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ORIGINAL ARTICLE

Structured neuromuscular warm-up for injury prevention in young elite football players☆

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KEYWORDS
Warm-up;
Prevention;
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Abstract
Objective: To gather evidence about the outcomes of structured neuromuscular warm-up programs without additional equipment, as prevention of non-contact injuries in young professional soccer players.
Materials and methods: A literature search was conducted during March and April 2013 (PubMed, Cochrane Library, The American Journal of Sports Medicine, The British Journal of Sports Medicine and the search engine Trip Database).
Results: After applying the inclusion and exclusion criteria, a total of 6 studies were obtained (3 clinical trials, one cohort study and 2 systematic reviews). ''FIFA 11+'' program showed a reduction of injuries of between 33% and 57%. These included 52% in knee, 22% in ankle, 40% in medial tibial stress syndrome, 50% in posterior thigh, and 21% in the anterior, and 12% in the groin area. ''FIFA 11'' program showed a 58% reduction in ankle sprains and 27% in anterior cruciate ligament (ACL) injuries. Other specific programs to prevent ACL injuries reduced them by 74% and ''Knäkontroll, SISU Idrottsböcker©'' by 64%. ''HarmoKnee'' program reduced knee injuries by 78%.
Discussion: Several methodological weaknesses were observed, but it seems that there is a trend toward a warm-up that contains basic stretching, strengthening and balance exercises, which could prevent injuries when those were regularly performed for more than three months.
Conclusions: ''FIFA 11+'' program might be a good preventive measure of injuries by implementing its program of structured warm-up. In any event new, better designed, studies are needed to assess this evidence.

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PALABRAS CLAVE
Calentamiento;
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Calentamiento neuromuscular estructurado como prevención de lesiones en futbolistas profesionales jóvenes

Resumen
Objetivo: Recopilar evidencia sobre los resultados de los programas de calentamiento neuromuscular estructurados sin equipo adicional como método de prevención de lesiones de no contacto en futbolistas jóvenes profesionales.
Material y métodos: Se realizó durante marzo y abril de 2013 una búsqueda de literatura (PubMed, Biblioteca Cochrane Plus, The American Journal Sports of Medicine, The British Journal of Sports Medicine y el motor de búsqueda Trip Database).
Resultados: Se obtuvieron, tras aplicar los criterios de inclusión y exclusión, un total de 6 estudios (3 ensayos clínicos, un estudio de cohortes y 2 revisiones sistemáticas). El programa «FIFA 11+» mostró una reducción de lesiones en un 33-57%, desgranándose en un 52% en rodilla, 22% en tobillo, 40% en síndrome de estrés medial tibial, 50% en muslo posterior y 21% en el anterior, y 12% en la zona inguinal. El programa «FIFA 11» mostró una reducción del 58% en esguinces de tobillo y del 27% en lesiones de LCA. Otros programas específicos de prevención de lesiones de LCA las redujeron en un 74% y «Knäkontroll, SISU Idrottsböcker©» en un 64%. El programa «HarmoKnee» redujo lesiones de rodilla en un 78%.
Discusión: Se observaron varias debilidades metodológicas, pero parece que existe la tendencia a que un calentamiento que contenga como base estiramientos, fortalecimiento y ejercicios de equilibrio, realizado durante más de tres meses y de manera regular podría prevenir lesiones.
Conclusiones: El programa «FIFA 11+» podría ser una buena medida preventiva de lesiones aplicando su programa de calentamiento estructurado. A pesar de ello, nuevos estudios mejor diseñados se requieren para poder valorar bien esta evidencia.

Introduction

Football (or soccer) is the most popular sport in the world. In recent decades, its popularity has increased among males and females, to the point that there are about 300 million registered players, referees and technical staff, 40 million of whom are female players.[1] At present, people start practicing sports at a younger age, thus forcing the rate of learning and the development of their biological condition. Along with the associated physical benefits, this level of demand at such early stages entails an increase of the associated risks and, therefore, the lesions derived thereof.

Sport in general is the leading cause of injury among adolescents.[2,3] Most lesions in football occur in the lower limbs, especially the knee and ankle. Majewski et al.[4] studied 17,397 patients with 19,530 sports injuries over a period of 10 years and observed that the sport which caused most lesions was football, with 35%. On average, an elite footballer suffers between 1.5 and 7.6 lesions for every 1000 h of training and 12–35 lesions for every 1000 h of competitive play.[5,6]

The main risk factors for injury are the level of play (higher risk among professionals than amateurs), the exercise load and the method of training.[6] There are only very few small or non-randomized studies on the prevention of lesions. Among the most recent are those which implement the so-called ''FIFA 11+''[1] of the *Fédération Internationale de Football Association* (FIFA), a full warm-up program to reduce injuries among footballers aged over 14 years.

The objective of this study was to carry out a literature review to gather information on the results of structured neuromuscular warm-up programs with no additional equipment as a method to prevent non-contact injuries among young elite footballers.

Materials and methods

Between March and April 2013 we conducted a literature search in various computerized databases (*PubMed*, *Cochrane Plus*, *The American Journal Sports of Medicine*, *The British Journal of Sports Medicine* and the search engine *Trip Database*) using the following keywords: prevention, warm-up, injury, football and young. These words were expanded to obtain the maximum possible relevant literature: (1) *prevention AND/OR Strategies AND/OR FIFA (primary + prevention)*; (2) *warm-up OR warm-up training OR neuromuscular warm-up*; (3) *injuries (wounds AND/OR injuries. Football + Injur$. Soccer + Injur$)*; (4) *football OR soccer (AND elite OR professional)*; and (5) *young OR adolescent OR youth*.

The keyword search returned 107 results. We assessed the abstracts and titles of all the studies and selected articles according to the type of study, applying inclusion and exclusion criteria according to the type of participants without taking into account gender, depending on the interventions conducted and the results measured. The search and selection phases, along with the criteria, are detailed in Fig. 1.

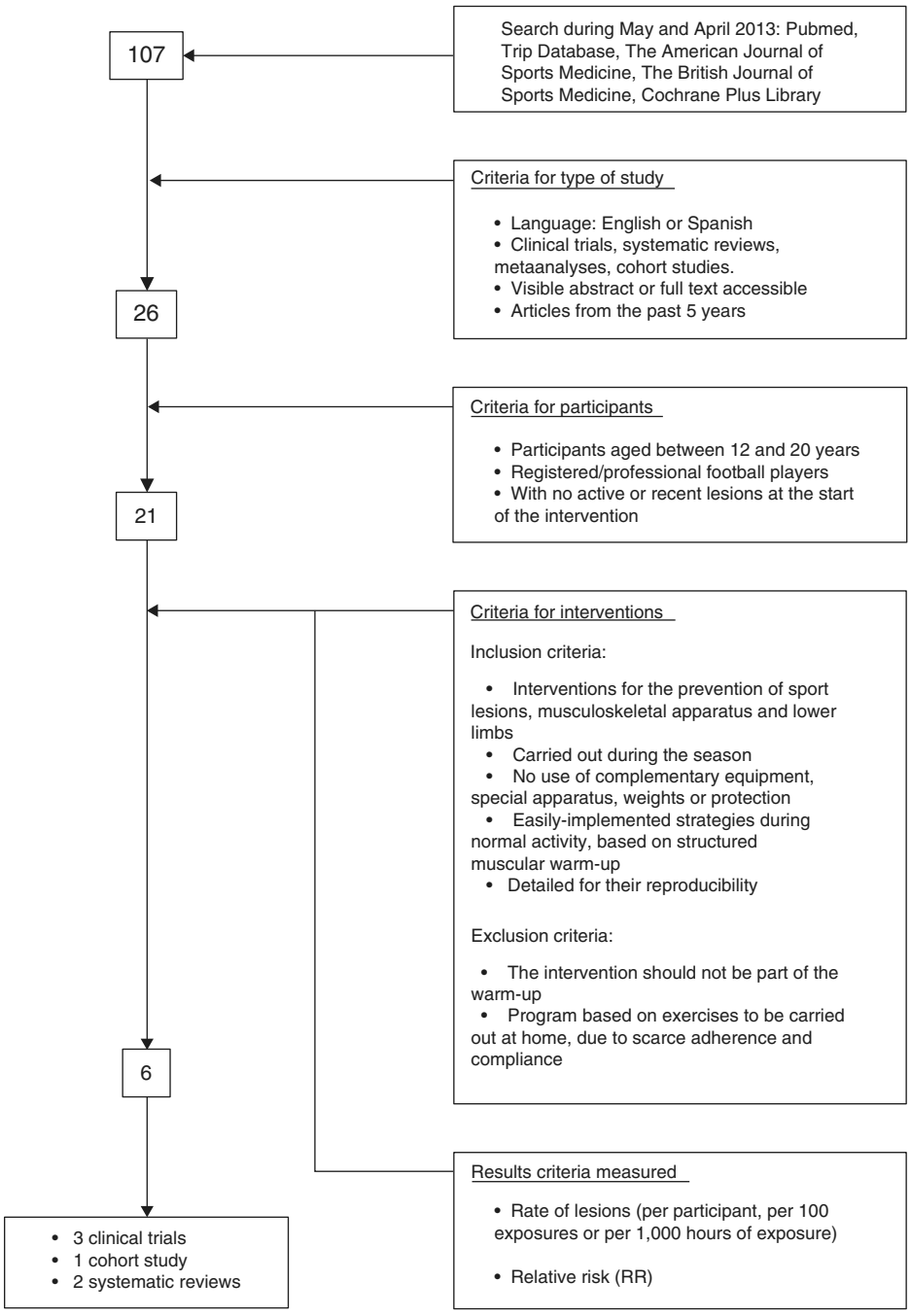

Figure 1 Summary of the search and selections phases.

Results

Two of the authors independently assessed the results of the search, their methodological quality and extracted the relevant data. The relative risk (RR) and 95% confidence intervals (95% CIs) were calculated for dichotomous variables and informed for grouped and individual data.

We obtained 6 studies which fulfilled the inclusion criteria: 3 randomized clinical trials,[7–9] 1 cohort study[10] and 2 systematic reviews.[11,12] The 3 clinical trials and the cohort study are presented in Table 1, along with a summary of the relevant aspects of each. The reviews are presented in Tables 2 and 3.

Despite dating back to 2007, the systematic review conducted by Abernethy and Bleakley[11] was included due to its high quality and importance. This work was a review of the different interventions available to date to prevent lesions among adolescent athletes, divided into 3 main groups: (1) related to protection equipment, (2) related to preseason conditioning and (3) strategies during the season (divided into proprioceptive training and structured warm-up). This general review included various sports, but the study

Table 1 Randomized clinical trials and prospective cohort study.

Author (year)	Participants	Groups/intervention	Variables	Comments
Hagglund et al.[7] (2009)	516 Swedish teams. Female players between 13 and 17 years	260 IG and 256 CG. Assessment of the warm-up program *Knäkontroll, SISU Idrottsböcker*© over a season	Primary: ACL lesion Secondary: knee lesion (except contusion)	Digitalized data collection. No radiographic confirmation
Walden et al.[8] (2012)	230 Swedish teams. Female players between 12 and 17 years	121 IG (2497 players) and 109 CG (2085 players). Assessment of the warm-up program *Knäkontroll, SISU Idrottsböcker*© over a season	Primary: ACL lesion Secondary: knee lesion (except contusion)	Collection of data through coaches. No radiographic confirmation
Steffen et al.[9] (2013)	31 Canadian teams. Female players between 13 and 18 years	3 groups (FIFA 11+ with physiotherapist, FIFA 11+ without physiotherapist, and control), over 4 months	Risk of lesion and adherence to the program	Digitalized data collection
Soligard et al.[10] (2010)	65 Norwegian teams. 1055 female players between 13 and 17 years and 65 coaches	Retrospective survey on FIFA 11+	Risk of lesion and adherence to the program	Data based on RCT by Soligard et al.[13] (2008)

ACL, anterior cruciate ligament; CG, control group; IG, intervention group; RCT, randomized clinical trial.

specified the different types in each of the articles reviewed and the intervention applied, so it was possible to select those referring to football and structured neuromuscular warm-up.

After applying the inclusion and exclusion criteria to the systematic review we observed that none fulfilled the criteria of having been published less than 5 years ago. Nevertheless, we decided to include them in this review in order to provide context and compare their results with those from more recent studies. We obtained 2 studies which fulfilled the requirements, which dealt with structured neuromuscular warm-up (Table 2).

After applying the inclusion criteria to the systematic review by Herman et al.,[12] we selected 6 studies, all conducted on female populations, which are summarized in Table 3.

The results of the statistical analysis, which are summarized in Fig. 2, showed that the ''FIFA 11+'' program for the prevention of lower limb (LL) lesions enabled a reduction of the RR of suffering LL lesions in the 3 studies selected.

Table 2 Studies selected in the review by Abernethy et al.[11]

Author (year), type of study	Participants	Groups/intervention	Variables	Comments
Junge et al.[14] (2002), prospective cohort study	14 teams in Switzerland. 194 players aged between 14 and 19 years	(A) IG: PPLEEII. (B) CG: training sessions and games as usual	Incidence and severity of lesions in LL	Data collection by physician
Mandelbaum et al.[18] (2005), prospective cohort study	1885 female players aged between 14 and 18 years in the US	(A) IG: PPLLCA1. (B) CG: training sessions and games as usual. During 2 years (2000 and 2001)	Incidence and severity of lesions in ACL	Collection of data through coaches. Radiographic confirmation

ACL, anterior cruciate ligament; CG, control group; IG, intervention group; LL, lower limbs; PPLEEII, program for the prevention of lesions in the lower limbs; PPLLCA1, program for the prevention of lesions in the ACL 1.

Table 3 Studies selected in the review by Herman et al.[12]

Author (year), type of study	Participants	Groups/intervention	Variables
Soligard et al.[13] (2008), RCT	125 Norwegian teams. 1892 female players between 13 and 17 years	1055 IG and 837 CG. Assessment of the warm-up program FIFA 11+	Lesions in LL
Pfeiffer et al.[20] (2006), NRCT	1439 female players between 14 and 18 years	Prevention program (PPLLCA2). For 2 seasons	Lesions in ACL
Gilchrist et al.[17] (2008), RCT	1435 female players with a mean age of 19.9 years	Prevention program (PPLR1)	Lesions in ACL and knee
Kiani et al.[16] (2010), NRCT	1506 female players between 13 and 19 years	Assessment of the warm-up program *HarmoKnee*	Lesions in knee
LaBella et al.[15] (2011), RCT	1558 female players with a mean age of 16 years	Prevention program (PPLR2)	Lesions in LL
Steffen et al.[19] (2008), RCT	2020 female players between 13 and 17 years	Assessment of the warm-up program FIFA 11	Lesions in LL

CG, control group; IG, intervention group; LL, lower limbs; PPLLCA, program for the prevention of lesions in the anterior cruciate ligament; PPLR, program for the prevention of lesions in the knee; NRCT, non-randomized clinical trial; RCT, randomized clinical trial.

The results in the first study[13] showed a RR of 0.67 (95% CI 0.54–0.84), the second study[9] showed a RR of 0.43 (95% CI 0.19–1.00) and the third study[10] showed a RR of 0.65 (95% CI 0.46–0.91). Studies assessing other programs based on structured warm-ups also demonstrated a reduction of the risk of lesions. The prevention program for lower limb lesions, referred to in this review as ''PPLEEII'',[14] showed a RR of 0.76 (95% CI 0.58–0.93) and the prevention program

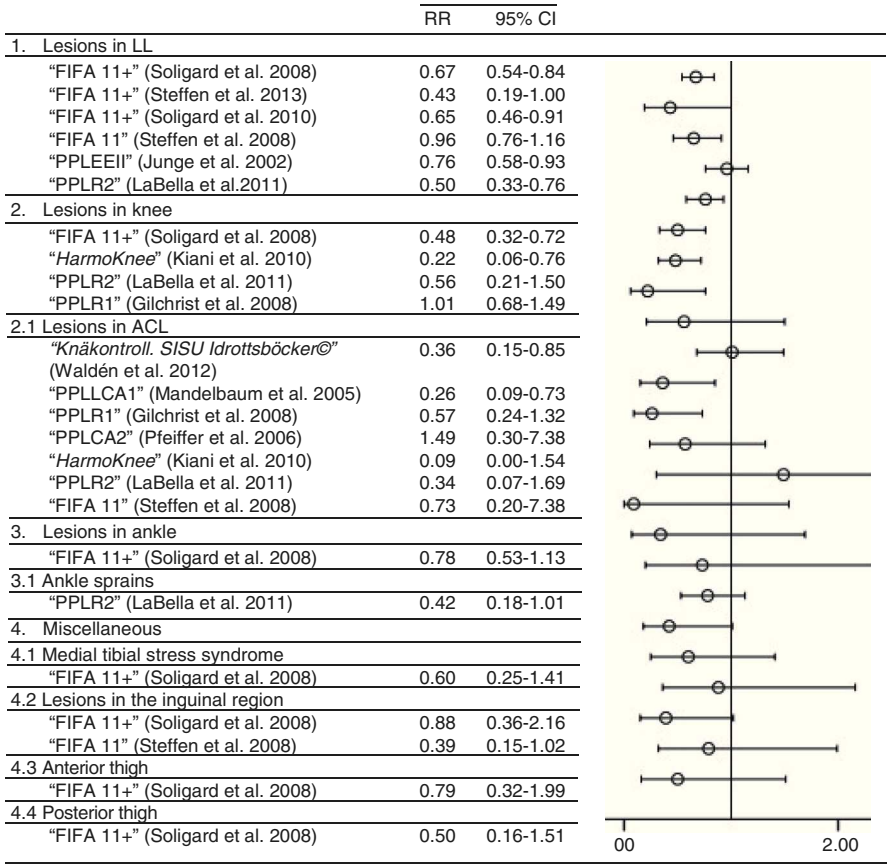

Figure 2 Summary of results.

for knee lesions, referred to in this review as ''PPLR2'',[15] showed a RR of 0.50 (95% CI 0.33–0.76).

Studies assessing knee injuries in general observed that the ''FIFA 11+''[13] program significantly reduced lesions, with a RR of 0.48 (95% CI 0.32–0.72). The prevention program ''*HarmoKnee*''[16] proved its effectiveness to reduce knee lesions in general, with a RR of 0.22 (95% CI 0.06–0.76). The program ''PPLR2''[15] also showed this result, albeit without reaching significance, with a RR of 0.56 (95% CI 0.21–1.50). The program for prevention of knee lesions referred to as ''PPLR1''[17] in this review did not prove its effectiveness.

Studies assessing lesions of the anterior cruciate ligament (ACL) concluded that the warm-up program ''*Knäkontroll, SISU Idrottsböcker*©''[8] achieved a reduction of lesions with a RR of 0.36 (95% CI 0.15–0.85), and the program for the prevention of anterior cruciate ligament lesions referred to as ''PPLLCA1''[18] in this review obtained a RR of 0.26 (95% CI 0.09–0.73). Another 3 warm-up programs showed a possible effectiveness to prevent ACL lesions: ''PPLR1''[17] with a RR of 0.57 (95% CI 0.24–1.32), ''PPLR2''[15] with a RR of 0.34 (95% CI 0.07–1.69) and ''FIFA 11''[19] with a RR of 0.73 (95% CI 0.20–2.73). The program for prevention of anterior cruciate ligament lesions ''PPLLCA2''[20] did not prove to be effective.

''FIFA 11+''[13] proved to be effective to reduce ankle lesions with a RR of 0.78 (95% CI 0.53–1.13), with no significant difference compared to ''FIFA 11''.[19] Another warm-up program[15] may also be effective to prevent ankle sprains with a RR of 0.42 (95% CI 0.18–1.01).

''FIFA 11''[19] showed a possible reduction of lesions in the inguinal region with a RR of 0.39 (95% CI 0.15–1.02). ''FIFA 11+''[13] could be effective to prevent medial tibial stress syndrome with a RR of 0.60 (95% CI 0.25–1.41), as well as lesions in the inguinal region with a RR of 0.88 (95% CI 0.36–2.16) and the thigh, both anterior and posterior with a RR of 0.79 (95% CI 0.32–1.99) and a RR of 0.50 (95% CI 0.16–1.51), respectively.

Discussion

This review investigated the effectiveness of structured neuromuscular warm-up strategies to prevent lesions among football players. Based on the data obtained, the strategies seem to be effective. Specifically, ''FIFA 11+'' may reduce lesions in the LL,[9,10,13] as may ''PPLEEII''[14] and ''PPLR2''.[15] The programs ''FIFA 11+''[13] and ''*HarmoKnee*''[16] seem to prevent knee lesions in general. The programs ''*Knäkontroll, SISU Idrottsböcker*©'' and ''PPLLCA1'' proved to be effective for ACL lesions in particular.[8,18] The programs ''FIFA 11'',[19] ''PPLR1''[17] and ''PPLR2''[15] proved a possible effectiveness but further studies are necessary to establish if their effect is significant. Lastly, ''FIFA 11+'' may be effective to prevent ankle lesions,[13] and ''PPLR2'' to prevent sprains.[15] In spite of this, the results of both programs were not significant.

The program is worth highlighting because it is accessible to everyone, free, simple to use and reproduce. There have also been various studies which have proven its beneficial overall effect in the LL. ''FIFA 11+''[1] could be a good choice as a method to prevent injuries in female football teams. This program has been developed by an international group of experts, based on practical experience with various injury prevention programs for amateur players aged 14 and over. It is a full warm-up routine which replaces the usual warm-up before training sessions. It involves a total of 15 exercises which should be done in a specific order. It has a duration of about 20–25 min and 3 sections; the first involves 6 low-speed exercises combined with active stretching and controlled contact with a partner, the second part comprises 6 groups of exercises focusing on core and LL strength, balance and plyometrics/agility, each with 3 levels of increasing difficulty, and the third part involves 3 moderate/high speed running exercises, with movements and changes of directions.

The reviewed studies have several methodological weaknesses affecting their internal validity. On the one hand, the follow-up periods were not sufficiently long to enable an assessment of specific lesions. In addition, most studies were only carried out by a female population. Double-blind studies are recommended to improve the level of evidence, as well as homogenizing the method of reporting lesions and monitoring, as there are too many variants (self-assessment, gathered by the coach, by the researcher, remotely, ...), thus leading to an incorrect collection, loss of data, and possibly compliance with programs below 100%.

It is also necessary to determine the mechanisms of effectiveness of warm-up and to identify the reason why the number of lesions is reduced; whether it is the result of each individual component or the combination of exercises. No studies were found which compared 2 types of programs, and this would be another aspect to work on.

Despite the fact that some studies offered data on prevention of lesions in the LL in a detailed manner,[13] the truth is that there is insufficient evidence (except in the knee region) to determine which types of lesions should be the target of warm-up programs. In other words, we observed a clear reduction of lesions in general, but it would be necessary to specify each type of lesion, depending on the anatomical region.

In the line of this review, several methods of neuromuscular warm-up which do not require additional equipment offer various levels of effectiveness in the prevention of LL lesions. It is possible to identify certain basic principles to reduce lesions when a warm-up program is incorporated, including: (1) stretching, strengthening and balance exercises; (2) following it for over 3 months; and (3) completing it every training session.

Conclusions

It appears that a warm-up program which includes strength, plyometrics, balance and agility exercises provides a reduction of LL lesions. In spite of this, the results obtained must be assessed with caution, as the supporting evidence is scarce and new studies with a better design (double blind, among male populations, with long follow-up periods) and for each type of lesion would be necessary.

Level of evidence

Level of evidence I.

Ethical responsibilities

Protection of people and animals. The authors declare that this investigation did not require experiments on humans or animals.

Confidentiality of data. The authors declare that this work does not reflect any patient data.

Right to privacy and informed consent. The authors declare that this work does not reflect any patient data.

Conflict of interest

The authors have no conflict of interests to declare.

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