Preventing Australian football injuries with a targeted neuromuscular control exercise programme: comparative injury rates from a training intervention delivered in a clustered randomised controlled trial

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ABSTRACT

Background Exercise-based training programmes are commonly used to prevent sports injuries but programme effectiveness within community men's team sport is largely unknown.

Objective To present the intention-to-treat analysis of injury outcomes from a clustered randomised controlled trial in community Australian football.

Methods Players from 18 male, non-elite, community Australian football clubs across two states were randomly allocated to either a neuromuscular control (NMC) (intervention n=679 players) or standard-practice (control n=885 players) exercise training programme delivered as part of regular team training sessions (2× weekly for 8-week preseason and 18-week regular-season). All game-related injuries and hours of game participation were recorded. Generalised estimating equations, adjusted for clustering (club unit), were used to compute injury incidence rates (IIRs) for all injuries, lower limb injuries (LLIs) and knee injuries sustained during games. The IIRs were compared across groups with cluster-adjusted Injury Rate Ratios (IRRs).

Results Overall, 773 game injuries were recorded. The lower limb was the most frequent body region injured, accounting for 50% of injuries overall, 96 (12%) of which were knee injuries. The NMC players had a reduced LLI rate compared with control players (IRR: 0.78 (95% CI 0.56 to 1.08), p=0.14.) The knee IIR was also reduced for NMC compared with control players (IRR: 0.50 (95% CI 0.24 to 1.05), p=0.07).

Conclusions These intention-to-treat results indicate that positive outcomes can be achieved from targeted training programmes for reducing knee and LLI injury rates in men's community sport. While not statistically significant, reducing the knee injury rate by 50% and the LLI rate by 22% is still a clinically important outcome. Further injury reductions could be achieved with improved training attendance and participation in the programme.

INTRODUCTION

Team-based exercise training programmes have become a popular method for delivering injury prevention at the club level in many sports. Until recently, evaluation of the benefits of such programmes has largely been undertaken in efficacy studies involving highly controlled or laboratory-based settings, thereby providing limited knowledge of real-world benefits.[1] Since the gap in research demonstrating the effectiveness of these programmes was recognised, there has been an increase in the number of investigations directly in the non-elite, community sport setting.[2] Recent systematic reviews summarising the effectiveness of training programmes for reducing injuries in team sport have identified varying outcomes for injury reduction.[3–6] The variation is attributed to a range of factors, including participant age and sex, level of competition, the type of components included in the programme and compliance with the programme. As such, specific investigations towards understanding the effectiveness of injury prevention training programmes for different sports settings is now required.

Australian football (AF) is one of the most popular team sports in Australia. At the community sport level, AF is played by all age groups, men and women. Adult male participants (generally between 18 years and 30 years old) commonly play in a weekend game, with training sessions once or twice weekly over 5–6 months of the year. The game is played at a fast pace, with players subject to continuous running, bursts of sprinting, sudden changes of direction, frequent jumping/landing and heavy physical contact. These characteristic movements of AF also present players with a high risk of injury.[7 8] Although the collection and quality of injury data in community AF is limited,[9] the burden of AF injury is large, it being ranked one of the highest of all team sports leading to hospital treated injury.[10] The lower limb is the most common body region injured in AF with the knee consistently reported as one of the most frequently injured body parts.[9–11] These injuries have high personal costs, leading to reduced or ceased participation, long-term degenerative joint damage and ongoing pain.[12–14] Interventions aimed at preventing all lower limb injuries (LLIs) are needed to support the long-term health and well-being of players and enable promotion of the positive health benefits gained from participation.

The Preventing Australian Football Injuries through eXercise (PAFIX) study was a clustered randomised controlled trial (cRCT) in community AF aimed at reducing the number of LLIs, particularly knee injuries.[15] Players from clubs assigned to the intervention arm undertook a programme of progressive, targeted exercises as part of their regular training sessions (a neuromuscular control (NMC) programme), beginning in the preseason and continuing throughout the competition-season.

The second group (control) of clubs/players was provided with a sham exercise programme that replicated common training practices in community AF.

This paper presents the intention-to-treat (ITT) analysis of the cRCT results in relation to whether the training programme led to a reduction in the rate of knee injuries or LLIs in games.

METHODS

This study was designed according to the CONSORT statement (refer to online supplementary appendix 1).[16] The study rationale, design and full protocol have been previously published.[15] The specific content and delivery of the trialled exercise training programme content have also been published.[17] Minor amendments to the original study protocol[15] were needed to adjust for procedural challenges that were encountered when implementing the trial. These amendments, structured around the CONSORT statement components,[16] are outlined in online supplementary appendix 2 and all published and procedural documents are available online (http://www.pafixproject.wordpress.com).

Inclusion and exclusion criteria

Community male AF clubs from two Australian states participated in the PAFIX trial over an 8-week preseason period and an 18-week playing season (26 weeks total), in 2007 or 2008. Eighteen clubs (nine in 2007 and nine in 2008) were included, resulting in 2017 players assessed for inclusion eligibility. Figure 1 shows the allocation of players to trial arms and the numbers of players involved in the final trial and its analysis.

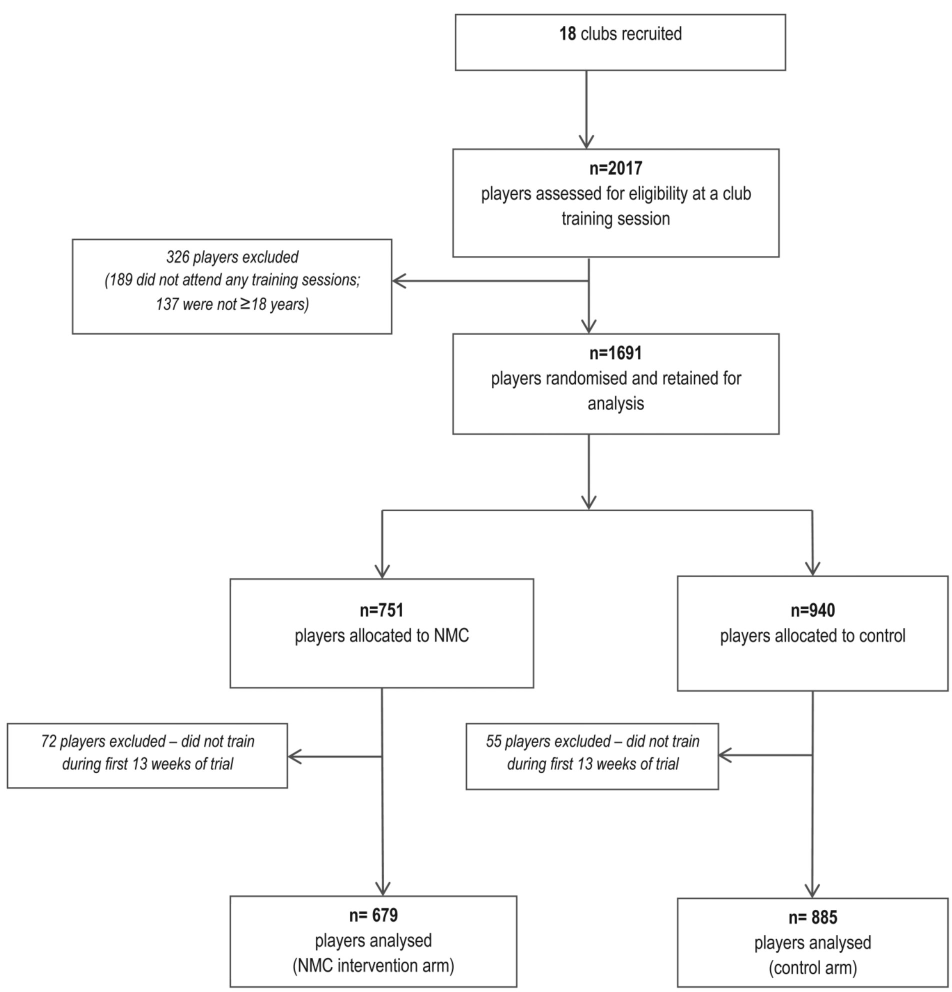
Full details of the inclusion and exclusion criteria are presented in online supplementary appendix 2. In short, players were included if they were registered to play for one of the participating teams, were at least 18 years of age and attended at least one training session in the first 13 weeks of the programme. Players from either group who did not train in the first 13 weeks (the point of transition from early season to mid-season) were excluded from analyses as they had not been exposed to a sufficient degree of the intervention; this was determined to be a reasonable failure-to-start exclusion that still met the criteria of an ITT analysis.[18]

The total number of players recruited into PAFIX was 1691. Of these, 751 were allocated to the NMC group with 679 retained for analysis (ie, met all inclusion criteria) and 940 players were allocated to the control group, from which 885 were retained. The total number of players included for analysis was 1564 (figure 1).

Intervention

Players from the NMC and control groups participated in a set of training exercises as part of their regular training programme twice per week.[17] The researchers trained team-based primary data collectors (PDCs) to deliver the prescribed exercises to the participating players. The NMC group received a programme of evidence-based neuromuscular and biomechanical exercises specifically targeted at reducing LLI, while the control group was provided with a 'sham' programme of exercises similar to those regularly undertaken at training.[17] Neither the players, clubs

Figure 1 Allocation of players to interventions in the PAFIX trial. Non-attendance at training sessions meant no exposure at all to any of the trial conditions so players were removed. NMC, neuromuscular control; PAFIX, Preventing Australian Football Injuries through eXercise.



nor PDCs were aware of what programme those in the other study condition received.

Data collection and coding

Each player participated over a 26-week period in 2007 or 2008. In this time, the PDC recorded the number of training sessions attended, the number of games played, the number of game hours played and the number of injuries sustained. An injury was defined as something that caused a player to seek medical attention (on or off the field) or to leave the field of play. Injury details were recorded by the PDC from observation and later confirmed with the player and medical staff where available. The injury definition and data collection procedures have been described elsewhere and shown to be reliable.[19] Training sessions in AF last for around 1.5 h with both programmes designed to take no more than the first 20 min of that time.

Consistent with the CONSORT statement,[16] an ITT analysis was performed. Injury incidence rates (IIRs) for all injury, all LLI and knee injury only were calculated for all players combined, as well as separately for the NMC and control groups. The estimated IIR was calculated as the number of injuries sustained divided by the exposure measure (game hours played.) For each IIR, a 95% CI was calculated assuming Poisson errors. The IIRs in the NMC (IIR-NMC) and control (IIR-CONTROL) groups were compared by calculating the IRR as IRR=IIR-NMC/IIR-CONTROL and the 95% CI as , where SE (ln(IRR)) is the IRR's SD.

To adjust for clustering effects (measured by the intraclass correlation (ICC)) associated with the sampling of teams within the clubs or states that may have influenced injury rates, a Generalised Estimating Equation (GEE) with Poisson distribution, log link function and an exchangeable autocorrelation structure was fitted to the injury rate data. The GEE assessed the effectiveness of the training programme in reducing the rate of injuries in games. Specifically, assessment of reduction in knee injuries sustained during games was undertaken as that was how the study was initially powered. Since the data were somewhat zero-inflated, a GEE with negative binomial distribution and exchangeable correlation structure was also fitted to account for overdispersion. As this obtained similar results to the first GEE model its results are not presented. The dependent variable was the player-specific IIR, with the trial arm included as an indicator factor and the football club effect nested within the state factor to account for clustering effects. Results for the GEE models are expressed as IRRs with 95% CIs and interpreted as the percentage change in IIR between the NMC and the control groups. To further confirm the modelling results, bootstrapping (which used repeated draws with replacement from the observed sample to create simulated samples) was undertaken and no significant difference to the main GEE results was found. Post hoc power calculations were based on Hayes' method.[20]

All data were originally double-entered into a database. Analyses were performed in statistical packages Stata (V.12.1) and R (R Core Team 2013, http://www.r-project.org, V.3.1.2). The statistical analyses were performed by author MA blinded to the intervention arm allocation.

RESULTS

Trial group characteristics

Each trial arm had nine clubs, with 38 NMC teams and 59 control teams, spread across the two geographical regions and years (table 1). It was not possible to fully assess baseline equivalence of the two groups in terms of player age or level of play because that information was only obtained from a (non-random) subset of players.

A total of 1032 injuries were recorded in 563 players, of which 773 injuries were sustained during games. The lower limb was the most frequent body region injured, accounting for 50% of injuries overall. The upper leg was the most frequently injured body part (table 2).

Injury incidence rate comparisons

As expected, there were no significant differences in the all-injury IIR between the NMC and control groups. The game IIR in the NMC group was smaller than that for the control group and the associated cluster-adjusted IRR of 0.92 for game injuries indicates an 8% non-significant reduction in all injures for the NMC group (table 3).

There was a significantly smaller IIR for LLI in the NMC group compared with the control group in games but this was not significant after cluster adjustment. Nonetheless, the cluster-adjusted IRR indicates a 22% reduction in the exposure-adjusted LLI IIR in the NMC group, compared with control players. The cluster-adjusted knee injury IRR was marginally not significant and indicated that knee injury rates were 50% lower in the NMC group, compared with control players.

For each injury category, the cluster adjustment led to smaller IIRs, in favour of the NMC intervention. However, CIs around them were larger, justifying the need for cluster adjustment. The observed overall rate of injuries, and the proportion of injuries that were to the knee, were both lower than what was used to justify the sample size calculations in the initial study protocol. For this reason, table 3 also includes post hoc power calculation for each of the cluster-adjusted IRRs.

DISCUSSION

This is the first study to report the effect of a targeted exercise programme on reducing injuries in game-related adult, male, community AF players. A lower, but not statistically significant, rate of knee injury and LLI overall was observed in players allocated to a specific programme of NMC training exercises compared with those allocated to a standard-practice sham exercise programme. Players who undertook the NMC programme had a 22% reduction in LLI rates and a 50% reduction in knee injury rates, when adjusted for exposure and clustering. These are important and highly clinically relevant outcomes given the frequency and associated costs of LLI arising from AF games, and the priority needs for prevention.[9] With growing evidence

Table 1 Number of clubs, teams and players allocated to study arms in the PAFIX clustered randomised controlled trial

	Intervention arm (neuromuscular control programme)	Control arm (sham programme)
Number of clubs	9	9
Number of teams	38	59
Number of teams by grade*		
Seniors	27	33
Reserves/Colts	11	26
Number of players	679	885

*Grade refers to the level of competitive play. 'Seniors' being a better standard of playing competition and 'Reserves/Colts' being a lower level standard. In Reserves/Colts, players tend to be slightly younger than players in Seniors teams. (Colts is an under 19 years competition in one region—but only those 18+ years are included in this trial, as per the protocol inclusion criteria).
PAFIX, Preventing Australian Football Injuries through Exercise.

Table 2 Proportion of game injuries by body region in players in the PAFIX clustered randomised controlled trial by study arm

Proportion of injuries by body region*	Study arm: All players n=773 injuries	NMC arm n=335 injuries	Control arm n=438 injuries
Lower limb total†	50.2	46.3	53.2
Upper leg	17.2	15.8	23.9
Knee	12.0	9.6	13.9
Lower leg	8.2	4.8	10.7
Ankle/foot/toes	12.8	16.1	10.3
Head/neck total†	17.9	23.3	13.7
Head and neck	7.1	8.7	5.9
Face/teeth/mouth	10.7	14.6	7.8
Upper limb total†	17.5	14.0	20.1
Shoulder/upper arm/elbow/lower arm	9.7	9.6	9.8
Hand/finger	7.8	4.5	10.3
Trunk total†	14.2	15.8	13.0
Trunk/abdomen/chest/back/glutes	8.9	9.9	8.2
Groin/Hip	5.3	6.0	4.8
Other	0.3	0.6	0.0

*Proportion of total game injuries for all players or by study arm.
†May differ from grouped totals presented due to rounding.
NMC, neuromuscular control; PAFIX, Preventing Australian Football Injuries through Exercise.

of the effectiveness of targeted exercise training programmes for injury prevention in other sports, this study provides the first support for such programmes in men's community AF.

The NMC programme was associated with improved LLI and knee injury rates. There was no significant difference in the all-injury rate across the two trial arms. This was to be expected as the exercise components and the PAFIX trial were specifically designed to address knee injury rather than all types of injury.[15] Since the PAFIX trial was first designed, it has become apparent that the same intervention exercise programme components could potentially reduce the risk of all LLIs, not just knee injuries.[3] For this reason, this paper considers the rate reductions in both groups of injury types.

The injury patterns reported in this study are generally consistent with those reported in previous studies of men's AF with the most frequent injured body parts being the upper leg/thigh and knee.[9 10] However, the proportion of all injuries to the knee was lower than that expected when the study sample size calculations were made (12% of all observed injuries, compared with the anticipated 33%). Post hoc power calculations indicate that the study was underpowered for all comparisons, but least so for the comparison of knee injury rates. Nonetheless, the observed reductions in knee injuries are highly significant from a clinical sports medicine point of view and have important implications for the design of future exercise training programmes in AF.

A number of features of injury prevention programmes influence injury outcomes and these can vary according to the participants of the study (eg, sex, age, level of play).[21 22] Most previous trials of the benefits of injury prevention exercise programmes in sport have been undertaken in female youth participating in soccer,[23 24] with just a few focused on adult male participants at a community (non-elite) level.[6 22] It is important to establish effectiveness in specific participant populations such as men as they comprise the majority of participants in many sports and certainly in AF. The current study adds new evidence about the effectiveness of injury prevention programmes in male community sports participants.

It is important for players to be compliant with prevention programmes for them to reduce injury rates.[25 26] Given that many players in PAFIX did not train regularly and most did not attend the two weekly sessions intended as part of the programme,[27] the ITT assessment of reduction in LLI rates in games is likely to have underestimated the true effect of the NMC programme. It is possible that a stronger intervention effect might have been identified if we had employed a per-protocol analysis[28] and this will be of interest in future work. While the frequency of exposure to the training programme could be quantified,[27] the quality of the actual exercise performance and programme fidelity were not formally measured. Ideally, frequency and quality of training should be captured, and linked to the injury outcomes, to provide stronger evidence of a connection between players who train, those who train well and players who do or do not get injured.[29]

Injury prevention programmes should have specific components or exercises that effectively target LLI, including knee

Table 3 Comparison of game related injury rates in the NMC intervention and sham (control) PAFIX trial groups

	Number of injuries	Number of hours spent in games	IIR per 1000 game hours (95% confidence limits)*	IRR (95% confidence limits) unadjusted for clustering effects	Intraclass correlation	Cluster-adjusted IRR (95% confidence limits)	Post hoc power for the cluster-adjusted IRR
All injuries							
NMC	335	12 790	26.2 (23.5, 29.2)	0.93 (0.81, 1.07) p=0.31	0.0117	0.92 (0.68, 1.23) p=0.57	9%
Control	438	15 537	28.2 (25.6, 31.0)				
All	773	28 327	27.3 (25.4, 29.3)				
Lower limb (knee, ankle, lower leg and thigh)							
NMC	151	12 790	11.8 (10.0, 13.8)	0.80 (0.65, 0.99) p=0.038	0.0007	0.78 (0.56, 1.08) p=0.14	45%
Control	228	15 537	14.7 (12.8, 16.7)				
All	379	28 327	13.4 (12.1, 14.8)				
Knee							
NMC	32	12 790	2.5 (1.7, 3.5)	0.65 (0.42, 0.99) p=0.046	0.0132	0.50 (0.24, 1.05) p=0.07	60%
Control	60	15 537	3.9 (2.9, 5.0)				
All	92	28 327	3.2 (2.6, 4.0)				

IRR, injury incidence rate; NMC, neuromuscular control; PAFIX, Preventing Australian Football Injuries through Exercise.

injuries, commonly seen in the sport.[22] Our NMC programme was designed based on detailed knowledge of the LLIs sustained in men in AF,[8 9 15] mechanisms for some of these LLIs (eg, anterior cruciate ligament injuries (ACL)[30–35]), and training measures that successfully addressed the mechanisms in laboratory based RCTs.[36–38] The intervention design also borrowed from previous studies that have been shown to be effective in preventing knee injuries specifically and LLIs in general.[39–41] As a result, the specific components of the programme were well targeted for the target population and could be readily adopted in community AF training sessions.[17 24] The developed NMC programme also has the potential to be transferable to other sports requiring change of direction, balance and landing tasks as skills to reduce injury risk.[21 39–41]

In addition to high reliability and completeness of data collection,[19] this cRCT has a number of other strengths. The group randomisation covered multiple clubs in different geographical locations that are representative of players in community AF. Injury rates are known to vary at different times of the season so data were collected over the entire preseason and playing season. Community AF players often join or leave a club at any stage so our criteria allowed inclusion up to 13 weeks, covering the preseason and start of the competition season, to enable time for players to be included in the trial, whether it was the NMC or the control arm. Injury rates were calculated on a per exposure basis, thereby accounting for players who were not present at every game or training session and, as such, did not contribute to the group of players at risk of injury. Allocation to the NMC and the control trial arms was blinded to PDCs, players, data coders and data analysts. This means that the PAFIX cRCT was as close as possible to a true double-blind trial, which is seldom reported in sports injury prevention studies. Finally, this study has adopted a very high standard of methodological reporting and analysis, which demonstrates the need to cluster-adjust results and report post hoc power calculations.

A limitation of this study is that the preseason baseline survey, aimed at collecting player characteristic information (eg, playing history, level of play, age and previous injury history), was only administered to, and completed by, around 50% of players. This was the only time where date of birth was recorded, so players' were excluded from the analysis when their age could not be confirmed. Likewise, comparison of pre-existing injuries was available only for the same, non-random subset of players. Although there is a lack of baseline data concerning the players' general health and injury history, the wide sampling of players from 18 teams in two different states means that the included players are likely to be an accurate representation of AF players in community leagues across Australia.

In conclusion, this ITT analysis indicates that clinically relevant reduced knee injury and LLI rates can be achieved through targeted exercise training programmes in men's community AF. The results should be considered alongside a range of additional issues including player compliance with the programme, since the preventive effect of the current programme was probably affected by low rates of programme reach and adoption.[27] However, this study adds value to the growing evidence in support of targeted exercise training programmes for injury reductions in community level sport.

What is already known on this subject

- Australian football players have a high risk of injury, particularly to the lower limb, and preventing these injuries is important for players' participation and long-term health.
- The primary types of lower limb injuries sustained by Australian football players have been established and the mechanisms of these lower limb injuries, particularly for the knee, have been ascertained.
- Exercise-based injury prevention programmes are a potentially useful way of delivering injury prevention benefits to sports participants although investigations of their real-world effectiveness are lacking.

What this study adds

- This is the first study to report on the effectiveness of any injury prevention programme in community level Australian football for male players.
- Robust information on the rate of injuries in Australian football games and a demonstration of the importance of appropriate cluster adjustment has been presented.
- The rate of knee injuries and other lower limb injuries in Australian football games can be lowered by employing a specific programme of neuromuscular training exercises into regular training sessions.

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ImPACT head injury prevention programme

ImPACT is a model for concussion management that works with New York schools' insurance companies to support a comprehensive head injury prevention programme. The programme helps manage sports injuries and trains staff to recognise, respond to and prevent concussions. Comment: the role of insurance companies in prevention should not be overlooked.