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Could targeted exercise programs prevent lower limb injury in community Australian Football?

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ABSTRACT

Background

Australian football is a popular sport in Australia, at both the community and elite levels. It is a high speed contact sport with a higher incidence of medically treated injuries when compared to most other organized sports. Hamstring injuries, ligament injuries to the knee or ankle, hip/groin injuries and tendinopathies are particularly common and often result in considerable time-loss from sport. Consequently, the prevention of lower limb injuries is a priority for both community and elite Australian football organizations.

There is considerable literature available on exercise programs aimed at reducing lower limb injuries in Australian football and other running related sports. The quality and outcomes of these studies have varied considerably, but indicate that exercise protocols may be an effective means of preventing lower limb injuries. Despite this, there has been limited high quality and systematic evaluation of these data.

Objective

The aim of this literature review was to systematically evaluate the evidence about the benefits of lower limb injury prevention exercise protocols aimed at reducing the most common severe lower limb injuries in Australian football.

Methods

The Cochrane Central Register of controlled trials, the Cochrane Bone Joint and Muscle Trauma Group Specialized Register, MEDLINE and other electronic databases were searched, from January 1990 to December 2010. Papers reporting the results of randomized controlled trials, quasi-randomized controlled trials, cohort, and case-control studies were extracted. Primary outcomes were injury reduction or risk factor identification and/or modification. Secondary outcomes were adherence to any trialled interventions, injury severity and adverse effects such as secondary injuries, muscle soreness. The methodological quality of extracted manuscripts was assessed and results collated.

Results

Forty-seven papers were identified and reviewed of which 18 related to hamstring injury, eight related to knee or ankle ligament injury, five related to tendon injury and four were hip or groin injury related. Another 12 papers targeted general lower limb injuries. Most n=27 (57%) were observational studies, investigating injury risk factors. Twenty reported the results of intervention trials. Of these, 15 were efficacy trials reporting the effects of an intervention in reducing injury rates, four were biomechanical interventions in which the impact of the intervention on a known injury risk factor was assessed and one reported changes in injury risk factors as well as injury rates.

The strength of the evidence base for exercise programs for lower limb injury prevention was found to be limited, primarily due to the research methods employed, low adherence to interventions by the study participants and a lack of statistical power. Limited evidence obtained from a small number of randomized controlled trials suggests that balance and control exercises might be efficacious in preventing ankle ligament injuries and a program involving a combination of balance and control exercises, eccentric hamstring, plyometrics and strength exercises could be efficacious in preventing all lower limb injuries.

Conclusions

Overall, the evidence for exercise programs as an efficacious lower limb injury prevention strategy is predominantly restricted to studies addressing injury aetiology and mechanisms. The findings of this review highlight the need to develop and test interventions in well-designed population-based trials with an emphasis on promoting intervention uptake and adherence, and hence intervention effectiveness. The results of this review can inform the development of the components of a future lower limb injury prevention exercise protocol for community level Australian football.

MANUSCRIPT

1. Introduction

Sports participation is an important means of promoting physical activity. However, injury during such activity can reduce the benefits of participation, and injury prevention strategies are critical. The implementation of evidence-informed safety policies and practices within community based sporting organizations is integral for optimizing the public health benefits of sports participation and reducing barriers to sports uptake.

Australian football is a popular spectator and participation sport in Australia. It is a high speed game that requires athleticism, endurance and agility. The game is characterized by explosive bursts of speed, cutting manoeuvres and heavy physical contact. Consequently, Australian football has the highest rate of medically treated injuries, compared to other organized sports, in Australian states where Australian football is the dominant football code [1,2].

Priority focus areas for sports injury prevention are determined by multiple factors including measures of: (a) injury frequency (incidence), (b) injury severity (time loss from sport, level and type of medical intervention); and (c) overall injury burden (mortality, disability adjusted life years). Other factors include the availability of effective interventions, the likely economic gain associated with implementing them and the potential for meaningful impacts on participation and performance [3,4].

Limited data are available on the incidence, characteristics and preventability of Australian football injuries at the community level. These data have consistently shown lower limb injuries to be the most common, especially to the knee, ankle and upper leg (thigh/hamstring) [5-7]. Injuries to muscle or tendon, joint or ligament sprains and superficial injuries such as abrasions and bruises are the most common injury types [5,7]. However, injuries such as hamstring injuries, ligament injuries to the knee or ankle, hip/groin injuries and tendinopathies are the most severe and often required medical treatment and rehabilitation [8]. Fractures, though severe, are less common and account for only around 5% of injuries [5,7].

There are no available data on the cost of injuries sustained during community Australian football. However, data from other sports has shown that lower limb joint, tendon and muscle injuries rank highest in terms of time-loss from sport [9,10] and can incur large direct (medical treatment) and indirect (income or productivity loss) costs [11]. It is therefore not surprising that lower limb injuries, such as knee and hamstring injuries, have been ranked the highest in terms of importance for prevention by community level club administrators and coaches [12].

The key elements of Australian football, such as endurance, agility and speed, are common to many competitive and recreational running-related sports and similar patterns and frequencies of lower limb injuries are reported in those sports [10,13,14]. The common manoeuvres and risks factors for lower limb injury in running sports suggests that interventions tested in other similar sports might also reduce lower limb injuries in Australian football.

The aim of this literature review was to systematically evaluate the evidence about the benefits of lower limb injury prevention exercise protocols aimed at reducing the most common severe lower limb injuries in Australian football.

2. Methods

2.1 Criteria for including studies in the review

2.1.1 Study types included in the review

The following study types were included:

1) Observational studies in which modifiable injury risk factors such as muscle strength or technique were identified or within-cohort differences in injury outcomes were observed
2) Biomechanical studies assessing the outcomes of interventions aimed at altering lower limb injury risk factors.
3) Studies aimed at determining the efficacy or effectiveness of intervention programs in preventing lower limb injuries during a competitive season.

Efficacy and biomechanical studies were included if the study design was a randomized controlled trial, quasi-randomized trial or cluster-randomized trial. Efficacy studies were those in which an intervention was implemented during a playing season and the impact on injury incidence evaluated in a researcher controlled trial. Biomechanical studies were those in which the influence of an injury prevention intervention on a recognized risk factor or surrogate outcome, such as muscle strength or external knee joint loading, was tested in a laboratory setting.

2.1.2 Study types excluded from the review

Cross-sectional studies in which performance measures or physical measures were assessed in the presence of existing impairment or injury were excluded. This was because cross-sectional studies cannot be used to infer any temporal sequence between the observed deficit and the injury. Case reports and case series were also excluded.

2.2 Anatomical structures focused on in the review

The choice of anatomical structures focused on in the review was informed by a yet to be published literature review performed by the authors, describing the type, nature and mechanisms of injuries in community Australian football.

The following priority areas were identified based on injury frequency and severity.

1) Lower limb muscle injuries, specifically hamstring, quadriceps and calf
2) Injuries to the ankle and knee ligaments or joints
3) Injuries to the hip or groin
4) Injuries to the Achilles or patellar tendons

2.3 Participant focus of reviewed studies

2.3.1 Sporting groups

Studies performed in physically active or sporting populations engaged in land-based activities with characteristics similar to Australian football were included. Hence, activities such as soccer, basketball, running and field hockey were included but activities such as cycling, horse riding, water sports and martial arts were excluded. Studies based on elite athletes, community sport participants, military recruits participating in exercise programs and recreational athletes were all included.

2.3.2 Age and gender groups

Studies in both male and female adults (aged 18 years or more) were included. Studies with adolescent participants were excluded as the pattern, frequency and severity of injuries can differ between those who are skeletally immature and those who are mature [15]. This is because injury risk factors specific to adolescents, such as increased muscle-tendon tightness due to growth spurts or decreased physical and physeal strength, have been associated with an increased risk of injury [15,16]. Studies in which adult teams included a small number of participants aged less than 18 years were still included in the review. To account for this, baseline comparisons of age or statistical adjustment for age differences between study groups was assessed when reviewing the methodological quality of studies.

2.3.3 Previous injury

Having sustained a previous lower limb injury is a well-established risk factor for sustaining a subsequent injury [17]. In some of the reviewed studies, some participants had reported a previous injury. However, the extent to which this was addressed in the study design, statistical analyses and baseline comparisons was taken into account when assessing the methodological quality of the studies.

2.4 Types of interventions

Papers that reported either the efficacy or effectiveness of interventions involving exercise-based lower limb injury prevention programs suitable for use in community sport were sought. However, no effectiveness studies were able to be identified. Program suitability and delivery factors could therefore only be assessed from the efficacy studies by examining the complexity, equipment requirements and cost of the intervention. Papers that aimed to identify risk factors that could potentially be modified through exercise-based interventions such as joint range, muscle strength or neuromuscular performance (balance and control) were included. However, those that only examined non-modifiable risk factors such as age or gender were excluded.

2.5 Types of outcome measures

2.5.1 Primary Measures

Papers in which the outcome provided a measure of association between intervention or risk factor and the injury of interest were included. Primary outcome measures included:

1) Change in injury incidence associated with an intervention or exercise technique
2) Association between modifiable risk factors and injury incidence
3) Change in injury risk factors associated with an intervention.

2.5.2 Secondary Outcomes

Secondary outcomes of interest were those associated with the suitability of the intervention for a community Australian football setting and the potential for uptake by targeted players.

Secondary outcomes were:

1) Level of adherence to the intervention, as indicated by the percentage of participants who completed the intervention
2) Adverse effects associated with the intervention e.g. muscle soreness, increase in incidence of other types of injuries
3) Changes in the severity of injuries sustained, as measured by time lost from sports participation
4) Factors related to the ability of the intervention to be implemented in a community based sports setting, e.g., cost, intervention complexity and dosage required for the intervention to be effective.

2.6 Search methods for identification of studies

The search strategy was guided by the Cochrane handbook [18] and Robinson et al [19]. Searches were performed using the Cochrane Central Register of Controlled Trials, the Cochrane Bone Joint and Muscle Trauma Group Specialized Register, MEDLINE, EMBASE, Cumulative Index to Nursing and Allied Health (CINAHL) and The Allied and Complementary Medicine Database (AMED), from January 1990 to January 2011. A standardized method was used to perform electronic searches based on word strings that covered relevant injury terms, study designs, study purposes and anatomical areas (Online Supplement I). Articles were restricted to those published in English. Grey literature sources such as conference proceedings, library catalogues and Google scholar were searched for relevant unpublished works. Experts in the field were contacted and reference lists of identified manuscripts and review articles were also searched. Manuscript lists were circulated between members of the authorship to identify duplicates. Where duplicates were identified, they were allocated to separate teams of researchers (from within the authorship team) based on consensus.

2.7 Data extraction and management

Searches were divided into the four anatomical division categories mentioned above. The literature search, study identification and data extraction for each of the three areas was performed by research teams with expertise in that specific area of sports injury prevention.

Potentially eligible studies were initially identified from the title and abstracts were screened.. Full text articles were retrieved for those that met the review criteria and in cases where eligibility was unclear from the abstract (See Figure 1). Standardized data extraction forms were developed to specifically address the aims of the study and were based on the Cochrane Collaboration guidelines [18] and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [20]. These forms are available from the authors on request. The data extraction forms were used to confirm the eligibility of studies and assess their methodological quality. Disagreement or uncertainty over eligibility was resolved by consensus from the authors.

The methodological quality of intervention studies was scored using a modification of the Cochrane Bone Joint and Muscle Trauma Group quality assessment tool (Online Supplements II-IV). Results from the observational risk factor studies were tabulated to identify risk factors for which there was an accumulation of evidence to suggest an association between the risk factor and injury (Table I).

3. Results

A total of 116 full text papers were retrieved of which 69 were excluded. Common reasons for exclusion were that they did not contain a control group, were performed in adolescent sporting groups or the intervention could not be performed using equipment available in a community sporting setting.

A total of 47 papers were included in the final review. Of these, 18 related to hamstring injury, eight related to knee or ankle ligament injury, five related to tendons and four were hip or groin injury related. Another 12 targeted general lower limb injuries. No papers specifically investigated calf or quadriceps muscle injuries (Figure I).

Of the included studies, 27 involved observational studies identifying risk factors and 20 reported the results of intervention studies. Of the intervention studies, 15 were efficacy (field-based) studies, four were biomechanical studies in which a surrogate outcome was reported and one reported changes in both a surrogate outcome measure as well as injury incidence. None were effectiveness trials.

Of the 20 papers that reported the results of intervention studies (efficacy and biomechanical), the majority (n=11) were conducted in elite athletes with only seven involving community level or recreational athletes. A further two were conducted in a military setting. Most studies investigated soccer players (n=9), with only four (17%) involving Australian football players. All study participants were aged between 17 and 42 years of age. Papers in which observational studies were reported, included mainly elite athletes (70%), with equal representation of soccer (30%) and Australian football players (30%)

3.1 Observational Study Results

A total of 19 modifiable risk factors associated with hamstring injury, tendinopathies, hip or groin injuries or general lower limb injuries were identified. No observational studies investigating risk factors specifically associated with knee and ankle ligament injuries were identified. However, this comment does require clarification. Many observational studies have shown that the majority of non-contact anterior cruciate ligament (ACL) injuries occur during the sporting manoeuvres of sidestepping and/or single leg landing [21,22,23]. However, these manoeuvres are an implicit part of sport and do not offer an avenue for intervention. Cadaveric studies [24] and observational laboratory research of landing and sidestepping [25-27] have shown that the biomechanical surrogates of combined externally applied flexion, valgus, internal rotation knee moments are the probable triad of external knee loads that cause ACL injuries during these sporting tasks [28 29]. Furthermore, one observational study has also linked externally applied valgus knee moments to ACL injury risk [30]. However this study was not included as it was in an adolescent population and tested double legged landing, which is a sporting manoeuvre not usually associated with ACL injury.

The association between pre-season testing of modifiable risk factors and injury outcome was tested most often. There were large variations in the quality of the methods employed and only a few studies adequately accounted for known confounders using appropriate statistical analyses [31-40]. Results were variable and often contradictory (Table I). However, there was an accumulation of evidence to suggest that:

1) Hamstring injury could be associated with a reduced hamstring/quadriceps strength ratio or reduced lower limb neuromuscular control/balance
2) Patellar tendon injury could be associated with reduced hamstring flexibility
3) Groin pain could be associated with reduced hip range of motion (ROM).

3.2 Intervention Studies

3.2.1 Hamstring Injuries

Interventions aimed at preventing hamstring injuries were assessed in five papers [41-45]. Most examined the efficacy of eccentric hamstring exercises for preventing hamstring injuries [41-45]. Four used partner assisted exercises (hamstring lowers) [42-45] whereas the other involved eccentric and concentric exercises using an ergometer [41]. In one paper, only those considered at risk of hamstring injury were given the exercise program [43]. In three of the papers, there was no difference in injury rates between the intervention and control group. This was primarily a consequence of the studies being underpowered, due to low adherence to the intervention [42,43] or low injury numbers [44]. Studies that had low intervention adherence had a trend towards reduced hamstring injuries for the intervention group. In the remaining papers, a reduction in hamstring injury rates was reported for the intervention group [41,45]. However, adherence was not reported and the authors did not use intention-to-treat analyses.

Two of the hamstring papers reported the impact of training programs on risk factors associated with hamstring injury, such as reduced hamstring/quadriceps ratio and neuromuscular control [46,47]. Specific training drills aimed at improving running technique and coordination significantly improved neuromuscular control/balance, as measured by a backward leg swing movement discrimination test [47]. In the other study, although the functional relevance of hamstring/quadriceps strength ratio has been questioned [48-50], eccentric hamstring exercises increased this ratio, but more importantly it also improved eccentric hamstring torque and isometric strength [46]. This intervention has subsequently been assessed in a number of efficacy trials [42-45]. The extent to which improvements in neuromuscular control directly lead to prevention of hamstring injury has yet to be investigated in any study.

3.2.2 Knee Joint/ligament injuries

The impact of interventions aimed at reducing knee ligament injuries were reported in five papers. Three involved efficacy trials [51-53] and two were biomechanical in which a surrogate outcome measure was used [54,55]. Of the efficacy studies, two assessed the impact of graded balance and control exercise [51,53] and one assessed the influence of a program combining balance and control exercises with strength exercise [52]. The neuromuscular control exercise was shown to be efficacious in only one of the trials [53]. However, confidence in the outcomes of this paper are limited as the authors did not report intervention adherence or use intention-to-treat analysis. The effect of strength exercise [54], and balance and control exercise programs[55], on knee kinematics and kinetics were assessed in two papers. In one [54], no difference between the intervention and control group was reported, whereas in the other, [55] the intervention group showed a 27% decrease in valgus knee moments after machine based strength exercise, a 62% reduction in valgus knee moments and a 32% reduction in internal rotation knee moments following balance exercise.

3.2.3 Ankle joint/ligament injuries

The efficacy of ankle balance and control exercise to improve neuromuscular control as a means of preventing ankle sprains was reported in a number of papers [43,56,57]. Intervention adherence of at least 75% of participants was reported in two studies [56,57], one study had good methods compared to other studies (defined as at least two thirds of criteria in Online Supplement IV being met) [13]. In these papers, a significant reduction in ankle sprains in the intervention group followed the performance of a graded balance and control exercise program.

3.2.4 Tendon/groin injuries

There were very few papers identified in which interventions targeting tendon or groin injuries were evaluated. The efficacy of a program involving hip adduction strength exercise and trunk stabilizing exercises in reducing groin injuries was reported in two papers [43,58]. In both, no significant difference was found between the intervention and control groups. Both studies were under-powered, one due to low injury numbers [58] or low adherence to the intervention [43]. Stretching and eccentric strength exercise for Achilles and patellar tendons were found to reduce the risk of developing patellar tendon imaging abnormalities but not Achilles tendon abnormalities in another study [59]. However, this did not translate to a reduction in injury rates in the intervention group.

3.2.5 General lower limb injuries

General lower limb injury was the outcome of interest in five papers [51,60-63]. The role of muscle static stretching programs in preventing injury was assessed in three studies [60,61,63]. Two of the stretching interventions were tested using military recruits [61,63]. The stretching programs varied in their efficacy, with only one demonstrating a reduction in lower limb injuries [63]. However, that intervention involved large amounts of stretching, three times a day for 13 weeks, which could be difficult to implement in other settings [63].

The efficacy of balance and control exercises alone [51], and in combination with plyometrics, strength exercise, eccentric hamstring exercise and stretching [62], on reducing the overall rate of lower limb injuries was assessed in two studies. An intervention, involving only balance and control exercises, did not significantly reduce the overall lower limb injury rate, despite good athlete adherence to the intervention [51]. However, the program was completed at home and adherence assessment was based on self-report, which may not be accurate. The other study, which used a combination of exercises specifically targeting multiple risk factors for lower limb injuries [62], was well designed. The authors reported that the intervention was fully delivered in 74% of sessions and intention to treat analyses were used. In this study, a statistically significant reduction in injury rates was demonstrated for the intervention group compared to the control group.

3.3 Risk of Bias

The methodological quality of the intervention studies was assessed for risk of bias. Overall the methods of only ten papers in this review fulfilled more than 50% of the quality assessment tool criteria (Online Supplement II-IV). Results were hampered by lack of adequate baseline comparisons, the use of non-standardized injury definitions and small injury numbers. When reported, adherence to the intervention was sometimes as low as 20% (Table II). In studies where intention-to-treat analyses were used, low adherence had the effect of diluting results [64]. Studies with low adherence that did not use intention-to-treat analysis were subject to bias as only the most motivated participants were analyzed. Intervention adherence was highest when the intervention program was integrated into the overall exercise program [57,62] and in balance and control exercise programs [56,57]. Intervention programs in which adverse consequences such as muscle soreness were reported, were associated with low adherence to the intervention [42].

4. Discussion

This is the most rigorous review to date to have systematically evaluated the evidence to justify using exercise as an intervention to reduce lower limb injuries in sport. The studies were evaluated on methodological quality, scientific basis, content, outcome and focus as well as their potential for direct application to the community Australian football context. Strategies aimed at preventing different injury types were evaluated in different study designs. The evidence for most of the injury prevention strategies was dependent on studies addressing injury aetiology and mechanisms. Efficacy studies in the form of randomized controlled trials provided evidence for the use of balance and control exercises to prevent ankle ligament injuries. A multi-faceted exercise program aimed at reducing general lower limb injuries was also shown to be efficacious. Many of the injury prevention programs, however, failed to show a positive impact on injury rates due to limited methods and limited uptake of the interventions. No effectiveness studies were identified for any relevant exercise intervention.

Developing an evidence base for injury prevention is a complex process involving a number of stages [65]. Early stages involve understanding injury aetiology and risk factors. Initial risk factor identification is usually obtained from large observational studies in which pre-season testing is used to identify potential injury risk factors. The evidence for tendon and groin injury prevention has its foundation only in observational research. While this is an important preliminary step in developing an injury prevention evidence base, it is not sufficient for establishing a causal relationship between the risk factor and the injury of interest, and hence for identifying a specific intervention.

The next stage involves the development of strategies to address the risk factors identified by observational studies [65]. This often involves *in-vitro*, *in-vivo, ex-vivo*, *in-silico* and laboratory-based biomechanical studies in which interventions are designed to address relevant risk factors [22-28]. An example of this is provided by the hamstring injury prevention literature. Evidence of hamstring injury risk factors was used to develop an injury prevention program that was shown to alter the targeted risk factor through a laboratory-based RCT [46]. This type of research provides a theoretical basis for the potential efficacy of interventions but does not ensure that it can then be translated into a community sport exercise environment.

The strongest efficacy evidence is provided by RCTs in which the scientific evaluation involves comparing injury occurrence in intervention and control groups. These studies are generally performed under highly controlled conditions in specifically selected groups [66,67] and should be analyzed using an intention-to-treat protocol [64,68]. Commonly, participants involved in RCTs are highly motivated, are already attending highly structured exercise sessions, making it easier to randomize them to either "usual training" or the intervention, and are coached by well qualified and motivated staff. This type of study design provides evidence of the efficacy of an intervention but does not provide evidence on how effective the intervention will be in preventing injuries within the broader injury prevention delivery context [66,67].

Neuromuscular control and balance exercise for the prevention of ankle ligament injuries and a multifaceted program for the prevention of lower limb injuries were the only interventions whose efficacy was supported by strong evidence from at least one study [56,62]. Unfortunately, the efficacy of the majority of the injury prevention programs developed from observational and biomechanical studies is yet to be supported by high quality evidence (Table III).

The strongest level of overall scientific evidence comes when the results of efficacy studies, are consistent with and supported by the evidence from observational and biomechanical studies. This consistency across different types of studies, increases thescientific understanding of the possible mechanisms involved in injury reduction. For example, it is exepcted that eccentric hamstring training would improve eccentric hamstring strength and thereby reduce hamstring injuries. Also balance and plyometric training should improve an athlete's motor control during sidestepping and/or landing tasks, which in turn reduces their peak valgus knee moments and hence the number of ACL injuries they would sustain [28]. This level of understanding could lead to new innovative training methods that may target the biomechanical aetiology of injury [65 29 ,69].

Though not specifically addressed by this review, some lessons can be learnt from efficacy studies about the factors likely to impact on intervention effectiveness and the uptake of specific interventions to reduce lower limb injuries in sport [66]. Implementation issues such as intervention adherence or the risk of adverse effects were often not reported, nor were intermediate changes such as behavior changes related to adoption of the intervention. Exploration of why participants did not adhere to the intervention or the influence of the broader context in which the intervention was or will be delivered was also not routinely explored (see Table II). This information is important for informing future implementation and effectiveness research in this area and identifying interventions that are likely to be successfully implemented in the real-world [66 ,67 70].

The low levels of adherence reported in many studies highlight the need to address the broader social and behavioral context of injury prevention [71]. This is particularly important for community level exercise environments that have unique challenges associated with implementing injury prevention exercise protocols across heterogeneous groups. Higher levels of adherence were reported in studies that incorporated the intervention into standard exercise programs or as part of a warm-up or cool-down session [52 ,57 ,58 ,60 ,62] (Table II). At the community level, interventions that do not involve specialized equipment, high level complex manoeuvres or expert instruction could also allow an exercise protocol to be implemented with greater ease. The ability to adapt exercise interventions to the existing exercise culture of these sports is also increased as they can be merged with existing exercise standards of that sport. This is important as both athletes and coaches are more supportive of injury prevention drills that will be perceived as also improving game performance [67,72].

5. Limitations

The purpose of this review was to comprehensively examine the injury prevention evidence for strategies to inform exercise guidelines for dissemination to adult community level Australian football clubs. Despite the comprehensiveness of this review, not all injuries sustained in this sport were able to be addressed. However, the most common injury types, responsible for participants having prolonged periods of time away from sport were included (unpublished review paper). The focus of this paper is on evidence to prevent the more “major” injuries. However, the reviewed interventions could also potentially reduce the number of superficial injuries.

Another limitation is that the majority of reviewed studies were performed with elite athletes. Injury risk factors, the ability to accurately perform an exercise intervention and issues related to adherence cannot be assumed to be the same for community and elite level athletes. These factors are all likely to influence the effectiveness and uptake of the reviewed interventions when placed in the context of community sport. The extent to which results obtained from a broad range of sporting populations can be translated into the Australian football context is also unknown [44,67,72].

This review was also limited to research performed in adult populations. This resulted in the exclusion of a number of well-designed studies performed in adolescents [73-76]. However, the physiological differences between adults and adolescents [15] meant that evidence from these studies could not be accurately translated to adult Australian football injury prevention.

6. Conclusion

Developing an evidence-based lower limb injury prevention program for implementation in community level Australian football will be challenging. The current evidence is limited and is primarily dependent on studies addressing injury aetiology and mechanisms, mainly in elite athletes. Consequently, the extent to which these results could be successfully translated to community sport is currently unknown. There is a need for further well-designed research in this area, aimed at developing and testing interventions in well designed randomized controlled efficacy and effectiveness trials with an emphasis on adherence. Nonetheless, the results of this review could be translated into exercise guideline content appropriate for community level Australian football clubs.

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Table I. Summary of observational study results showing whether or not an association was found between commonly perceived risk factors and injury outcomes

Risk Factor	Hamstring muscle	Patella tendon	Achilles tendon	Hip/groin pain	General LL injury
Decreased hamstring flexibility	+ 34 - 31 ,32 ,35-37 ,45 ,77 ,78	+ 33 ,34 - 79			
Decreased hamstring eccentric strength	+ 78 - 35 ,80				
Decreased hamstring concentric strength	+ 81 - 80 ,82				83
Decreased hamstring/quads strength ratio	+ 37 ,80 ,81 ,84				
Decreased hamstring stiffness	+ 85				
Decreased calf flexibility or ankle dorsiflexion (<45°)	- 31 ,32	+ 79	- 40		86 ,87
Increased calf flexibility or ankle dorsiflexion			+ 40		
Calf weakness/decreased PF strength		- 79	+ 40		
Decreased DF strength			- 40		
Decreased quadriceps flexibility		+ 33			
Decreased quadriceps concentric strength	- 81				- 83
Decreased hip adduction strength				+ 38 - 39	
Decreased adductor/abductor strength ratio				- 38	
Decreased total hip range of motion				+ 87-89	

Decreased hip adductor flexibility				- 38 ,39	
Decreased hip flexor flexibility					
Decreased psoas flexibility	- 31 ,32				
Correct landing posture					
Correct limb alignment when side stepping					
Static and dynamic balance control	+ 80 ,90 - 35				- 91
Ligament laxity					- 83 ,92

Table II. Intervention adherence rates and programme implementation for papers that reported adherence levels

Paper	Percentage that adhered to or completed the program	How program was implemented	Reasons for non adherence
Engebretsen 2008 [43]	21% hamstring program 29% knee program 28% ankle program 19% groin program	Program was in addition to training	Not stated
Gabbe 2006 [42]	<10% of participants	Program was in addition to training	Post-intervention muscle soreness
Gabbe 2005 [32]	80% of participants	In addition to training	
Gilchrist 2008 [52]	68% of teams	Performed during warm up	Not stated
Cumps 2007 [57]	92% of participants	Performed during warm up	Personal reasons
Hartig 1999 [63]	88% of participants	In addition to training	Not available for post-intervention testing
Pasanen 2008 [62]	74% of session were completed	Performed during warm up	Not stated
Pope 2000 [61]	71% of participants	Performed during warm up	Moved from military unit
Soderman 2000 [51]	78% of participants	Performed at home in addition to training	Not stated
van Mechelan 1993 [60]	91.8% for warm up, 89.5% for cool down, 61.4% for stretches	Performed in addition to training	Not stated
Holmich 2010 [58]	81% of teams	Performed during warm up	Too much work, change of coach, coach attitudes
Verhagen 2004 [56]	73% of participants	Performed during warm up	Change of coach, Coach attitudes, individual / personal reasons.

Table III. Summary of Results

Intervention / risk factor	Injury type	Study type
Efficacy intervention trials*		
Balance and control exercises [56] - Exercise without material - Exercise with balance board only - Exercise with ball only - Exercise with balance board and ball 5 minutes per day at each training session for 36-wks	Ankle ligament injuries	RCT – efficacy trial
Combined program [62] - Running exercises (5-7 minutes): - Balance and body control exercises (5-7 minutes) - Plyometrics (5-7 minutes) - Strengthening exercises for lower legs and core stability(5-7 minutes) - Nordic hamstrings—2-3×4-8 repetitions - Stretching exercises (5 minutes) Intensive training during the pre-season and season break of 2-3 times a week and maintenance training of one training session a week during the season.	Lower limb injuries	RCT – efficacy trial
Biomechanical intervention trials*		
Eccentric hamstring exercises (hamstring lowers) [46] - Participants were instructed to fall forward from a kneeling position whilst resisting the fall as much as possible using their hamstring Week 1: 1 session 2 x 5 repetitions Week 2: 2 sessions 2 x 6 repetitions Week 3: 3 sessions 3 x 6-8 repetitions Week 4: 3 sessions 3 x 8-10 repetitions Week 5: 3 sessions 3 x 12-10-8 repetitions	Hamstring injury risk factor	RCT – biomechanical trial

Aetiology studies[#]		
Reduced hamstring/quadriceps strength ratio [37,80,81,84]	Hamstring injury	Cohort study
Reduced neuromuscular control/balance [87,99]	Hamstring injury [80,90]	Cohort study
Reduced hamstring flexibility [33,34]	Patellar tendon injury	Cohort study
Reduced hip range of motion [87-89]	Groin pain	Cohort study

* Where evidence is obtained from at least one properly designed randomised controlled trial
[#] Where there is an accumulation of evidence from properly designed prospective cohort studies