; 1.12]	.084	0.75 [0.33; 1.69]	.489
Multivariate	**Age**	1.57 [1.44; 1.72]	< .001	1.78 [1.57; 2.01]	< .001	1.70 [1.48; 1.94]	< .001
	Sex	1.16 [0.59; 2.26]	.662	1.50 [0.73; 3.07]	.264	0.77 [0.24; 2.42]	.652
	Body height percentile cat.	1.28 [1.13; 1.45]	< .001	1.37 [1.16; 1.60]	< .001	1.37 [1.14; 1.63]	< .001
	MTR	1.39 [1.11; 1.73]	.004	1.46 [1.08; 1.94]	.013	1.76 [1.27; 2.43]	< .001

Abbreviations: cat. = Category; BMI = Body Mass Index; MTR = Match-Training-Ratio; * = Reference Category

Appendix 9: Frailty Shared (recurrent injuries). Hazard ratios with 95%-confidence intervals and corresponding P-values of overall, match, and training injuries.

		Overall Injuries		Match Injuries		Training Injuries	
		HR [95%-CI]	P	HR [95%-CI]	P	HR [95%-CI]	P
Univariate	Age	1.46 [1.35; 1.58]	< .001	1.34 [1.22; 1.47]	< .001	1.55 [1.41; 1.70]	.001
	Sex	1.64 [0.91; 2.93]	.097	0.59 [0.19; 1.83]	.358	2.03 [1.08; 3.82]	.029
	Body height percentile cat.	1.13 [0.97; 1.31]	.115	1.20 [1.01; 1.43]	.039	1.17 [0.99; 1.38]	.071
	Body mass percentile cat.	1.00 [0.83; 1.21]	.971	0.95 [0.77; 1.18]	.669	1.13 [0.91; 1.39]	.265
	BMI percentile cat.	0.98 [0.88; 1.09]	.742	0.91 [0.81; 1.03]	.122	1.07 [0.95; 1.21]	.249
	MTR	1.64 [1.38; 1.96]	< .001	0.68 [0.52; 0.89]	.005	2.19 [1.67; 2.87]	< .001
	Defense*	1	-	1	-	1	-
	Attack	1.13 [0.73; 1.74]	.584	1.24 [0.83; 1.86]	.302	0.81 [0.47; 1.37]	.429
	Goal	1.12 [0.76; 2.39]	.145	1.08 [0.59; 1.95]	.800	1.10 [0.55; 2.20]	.776
	Midfield	2.07 [1.36; 3.13]	.001	1.51 [0.99; 2.30]	.055	2.34 [1.50; 3.65]	< .001
	Right foot preferred*	1	-	1	-	1	-
	Left foot preferred	1.32 [0.92; 1.89]	.126	0.99 [0.63; 1.54]	.941	1.57 [1.06; 2.31]	.023
	No preference	1.31 [0.76; 2.24]	.331	1.20 [0.60; 2.41]	.609	0.92 [0.43; 1.97]	.834
Multivariate	Age	1.56 [1.43; 1.71]	< .001	1.50 [1.32; 1.70]	< .001	1.72 [1.49; 1.98]	< .001
	Sex	1.46 [0.80; 2.65]	.220	0.83 [0.25; 2.74]	.760	1.95 [0.95; 4.02]	.069
	Body height percentile cat.	1.31 [1.15; 1.48]	< .001	1.30 [1.08; 1.55]	.005	1.36 [1.13; 1.64]	< .001
	MTR	1.25 [1.01; 1.55]	.043	0.55 [0.39; 0.77]	< .001	1.44 [1.04; 2.00]	.029

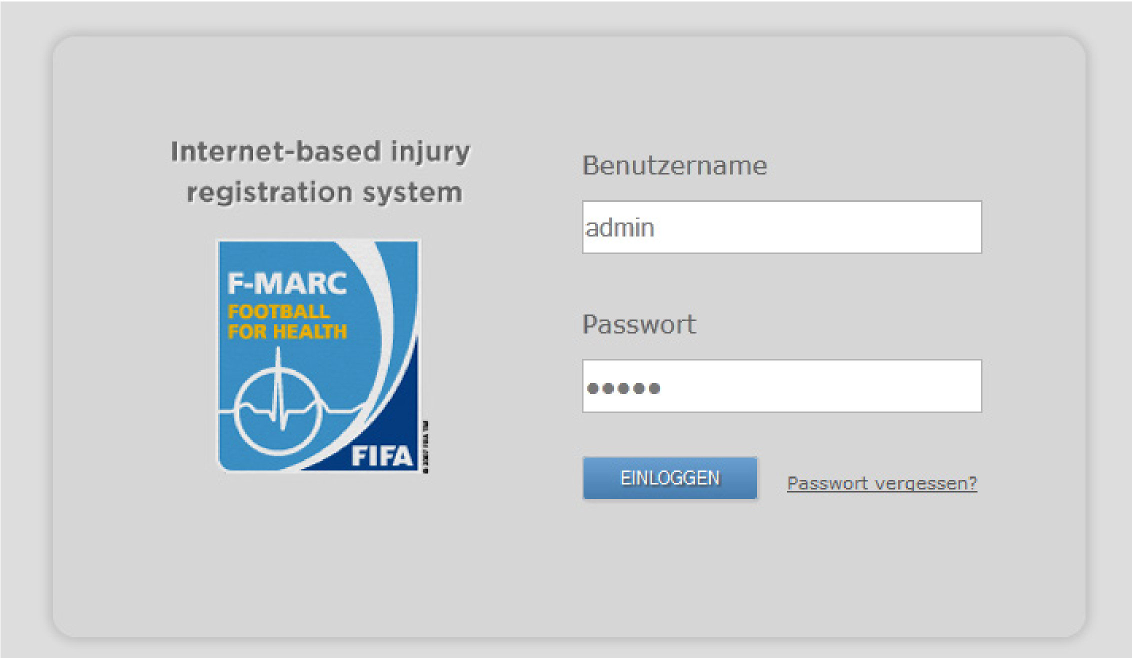
Abbreviations: cat. = Category; BMI = Body Mass Index; MTR = Match-Training-Ratio; * = Reference Category

Appendix 10: Frailty Shared (recurrent injuries). Hazard ratios with 95%-confidence intervals and corresponding P-values of acute, overuse, and severe injuries.

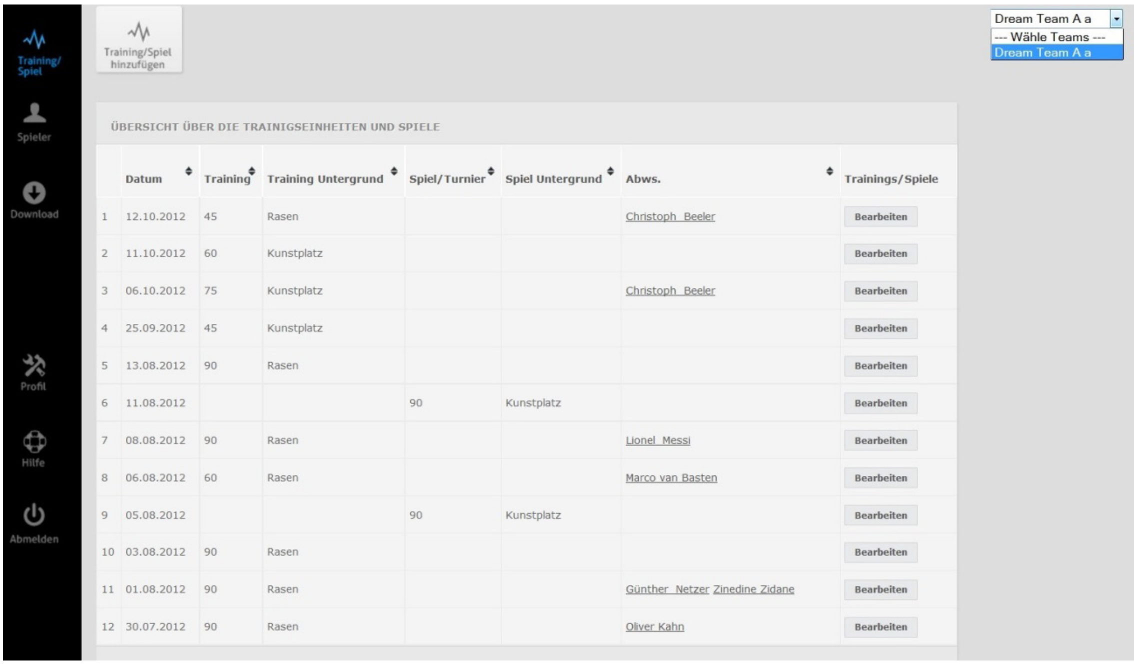
		Acute Injuries		Overuse Injuries		Severe Injuries	
		HR [95%-CI]	P	HR [95%-CI]	P	HR [95%-CI]	P
Univariate	Age	1.44 [1.34; 1.45]	< .001	1.67 [1.50; 1.86]	< .001	1.50 [1.34; 1.68]	< .001
	Sex	1.27 [0.71; 2.27]	.415	1.88 [0.90; 3.92]	.090	0.80 [0.24; 2.68]	.693
	Body height percentile cat.	1.15 [1.02; 1.30]	.264	1.19 [1.01; 1.40]	.052	1.23 [1.02; 1.49]	.034
	Body mass percentile cat.	0.95 [0.81; 1.11]	.538	1.03 [0.84; 1.27]	.852	1.12 [0.88; 1.43]	.366
	BMI percentile cat.	0.95 [0.87; 1.03]	.222	0.98 [0.88; 1.11]	.666	0.98 [0.85; 1.12]	.723
	MTR	1.68 [1.39; 2.03]	< .001	1.56 [1.20; 2.04]	< .001	1.65 [1.24; 2.21]	< .001
	Defense*	1	-	1	-	1	-
	Attack	1.06 [0.76; 1.50]	.771	0.86 [0.55; 1.34]	.518	0.97 [0.60; 1.57]	.897
	Goal	1.28 [0.80; 2.04]	.325	0.75 [0.39; 1.48]	.407	0.79 [0.37; 1.65]	.522
	Midfield	1.84 [1.32; 2.57]	< .001	1.56 [1.02; 2.38]	.038	1.54 [0.95; 2.49]	.077
	Right foot preferred*	1	-	1	-	1	-
	Left foot preferred	1.14 [0.84; 1.55]	.411	1.28 [0.85; 1.95]	.237	1.21 [0.76; 1.94]	.421
	No preference	1.04 [0.61; 1.77]	.898	0.33 [0.11; 0.94]	.039	0.60 [0.24; 1.46]	.261
Multivariate	Age	1.57 [1.42; 1.72]	< .001	1.77 [1.53; 2.05]	< .001	1.63 [1.40; 1.90]	< .001
	Sex	1.28 [0.64; 2.57]	.479	2.10 [0.98; 4.51]	.057	1.42 [0.42; 4.84]	.571
	Body height percentile cat.	1.28 [1.12; 1.46]	< .001	1.35 [1.13; 1.62]	.001	1.38 [1.12; 1.68]	.002
	MTR	1.28 [1.02; 1.62]	.037	1.27 [0.93; 1.73]	.138	1.40 [1.00; 1.96]	.051

Abbreviations: cat. = Category; BMI = Body Mass Index; MTR = Match-Training-Ratio; * = Reference Category

8.5 Online injury/exposure recording system: “TeamRec”

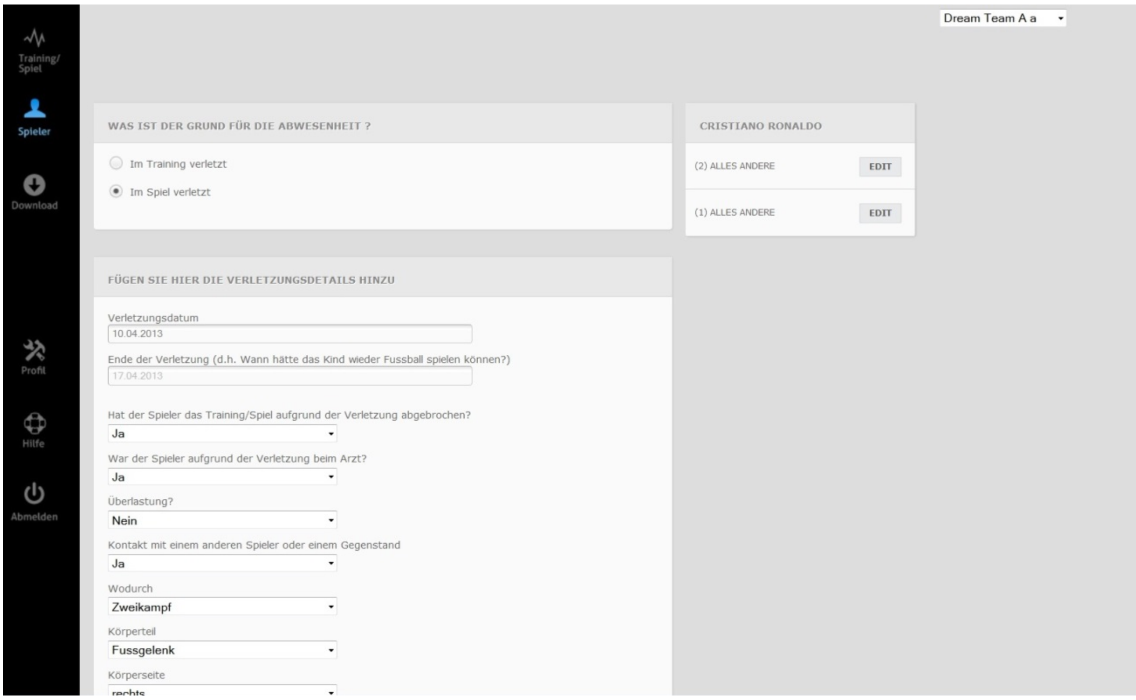


Appendix 11: Login page of the online injury/exposure registration platform “TeamRec” which was developed for this project. Each coach received personal login data to have access to his team/teams.

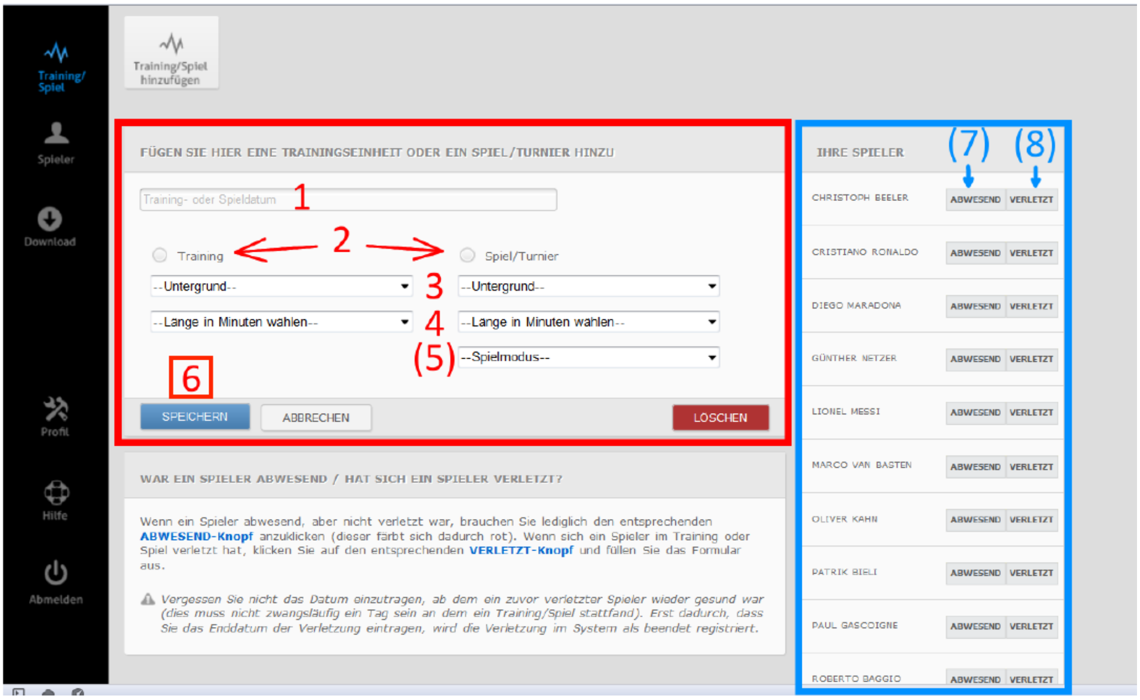


	Datum	Training	Training Untergrund	Spiel/Turnier	Spiel Untergrund	Abws.	Trainings/Spiele
1	12.10.2012	45	Rasen			Christoph Beeler	Bearbeiten
2	11.10.2012	60	Kunstplatz				Bearbeiten
3	06.10.2012	75	Kunstplatz			Christoph Beeler	Bearbeiten
4	25.09.2012	45	Kunstplatz				Bearbeiten
5	13.08.2012	90	Rasen				Bearbeiten
6	11.08.2012			90	Kunstplatz		Bearbeiten
7	08.08.2012	90	Rasen			Lionel Messi	Bearbeiten
8	06.08.2012	60	Rasen			Marco van Basten	Bearbeiten
9	05.08.2012			90	Kunstplatz		Bearbeiten
10	03.08.2012	90	Rasen				Bearbeiten
11	01.08.2012	90	Rasen			Günther Netzer Zinedine Zidane	Bearbeiten
12	30.07.2012	90	Rasen			Oliver Kahn	Bearbeiten

Appendix 12: Overview page in “TeamRec” showing training sessions and matches, accessible by coaches.



Appendix 13: Page to enter injuries in “TeamRec”.



Appendix 14: Example of the “TeamRec” manual: Each step was explained in a 6-page PDF file which was handed out to the coaches.

8.6 "FIFA 11+ Kids" manual

Conception

Oliver Faude

Roland Rössler

Mario Bizzini

Evert Verhagen

Astrid Junge

Collaborators

Karen aus der Fünten

Jiri Chomiak

Tim Hewett

Nicolas Mathieu

Ralf Roth

Layout and Design

Roland Rössler

Oliver Faude

Eric Lichtenstein

This manual shows the version 2 of the "FIFA 11+ Kids" programme. It was used in our subsequent large-scale study which was designed to assess the efficacy of this warm-up programme regarding injury prevention (Chapter 7.5). All coaches of the intervention group received a printed version of this manual at the beginning of the study. All coaches of the control group received the manual after the study was finished.
The manual (here in Swiss German) was translated into Czech, Dutch, and German.

FIFA 11+ Kids

Ein Aufwärmprogramm

zur Verletzungsprävention im Kinderfussball

Manual für den Trainer

F-MARC FOOTBALL FOR HEALTH

FIFA

Entwicklung und inhaltliche Konzeption

PD Dr. Oliver Faude (Departement für Sport, Bewegung und Gesundheit, Universität Basel, Schweiz)

M. Sc. Roland Rössler (Departement für Sport, Bewegung und Gesundheit, Universität Basel, Schweiz)

Dr. Mario Bizzini (FIFA Medical Assessment and Research Centre, Zurich, Switzerland)

Prof. Dr. Evert Verhagen (VU University Medical Center Amsterdam, The Netherlands)

Prof. Dr. Astrid Junge (FIFA Medical Assessment and Research Centre, Zurich, Switzerland)

Unter Mitarbeit von

Dr. Karen aus der Fünten (Institut für Sport- und Präventivmedizin, Universität des Saarlandes, Saarbrücken, Deutschland)

Prof. Dr. Jiri Chomiak (Department of Orthopaedics, 1st Faculty of Medicine, Charles University and Hospital, Prague, Czech Republic)

Prof. Dr. Tim Hewett (The Ohio State University Wexner Medical Center, Ohio, United States)

M. Sc. Nicolas Mathieu (Bereich Physiotherapie Fachhochschule Westschweiz, Leukerbad, Schweiz)

M. Sc. Ralf Roth (Departement für Sport, Bewegung und Gesundheit, Universität Basel, Schweiz)

UNIVERSITY OF BASEL
Department of Sport, Exercise and Health

Inhaltsverzeichnis

Inhaltsverzeichnis

Einleitung 4

Inhalt und Aufbau 4

Erreichen des nächsten Levels 5

Organisation auf dem Platz 5

Korrekte Ausführung und Kernelemente 6

Übung 1: Laufspiel „Wachmann“ 8

Übung 2: Skating-Sprünge 12

Übung 3: Einbeinstand 16

Übung 4: Liegestütz 20

Übung 5: Einbeinsprünge 24

Übung 6: Spiderman 28

Übung 7: Seitliches Abrollen 32

Der folgende Text meint Mädchen/Frauen und Jungen/Männer gleichermassen. Aufgrund der Lesbarkeit wird die männliche Form verwendet.

Einleitung

Beim Fussballspiel sind Ausdauer, Schnelligkeit, Beweglichkeit und Kraft sowie technisches und taktisches Spielverständnis leistungsbestimmend. Durch gezieltes Training werden diese Fertigkeiten verbessert. Fussballspielen hat viele positive Effekte auf die Gesundheit, doch es birgt auch ein gewisses Verletzungsrisiko. Deshalb sollte ein ganzheitliches Training Übungen zur Verletzungsprävention beinhalten. Das neue Verletzungspräventionsprogramm „FIFA 11+ Kids" wurde von einer internationalen Expertengruppe für Kinder im Alter von 7 bis 12 Jahren entwickelt. Es ist ein Aufwärmprogramm und ersetzt das herkömmliche Aufwärmen vor dem Training. Das Programm zielt auf eine Reduktion der Risikofaktoren ab, die zu Verletzungen führen können. Zudem kann FIFA 11+ Kids die motorische Leistungsfähigkeit der Spieler verbessern.

Inhalt und Aufbau

FIFA 11+ Kids fokussiert drei wichtige Bereiche der Verletzungsprävention:

- Verbesserung von Koordination und Gleichgewicht
- Kräftigung von Bein- und Rumpfmuskulatur
- Optimierung von Falltechniken

Das Programm besteht aus insgesamt sieben Übungen, die in der angegebenen Reihenfolge zu Beginn jedes Trainings durchgeführt werden sollen. Für jede Übung gibt es fünf aufeinander aufbauende Schwierigkeitsstufen (Level 1 bis 5). Beginnen Sie mit Level 1. Die Anweisungen für die Kinder sollen so kurz, klar und deutlich wie möglich sein. Achten Sie auf eine korrekte Körperhaltung und eine gute Körperkontrolle:

- Gerade Beinachse: Das Knie ist leicht gebeugt und weicht nicht seitlich aus. Die Fussspitze zeigt nach vorne.
- Körperspannung: Bauch- und Rückenmuskulatur sind angespannt. Der Rücken ist gerade und der Kopf in Verlängerung der Wirbelsäule.

Korrigieren Sie alle Fehler sorgfältig! Hinweise dazu sind bei den einzelnen Übungen beschrieben. Zu Beginn sollten die Wiederholungszahlen und Distanzen reduziert werden. Erst wenn die Übung korrekt ausgeführt wird, sollten die Dauer bzw. die Anzahl der Wiederholungen bis zur vorgeschlagenen Intensität erhöht werden.

Die Bilder zu den einzelnen Übungen verdeutlichen den Bewegungsablauf. Sie sind von links nach rechts in chronologischer Abfolge angeordnet. Das heisst die Startposition ist links und die Endposition rechts abgebildet.

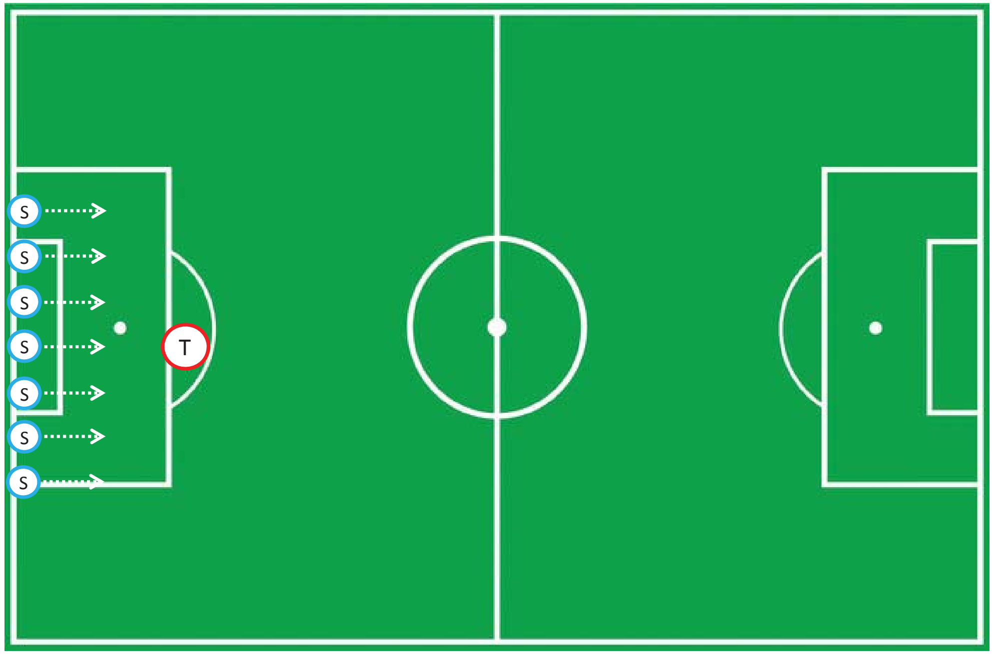
Erreichen des nächsten Levels

Ein Spieler kann mit dem nächsten Level beginnen, wenn die Übung in mehreren aufeinanderfolgenden Trainingseinheiten korrekt über die vorgegebene Dauer bzw. mit der vorgegebenen Wiederholungszahl durchführt wurde. Das ist der Fall, wenn der Trainer dem Spieler keine oder nur noch wenige Korrekturen geben muss und die Übungsausführung sicher beherrscht wird. Die Zeit bis zum Erreichen des nächsten Levels kann von Spieler zu Spieler und von Übung zu Übung stark variieren. Die Levels sollen nacheinander absolviert und nicht übersprungen werden. Es ist durchaus möglich (und erwünscht), dass sich ein Spieler bei einer Übung auf Level 1 befindet und bei einer anderen Übung bereits das Level 3 beherrscht. Mit FIFA 11+ Kids kann individuell reagiert und trainiert werden.

Organisation auf dem Platz

Die Durchführung des Programms dauert ca. 15 Minuten. Als Hilfsmittel wird ein Ball pro Spieler benötigt. Je nach Leistungsniveau, Alter und Mannschaftsgrösse variiert der Platzbedarf zwischen der Strafraumgrösse bzw. der Hälfte eines Fussballfelds. Der Trainer soll so stehen, dass er alle Spieler sehen kann und auch von allen Spielern gesehen wird.

In der Abbildung ist die Position des Trainers (T) und der Spieler (S) dargestellt. Die weissen Pfeile zeigen die Bewegungsrichtung der Spieler zur gegenüberliegenden Linie. Es ist auf genügend Abstand zwischen den Spielern zu achten, insbesondere bei den Sprung- und Fallübungen.



Korrekte Ausführung und Kernelemente

Gerade Beinachse und stabiler, aufrechter Oberkörper

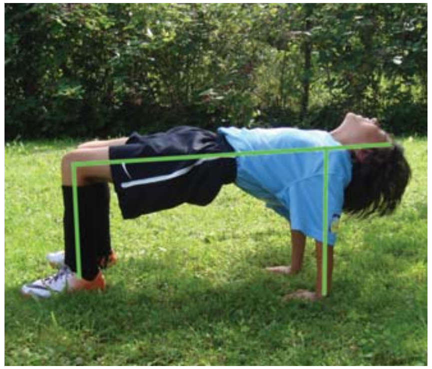
- Fuss, Knie und Hüfte des Standbeins bilden von vorne betrachtet eine gerade Linie
- Fussspitze des Standbeins zeigt nach vorne
- Oberkörper ist aufrecht und zentral positioniert
- Linke und rechte Hüfte sind auf einer Höhe

Gebeugtes Knie im Einbeinstand und bei der Landung

- Fussspitze des Standbeins zeigt nach vorne
- Das Knie des Standbeins ist im Stand leicht gebeugt bzw. wird bei der Landung zum Abfedern gebeugt
- Oberkörper ist aufrecht und zentral positioniert
- Der Kopf ist in Neutralstellung

Knie in einer Linie mit der Fussspitze

- Fussspitze und Knie befinden sich in einer Linie
- Auch bei gebeugtem Knie zeigen Knie und Fussspitze in die selbe Richtung



Körperspannung in der „Spider"-Position

- Kopf, Oberkörper und Oberschenkel sind in einer möglichst geraden Line
- Gesäss und Rückenmuskulatur sind angespannt
- Die Spannung wird auch bei der Vorwärtsbewegung gehalten
- Hände sind etwa schulterbreit auseinander

Körperspannung in der Liegestütz-Position

- Kopf, Oberkörper und Beine sind in einer möglichst geraden Line
- Die Bauchmuskulatur ist angespannt
- Der Kopf ist in Neutralstellung
- Hände und Füsse etwa schulterbreit auseinander

Abrollen über den Rücken

- Die Arme sind beim Bodenkontakt leicht gebeugt
- Abgerollt wird über den vorderen Arm
- Der Kopf berührt nie den Boden
- Abrollbewegung erfolgt diagonal über den Rücken

Für alle Levels gilt:

Fokus: Verbesserung von Gleichgewicht und Koordination.
Ziel: Nach jedem Stopp-Kommando 3 Sekunden stabil auf einem Bein stehen.
Anweisung an die Spieler: „Laufe schnell, bremse ab und stehe stabil auf einem Bein bis zum nächsten Kommando!“

Level 1: Stopp-Kommando hören

Ausgangsposition: Die Spieler stehen an der Grundlinie mit ca. 2 m Abstand zu den Mitspielern. Der Trainer steht etwas ausserhalb des Strafraums (die Distanz altersgemäss anpassen).

Aktion: Auf Kommando des Trainers laufen die Spieler geradeaus in Richtung des Trainers. Wenn der Trainer „rechts“ bzw. „links“ ruft, sollen die Kinder sofort auf dem rechten bzw. linken Bein stehen bleiben und auf einem Bein stehend das Gleichgewicht ca. 3 Sekunden halten. Zwischenhüpfer sind erlaubt, um das Gleichgewicht zu finden. Das Knie des Standbeins soll dabei nicht ganz durchgestreckt sein. Die Arme können zum Ausbalancieren genutzt werden. Wenn ein Spieler nach dem Stopp-Kommando nicht auf einem Bein steht oder innerhalb von 3 Sekunden mit dem anderen Fuss den Boden berührt, so muss er zurück zur Grundlinie joggen. Der Trainer gibt dann erneut das Kommando zum Loslaufen und zum Stoppen (insgesamt pro Durchgang 5 Mal). Dann joggen alle Spieler gemeinsam zurück zur Grundlinie.

Wiederholungen: 3 Durchgänge mit jeweils 5 Stopp-Kommandos.

Level 2: Stopp-Kommando sehen

Ausgangsposition und Aktion: Wie Level 1, jedoch sollen die Kinder den Trainer beobachten und das Stopp-Kommando sehen. Der Trainer zeigt an, ob die Kinder auf dem rechten oder linken Bein stoppen sollen.

Wiederholungen: 3 Durchgänge mit jeweils 5 Stopp-Kommandos.

Level 3: Ball in den Händen und Stopp-Kommando hören

Ausgangsposition und Aktion: Wie Level 1, zusätzlich halten die Spieler bei der Übung einen Ball mit beiden Händen.

Wiederholungen: 3 Durchgänge mit jeweils 5 Stopp-Kommandos.

Level 4: Ball in den Händen und Stopp-Kommando sehen

Ausgangsposition und Aktion: Wie Level 2, zusätzlich halten die Spieler bei der Übung einen Ball mit beiden Händen.

Wiederholungen: 3 Durchgänge mit jeweils 5 Stopp-Kommandos.

Level 5: Ball dribbeln und Stopp-Kommando hören

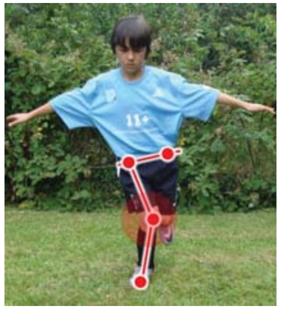
Ausgangsposition und Aktion: Wie Level 1, zusätzlich dribbeln die Kinder mit dem Ball am Fuss. Beim Stopp-Kommando stoppen sie den Ball kurz mit dem Fuss ab und bleiben dann auf einem Bein stehen, wobei der freie Fuss den Ball nicht berührt.

Wiederholungen: 3 Durchgänge mit jeweils 5 Stopp-Kommandos.

Wichtig und richtig:

- ✓ Hüfte, Knie und Fuss sollen von vorne gesehen eine gerade Linie bilden.
- ✓ Das Knie des Standbeins soll leicht gebeugt sein.
- ✓ Fuss gerade aufsetzen, Fussspitze soll nach vorne zeigen.
- ➢ Laufstrecke altersgerecht anpassen.

Diese Fehler bitte unbedingt korrigieren:



Fehler: Knie-Knick und schiefes Becken

Fehler: Fussdrehung nach innen

Fehler: Fussdrehung nach aussen

Für alle Levels gilt:

Fokus: Stabilisation von Fuss- und Kniegelenk.
Ziel: Nach jeder Landung das Gleichgewicht finden und 3 Sekunden auf einem Bein stehen.
Anweisung an die Spieler: „Springe weit, lande sicher und stehe stabil bis zum nächsten Sprung!“

Level 1: Landen lernen

Ausgangsposition: Die Spieler stehen an der Grundlinie mit ca. 2 m Abstand zu den Mitspielern. Der Trainer sagt an, auf welchem Bein die Spieler stehen sollen und achtet darauf, dass alle Spieler auf dem gleichen Bein stehen.

Aktion: Auf Kommando des Trainers („und hopp“) springen die Spieler einbeinig nach *schräg vorne* und landen auf dem *anderen* Bein. Der Trainer zeigt die Richtung an, um Kollisionen zu vermeiden. Beispiel: Erfolgt der Absprung vom linken Bein, so springen die Spieler nach rechts vorne. Nach der Landung sollen die Spieler das Gleichgewicht finden und ca. 3 Sekunden auf einem Bein stehen bleiben. Während des Balancierens ist das Knie des Standbeins leicht gebeugt. Das Ausbalancieren mit den Armen ist erlaubt. Dann gibt der Trainer das Kommando zum nächsten Sprung in die andere Richtung. Bei jedem Sprung soll eine deutliche Seitwärtsbewegung erzielt werden, sodass sich die Spieler im Zick-Zack vorwärts bewegen. Nach 5 Sprüngen auf jedem Bein gehen die Spieler langsam zur Grundlinie zurück.

Wiederholungen: 2 Durchgänge mit jeweils 10 Sprüngen (5 pro Bein).



Level 2: Ball in beiden Händen

Ausgangsposition und Aktion: Wie Level 1, zusätzlich halten die Spieler bei der Übung einen Ball mit beiden Händen.

Wiederholungen: 2 Durchgänge mit jeweils 10 Sprüngen (5 pro Bein).



Level 3: Ball in einer Hand balancieren

Ausgangsposition und Aktion: Wie Level 1, zusätzlich balancieren die Spieler den Ball auf der offenen Handfläche (ein Durchgang auf der rechten und ein Durchgang auf der linken Hand).

Wiederholungen: 2 Durchgänge mit jeweils 10 Sprüngen (5 pro Bein).


Level 4: Ball auf den Boden tippen

Ausgangsposition und Aktion: Wie Level 2, zusätzlich strecken die Spieler nach der Landung, während sie auf einem Bein stehen, den Ball über den Kopf, beugen sich dann nach vorne, tippen den Ball kurz auf den Boden und richten sich anschliessend gleich wieder auf. Dies soll langsam und kontrolliert geschehen.

Wiederholungen: 2 Durchgänge mit jeweils 10 Sprüngen (5 pro Bein).




Level 5: Dynamische Standwaage mit Ball

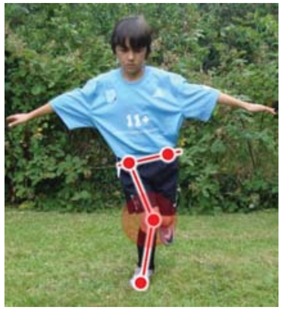
Ausgangsposition und Aktion: Wie Level 4, zusätzlich strecken die Spieler nach der Landung das freie Bein nach hinten-oben und beide Arme nach vorne aus und kehren danach zurück in den normalen Einbeinstand. Anschliessend erfolgt der nächste Sprung. Die Spieler sollen sich beim Strecken „möglichst lang machen". Ideal ist es, wenn Ball, Kopf, Rumpf und das angehobene Bein eine waagerechte Linie bilden (parallel zum Boden).

Wiederholungen: 2 Durchgänge mit jeweils 10 Sprüngen (5 pro Bein).


Wichtig und richtig:

- ✓ Hüfte, Knie und Fuss des Sprungbeins sollen von vorne gesehen eine gerade Linie bilden.
- ✓ Hüfte und Knie des Standbeins immer leicht gebeugt halten.
- ✓ Mit gebeugtem Knie weich landen und abfedern.
- ✓ Spieler sollen nach jeder Landung das Gleichgewicht finden.
- ✓ Körperspannung: Bauch- und Rückenmuskulatur sind angespannt. Der Rücken ist gerade und der Kopf in Verlängerung der Wirbelsäule
- ➢ Sprungrichtung anzeigen, damit alle in dieselbe Richtung springen.

Diese Fehler bitte unbedingt korrigieren:



Fehler: Knieknick und schiefes Becken

Fehler: Starke Hüftbeugung, nach vorne Überlehnen

Fehler: Öffnen des Beckens, Rumpf zur Seite geneigt

Für alle Levels gilt:

Fokus: Gleichgewicht bei Zusatz-Aufgaben.

Ziel: Auch in schwierigen Situationen stabil auf einem Bein stehen können.

Anweisung an die Spieler: „Behaltet das Gleichgewicht auch in schwierigen Situationen!"

Level 1: Ball zuwerfen

Ausgangsposition: Zwei Spieler stehen sich mit ca. 3-5 m Abstand im Einbeinstand gegenüber.

Aktion: Die Spieler werfen sich den Ball abwechselnd zu. Anfangs sollte der Abstand verkürzt werden und eine einfache Wurftechnik verwendet werden. Wurfvarianten (beidhändig, einhändig, Druckpass usw.) sind später denkbar.

Wiederholungen: 1 Durchgang auf jedem Bein mit je 5 Würfen pro Spieler.

Level 2: Ball zuwerfen und um das angehobene Spielbein kreisen

Ausgangsposition und Aktion: Wie Level 1, zusätzlich kreist der Spieler den Ball nach dem Fangen um das angehobene Spielbein.

Wiederholungen: 1 Durchgang auf jedem Bein mit je 5 Würfen pro Spieler.

Level 3: Passspiel

Ausgangsposition: Zwei Spieler stehen sich mit ca. 2-5 m Abstand im Einbeinstand gegenüber.

Aktion: Die Spieler passen sich den Ball flach mit der Fussinnenseite zu. Vor dem Zurückpassen sollte der Ball zuerst gestoppt werden. Die Pässe sollen so präzise wie möglich erfolgen, sodass die Spieler auf der Stelle stehenbleiben können. Passvarianten sind später denkbar.

Wiederholungen: 1 Durchgang auf jedem Bein mit je 5 Pässen pro Spieler.

Level 4: Ball zuwerfen und ohne Bodenberührung zurückpassen

Ausgangsposition: Wie Level 3.

Aktion: Ein Spieler wirft dem Partner den Ball so zu, dass dieser den Ball mit dem Fuss zurückpassen kann. Der Pass soll volley aus der Luft (d.h. ohne vorherigen Bodenkontakt) und so präzise wie möglich gespielt werden, sodass der Spieler, der den Ball geworfen hat, den Ball auch wieder fangen kann. Damit der Spieler korrekt zurück passen kann ist es wichtig, dass der Partner präzise wirft. Zwischenhüpfer sind erlaubt.

Wiederholungen: 1 Durchgang auf jedem Bein mit je 5 Würfen pro Spieler.

Level 5: Gleichgewicht des Partners testen

Ausgangsposition: Zwei Spieler stehen sich im Einbeinstand in Reichweite gegenüber. Beide halten jeweils einen Ball frei vor dem Körper in beiden Händen.

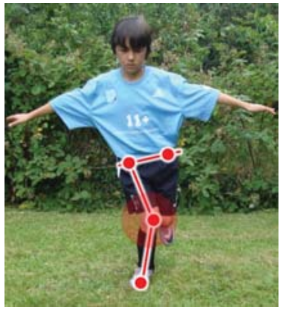
Aktion: Nun drücken sie die Bälle auf Brusthöhe gegeneinander und versuchen, sich gegenseitig aus dem Gleichgewicht zu bringen. Berührt ein Spieler mit dem angehobenen Fuss (Spielbein) den Boden, wird neu begonnen. Die Spieler dürfen auf einem Bein hüpfen, um das Gleichgewicht zu halten. Es dürfen keine schlagenden Bewegungen ausgeführt werden, die Bälle müssen ständig im Kontakt bleiben. Der Trainer wählt die Übungspartner in Abhängigkeit von Grösse und Geschicklichkeit aus. Es ist möglich, einen Wettkampf aus der Übung zu machen: Der Spieler, der seinen Partner aus dem Gleichgewicht bringt, bekommt einen Punkt.

Wiederholungen: 1 Durchgang auf jedem Bein für jeweils 20 Sekunden.

Wichtig und richtig:

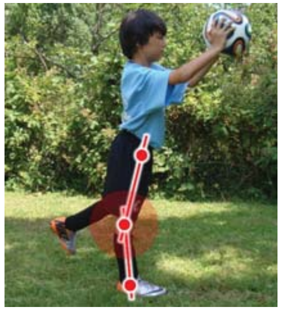
- ✓ Die Fussspitze des Standbeins zeigt nach vorne.
- ✓ Hüfte, Knie und Fuss des Sprungbeins sollen von vorne gesehen eine gerade Linie bilden.
- ✓ Hüfte und Knie des Standbeins immer leicht gebeugt halten.
- ✓ Die Beckenlinie ist waagerecht.
- ✓ Körperspannung: Bauch- und Rückenmuskulatur sind angespannt. Der Rücken ist gerade und der Kopf in Verlängerung der Wirbelsäule.

Diese Fehler bitte unbedingt korrigieren:



Fehler: „Knieknick“ und schiefes Becken

Fehler: Fussspitze des Standbeines nicht in Passrichtung



Fehler: Überstrecktes Knie

Für alle Übungen gilt:

Fokus: Kräftigung der Rumpf- und Armmuskulatur.

Ziel: Die Körperspannung während der Übungen halten können.

Anweisung an die Spieler: „Euer Körper bildet vom Kopf bis zu den Füssen eine möglichst gerade Linie! Spannt Bauch und Rücken an!"

Level 1: Tunnel

Ausgangsposition: Ein Spieler steht, die restlichen Spieler befinden sich dicht nebeneinander in der Liegestützposition und bilden gemeinsam einen „Tunnel". Hände und Füsse sind dabei jeweils etwa hüftbreit auseinander.

Aktion: Der stehende Spieler rollt einen Ball durch den Tunnel. Anschliessend geht er am Anfang des Tunnels in die Liegestütz-Position und erweitert so den Tunnel. Nachdem der Ball unter allen Spielern hindurchgerollt ist, nimmt der letzte Spieler des Tunnels den Ball auf, läuft zum Anfang des Tunnels, rollt den Ball durch den Tunnel und geht am Anfang des Tunnels in die Liegestützposition. Der Tunnel „wandert" dadurch weiter. Die Übung kann als Wettkampf zwischen zwei Gruppen durchgeführt werden.

Wiederholungen: 2 Durchgänge, bei denen jedes Kind jeweils einmal den Ball rollt (maximal 8 Kinder pro Gruppe).

Level 2: Unterarmstütz; Schienbeine liegen auf dem Ball

Ausgangsposition: Die Spieler sind in der Unterarmstützposition. Dabei liegen die Unterarme flach auf dem Boden. Beide Schienbeine liegen mittig auf dem Ball auf und der Blick ist auf den Boden gerichtet. Der Körper bildet vom Kopf bis zu den Füßen eine gerade Linie.

Aktion: Zunächst ziehen sich die Spieler auf dem Ball nach vorne, bis der Ball die Füsse leicht berührt und anschliessend schieben sie sich nach hinten, bis der Ball sich fast unter den Knien befindet. Die Bewegungen werden langsam und kotrolliert ausgeführt. Die Unterarme bleiben dabei an derselben Stelle und die Beine immer auf dem Ball.

Wiederholungen: 3 Durchgänge à je 15 Sekunden.

Level 3: Ball um die Hände rollen

Ausgangsposition: Die Spieler sind in der Liegestützposition. Es liegt ein Ball vor jedem Spieler.

Aktion: Sie heben eine Hand vom Boden und rollen mit dieser Hand den Ball um die andere, abgestützte Hand. Dann stützten sie sich mit der zuvor freien Hand ab und rollen den Ball um die andere Hand. So rollen sie den Ball abwechselnd mit beiden Händen in Form einer Acht.

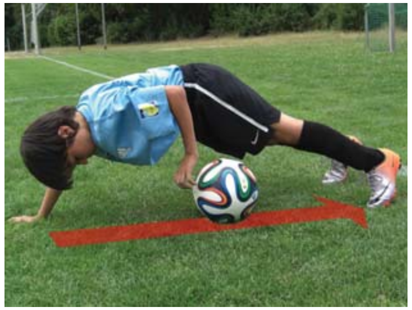
Wiederholungen: 3 Durchgänge à je 15 Sekunden.

Level 4: Ball zwischen Händen und Füssen rollen

Ausgangsposition: Wie Level 3.

Aktion: Die Spieler rollen den Ball mit der linken Hand unter dem Körper zum linken Fuss. Anschliessend passen sie sich den Ball mit dem linken Fuss zur rechten Hand. Dann wiederholen sie die Übung beginnend mit der rechten Hand (zum rechten Fuss und von dort wieder zur linken Hand) und wechseln so beide Seiten ab.

Wiederholungen: 3 Durchgänge à je 15 Sekunden.



Level 5: Hände auf dem Ball

Ausgangsposition: Wie Level 3, jedoch stützen sich die Spieler mit beiden Händen auf dem Ball ab.

Aktion: Sie gehen langsam mit den Füssen in kleinen Schritten möglichst weit nach hinten und dann wieder nach vorne, in die Ausgangsstellung zurück. Die Bewegungen sollen unbedingt ruhig und kontrolliert ausgeführt werden. Hinweis: Bei feuchtem Rasen auf Level 4 ausweichen.

Wiederholungen: 3 Durchgänge à je 10 Sekunden.

Wichtig:

- ✓ Kopf, Schultern, Rücken und Becken bilden eine gerade Linie.
- ✓ Bauch und Gesäss anspannen.
- ✓ Blick nach unten auf den Boden.
- ✓ Bewegungen langsam und kontrolliert ausführen.

Diese Fehler bitte unbedingt korrigieren:

Fehler: Becken zu tief

Fehler: Becken zu hoch

Fehler: Eindrehen der Füsse

Fehler: Ausdrehen der Füsse

Für alle Übungen gilt:

Fokus: Kräftigung der Beinmuskulatur, Verbesserung von Balance und Koordination.

Ziel: Sicheres, kontrolliertes Landen und weites Springen.

Anweisung an die Spieler: „Springe weit, lande sicher und stehe stabil bis zum nächsten Sprung!"

Level 1: Nach vorn

Ausgangsposition: Die Spieler stehen im Einbandstand an der Grundlinie mit deutlichem Abstand (ca. 2 m) zu den Mitspielern.

Aktion: Auf Kommando des Trainers springen die Spieler einbeinig geradeaus. Der Sprung und die Landung erfolgen auf demselben Bein. Die Sprünge sollen deutlich in die Weite gehen. Nach der Landung erfolgt eine kurze stabile Standphase (ca. 3 Sekunden). Nach einem kompletten Durchgang (insgesamt 10 Sprünge) gehen die Spieler langsam zur Grundlinie zurück.

Wiederholungen: 2 Durchgänge mit je 5 Sprüngen auf dem einen und dann 5 Sprüngen auf dem anderen Bein.



Level 2: Vor und zurück

Ausgangsposition: Die Spieler stehen im Einbandstand ca. 2 m vor der Grundlinie mit deutlichem Abstand (ca. 2 m) zu den Mitspielern.

Aktion: Wie Level 1, jedoch zeigt der Trainer an, ob vorwärts oder rückwärts gesprungen wird.

Wiederholungen: 2 Durchgänge mit je 5 Sprüngen auf dem einen und dann 5 Sprüngen auf dem anderen Bein.



Level 3: Seitwärts

Ausgangsposition und Aktion: Wie Level 2, jedoch springen die Spieler seitwärts. Der Trainer zeigt die Richtung an. Es ist stets auf genügend Abstand zwischen den Spielen zu achten, um Kollisionen zu vermeiden.

Wiederholungen: 2 Durchgänge mit je 5 Sprüngen auf dem einen und dann 5 Sprüngen auf dem anderen Bein.


Level 4: Trainer gibt die Richtung an

Ausgangsposition und Aktion: Wie Level 2, jedoch springen die Spieler in die vom Trainer vorgegebene Richtung (nach vorne, nach hinten, nach links, nach rechts). Der Trainer gibt das Kommando („und hopp") und zeigt gleichzeitig die Richtung an, um Kollisionen zu vermeiden. Auf genügend Abstand zwischen den Spielen achten!

Wiederholungen: 2 Durchgänge mit je 5 Sprüngen auf dem einen und dann 5 Sprüngen auf dem anderen Bein.

Level 5: Trainer gibt Richtung an; Ball in beiden Händen

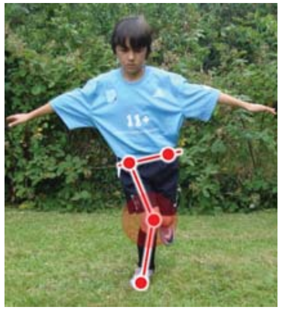
Ausgangsposition und Aktion: Wie Level 4, jedoch halten die Spieler einen Ball in den Händen.

Wiederholungen: 2 Durchgänge mit je 5 Sprüngen auf dem einen und dann 5 Sprüngen auf dem anderen Bein.

Wichtig und richtig:

- ✓ Hüfte, Knie und Fuss des Sprungbeins sollen von vorne gesehen eine gerade Linie bilden.
- ✓ Hüfte und Knie des Standbeins immer leicht gebeugt halten.
- ✓ Mit gebeugtem Knie weich auf dem Fussballen landen und abfedern.
- ✓ Spieler sollen nach jeder Landung das Gleichgewicht finden.
- ✓ Auf ausreichend seitlichen Abstand zwischen den Spieler achten!
- ✓ Körperspannung: Bauch- und Rückenmuskulatur sind angespannt. Der Rücken ist gerade und der Kopf in Verlängerung der Wirbelsäule.

Diese Fehler bitte unbedingt korrigieren:



Fehler: Knieknick und schiefes Becken

Fehler: Beugung in der Hüfte, starkes Nach-Vorne-Lehnen

Fehler: Blick zum Boden

Fehler: Fussdrehung nach innen

Fehler: Fussdrehung nach aussen

Für alle Übungen gilt:

Fokus: Kräftigung der Rumpfmuskulatur und der Oberschenkelrückseite.

Ziel: Körperspannung während der gesamten Übung halten können.

Anweisung an die Spieler: „Nehmt das Gesäss hoch! Spannt Bauch und Rücken an!"

Level 1: Ball antippen

Ausgangsposition: Die Spieler stützen sich auf Händen und Füssen ab. Hände und Füsse sind dabei jeweils hüftbreit auseinander. Der Rücken zeigt zum Boden. Der Körper bildet eine möglichst gerade Linie vom Kopf bis zu den Knien. Der Ball liegt direkt vor den Füssen.

Aktion: Die Spieler heben ein Bein vom Boden ab, tippen mit dem Fuss auf den Ball und rollen diesen leicht nach vorne und wieder nach hinten. Die Spieler wiederholen die Übung mit dem anderen Bein und führen die Bewegung abwechselnd mit beiden Beinen durch. Die Bewegung soll langsam und kontrolliert ausgeführt werden.

Wiederholungen: 3 Durchgänge à 15 Sekunden.



Level 2: Recken und Strecken

Ausgangsposition: Wie Level 1.

Aktion: Aus der Grundposition tasten sich die Spieler zunächst mit den Händen nach hinten und wieder zurück in die Ausgangsstellung (oberes Bilderpaar) und anschliessend mit den Füssen nach vorne bis der Körper möglichst gestreckt ist und wieder zurück (unteres Bilderpaar). Die Spieler tun dies langsam und kontrolliert. Sie wiederholen die Bewegungen immer abwechselnd.

Wiederholungen: 3 Durchgänge à 15 Sekunden.




Level 3: Krabbeln

Ausgangsposition: Wie Level 1.

Aktion: Die Spieler bewegen sich auf „allen Vieren" vorwärts (Füsse voraus) in Richtung des Trainers.

Wiederholungen: 3 Durchgänge (je nach Leistungsniveau 5-10 m).


Level 4: Dribbeln

Ausgangsposition und Aktion: Wie Level 3, jedoch „dribbeln" die Spieler einen Ball. Der Ball soll dabei kontrolliert geführt werden.

Wiederholungen: 3 Durchgänge (je nach Leistungsniveau 5-10 m).

Level 5: Kugelläufer

Ausgangsposition: Wie Level 1, jedoch stützen sich die Spieler mit den Füssen auf dem Ball ab.

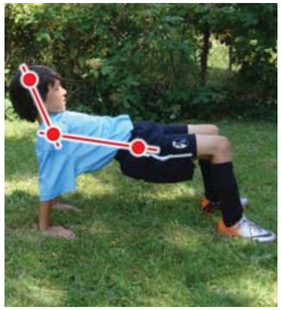
Aktion: Die Spieler rollen den Ball unter den Füssen und bewegen sich dadurch langsam und kontrolliert vorwärts.

Wiederholungen: 3 Durchgänge (je nach Leistungsniveau 3-7 m).

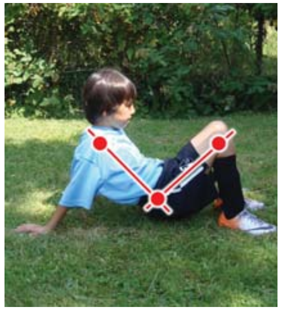
Richtig und wichtig:

- ✓ Das Gesäss soll oben gehalten werden.
- ✓ Der Körper ist in einer möglichst geraden Linie von den Schultern bis zu den Knien.
- ✓ Der Kopf ist in neutraler Stellung.
- ✓ Die Füsse sind immer *unter* oder *vor* den Knien (Kniewinkel immer grösser als 90°)

Diese Fehler bitte unbedingt korrigieren:



Fehler: Falsche Kopfposition



Fehler: Durchhängen des Körpers

Fehler: Ausdrehen der Füsse

Fehler: Eindrehen der Füsse

Für alle Übungen gilt:

Fokus: Fallen und Abrollen lernen.

Ziel: Die Rollübungen in beide Richtungen zu beherrschen.

Anweisung an die Spieler: „Macht euch beim Abrollen klein und rund wie ein Ball!"

Level 1: Aus der Hocke

Ausgangsposition: Die Spieler sind in der Hockposition mit mindestens 2 m Abstand zu den Mitspielern.

Aktion: Die Spieler setzen beide Hände vor dem Knie auf dem Boden auf. Nun senken die Spieler den Kopf, sodass das Kinn nahe an der Brust ist und rollen sich diagonal über Arm, Schulter und Rücken ab. Beispiel: Soll über die rechte Seite abgerollt werden, so ist der rechte Arm vorne in einer gebeugten Position. Die Abrollbewegung erfolgt dann über die Aussenseite des rechten Armes, die rechte Schulter und schliesslich diagonal über den Rücken zurück auf die Füsse. Der Trainer wartet nach jeder Rolle mindestens 5 Sekunden bis zum nächsten Kommando. Die Spieler konzentrieren sich auf jede einzelne Rolle. Der Trainer gibt für jede Rolle die Richtung an.

Wiederholungen: 5 Rollen pro Seite.




Level 2: Langsam aus dem Stand

Ausgangsposition: Die Spieler sind im aufrechten Stand mit mindestens 2 m Abstand zu den Mitspielern.

Aktion: Das in Level 1 erlernte Abrollen wird nun aus dem aufrechten Stand eingeleitet. Die Spieler gehen aus Stand in die Hocke, indem sie die Knie beugen. Gleichzeitig richten sie den Blick nach unten und bewegen das Kinn zur Brust. Der Handaufsatz erfolgt langsam und kontrolliert, sodass die Spieler den Ablauf verinnerlichen können. Die anschliessende Rollbewegung entspricht Level 1.

Wiederholungen: 5 Rollen pro Seite.



Level 3: Dynamisch aus dem Stand

Ausgangsposition: Wie Level 2.

Aktion: Das in Level 2 erlernte „in-die Hocke-gehen" wird nun schneller und dynamischer ausgeführt und die in Level 1 erlernte Abrollbewegung wird dynamisch eingeleitet.

Wiederholungen: 5 Rollen pro Seite.



Level 4: Aus dem langsamen Gehen

Ausgangsposition: Wichtig ist, dass die Spieler das in Level 3 erlernte schnelle Abrollen aus dem Stand in beide Richtungen sicher ausführen können.

Aktion: Das in Level 3 erlernte in die Hocke gehen und Abrollen wird aus dem langsamen Gehen eingeleitet.

Wiederholungen: 5 Rollen pro Seite.



Level 5: Aus der schnelleren Vorwärtsbewegung

Ausgangsposition: Wichtig ist, dass die Spieler die in Level 4 erlernte Bewegung sicher in beide Richtungen ausführen können. Erst dann darf Level 5 ausgeführt werden.

Aktion: Wie Level 4, jedoch aus der schnelleren Vorwärtsbewegung (schnelles Gehen/Joggen) heraus.

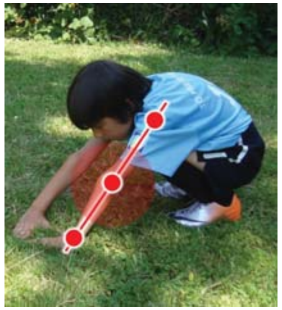
Wiederholungen: 5 Rollen pro Seite.




Wichtig und richtig:

- ✓ Das Kinn wird zur Brust genommen.
- ✓ Über die Aussenseite des Arms, die Schulter und schliesslich diagonal über den Rücken abrollen!
- ➢ Vor jeder Rolle unbedingt auf genügend Abstand zu den anderen Spielern achten!
- ➢ Ausreichende Pause nach jeder Rolle (mindestens 5 Sekunden)
- ➢ Der Trainer gibt ein Startkommando und die Richtung für jede Rolle vor

Diese Fehler bitte unbedingt korrigieren:



Fehler: Arme sind gestreckt

Fehler: Kopf berührt den Boden, gerades Rollen über den Rücken

Gestaltung und Fotos

Roland Rössler, Oliver Faude, Eric Lichtenstein

Kontakt

Roland Rössler, M. Sc.

Universität Basel

Departement für Sport, Bewegung und Gesundheit (DSBG)

Postadresse: Birsstrasse 320B, CH - 4052 Basel

Tel. 0041 (0)61 377 87 39

E-Mail: kinderfussball-dsbg@unibas.ch

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8.7 "FIFA 11+ Kids" short-version of the manual

This short version was used in in our subsequent intervention study (Chapter 7.5) next to the full version of the manual. It was intended to provide coaches a handy (and water resistant) abbreviated version of the manual which they could use during their training sessions on the pitch.

FIFA 11+ Kids: Ein Aufwärmprogramm zur Verletzungsprävention im Kinderfussball

Die Kurzversion „für den Platz“

	Level 1	Level 2	Level 3	Level 4	Level 5
Übung 1: Laufspiel „Wachmann“	**Stopp-Kommando hören** 	**Stopp-Kommando sehen** 	**Ball in den Händen und Kommando hören** 	**Ball in den Händen und Kommando sehen** 	**Ball dribbeln und Kommando hören** 
Übung 2: Skating-Sprünge	**Landen lernen** 	**Ball in beiden Händen** 	**Ball in einer Hand balancieren** 	**Ball auf den Boden tippen**  	**Dynamische Standwaage mit Ball** 
Übung 3: Einbeinstand	**Ball zuwerfen** 	**Ball zuwerfen und um das Spielbein kreisen** 	**Passspiel** 	**Ball zuwerfen und mit dem Fuss zurückpassen** 	**Gleichgewicht des Partners testen** 

	Level 1	Level 2	Level 3	Level 4	Level 5
Übung 4: Liegestütz	**Tunnel** 	**Unterarmstütz: Schienbeine auf dem Ball** 	**Ball um die Hände rollen** 	**Ball zwischen Händen und Füssen rollen** 	**Hände auf dem Ball** 
Übung 5: Einbeinsprünge	**Nach vorne** 	**Vor und zurück** 	**Seitwärts** 	**Trainer gibt die Richtung an** 	**Trainer gibt Richtung an Ball in den Händen** 
Übung 6: Spiderman	**Ball antippen** 	**Recken und Strecken** 	**Krabbeln** 	**Dribbeln** 	**Kugelläufer** 
Übung 7: Seitliches Abrollen	**Aus der Hocke** 	**Langsam aus dem Stand** 	**Dynamisch aus dem Stand** 	**Aus dem langsamen Gehen** 	**Aus der schnelleren Vorwärtsbewegung**