

A Mesh Meta-Analysis of the Effectiveness of Different Warm-Up Exercises to Prevent Knee Injuries in Young Child Soccer Players

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Abstract

Objective: A mesh Meta-analysis was used to evaluate the effectiveness of four warm-up exercises to prevent knee injuries in juvenile soccer players.

Method: They are a randomized controlled trial (RCT) on FIFA 11+ integrated warm-up, FIFA 11+ Kids integrated warm-up, and neuromuscular training (NMT) warm-up for the prevention of knee joint in juvenile soccer players by a computer search of CNKI, CBMdisc, WanFangdata, Pubmed, Web of science, and SPORTDiscus database. The search period was from the establishment of each database to February 2022. Two investigators screened the literature, extracted data, and assessed risk bias for the included studies according to the pre-defined inclusion and exclusion criteria, and finally analyzed the data using Stata 14.0 software and OpenBUGS software. **Results:** A total of 10 RCT studies with 17,143 subjects, spanning the age range of 7 to 19 years, were included. The results of the reticulated Meta-analysis showed that all three warm-up modalities were effective in reducing the incidence of knee injuries in junior soccer players compared to conventional warm-up, with the optimality in descending order of FIFA 11+ Kids comprehensive warm-up (SUCRA = 85.3), neuromuscular training warm-up (SUCRA = 66.7), and FIFA 11+ combined warm-up (SUCRA = 44). **Conclusion:** The FIFA 11+ Kids comprehensive warm-up is the most effective warm-up exercise for the prevention of knee injuries in junior and child soccer players, but the above findings need further validation due to the quantity and quality of the literature and the quality of the evidence.

Keywords

Adolescent Children, Soccer, Effectiveness, Knee Injury, Injury Prevention, Reticulated Meta-Analysis

1. Introduction

Soccer is one of the most played sports in the world, and the popularity of the sport continues to grow, especially among children and teenagers [1]. The sport has a potentially beneficial effect on the health of children and adolescents, however, due to the highly combative nature of soccer, participation in the sport can be accompanied by a large number of sports injuries, and Leppänen's research shows that the knee area is the most frequently injured in soccer players aged 9 - 14 [2]. Injuries to the knee area not only reduce a sportsperson's current and future opportunities to participate in sports but also result in significant medical and social costs [3] [4]. However, it is widely believed that the benefits of participation in soccer for the social development, leadership development, and overall physical and mental health of children and youth outweigh the risk of injury [5] [6]. Therefore, effective warm-up activities to avoid injuries are crucial for the development of soccer in children and youth.

At present, the warm-up activities for young children's soccer mainly include FIFA 11+ integrated warm-up, FIFA 11+ Kids integrated warm-up, neuromuscular training warm-up (NMT), and regular warm-up. FIFA 11+ integrated warm-up has been adopted by a large number of professional and amateur soccer players since it was launched by FIFA in 2006 and has an improvement effect in reducing the incidence of knee injuries [7] [8]. FIFA 11+ Kids Comprehensive Warm-up is an injury prevention exercise developed by the F-MARC International Expert Panel for children aged 7 - 13 years old, which can effectively reduce sports injuries and the social costs brought about by injuries [9] [10]. Neuromuscular warm-up programs are primarily a combination of multi-modal exercise activities, such as balance exercises, strength exercises, and core stability exercises, that are equally effective in reducing sports injuries and improving athletic performance. The effectiveness of these warm-up activities in preventing sports injuries has been demonstrated by numerous RCT studies and Meta-analyses, but the relative effectiveness of various warm-up activities in preventing knee injuries has yet to be verified. Therefore, this study used a reticulated Meta-analysis to indirectly compare a variety of warm-up activities to rank the relative effectiveness of different warm-up activities for preventing knee injuries in children and youth soccer players to provide a theoretical reference for training applications.

2. Method

2.1. Inclusion and Exclusion of Literature

2.1.1. Participants (P)

Children and youth soccer players.

2.1.2. Intervention (I)

The experimental groups were FIFA 11+ integrated warm-up, FIFA 11+ Kids integrated warm-up, and neuromuscular training warm-up. The specific warm-up exercises were as follows (Table 1).

Table 1. Specific description of each warm-up strategy.

Warm-up exercises	FIFA 11+ integrated warm-up	FIFA 11+ Kids integrated warm-up	neuromuscular training warm-up	Regular warm-up training
Summarizing description	FIFA 11+ is a structured, sport-based warm-up program for soccer players aged 14 and above. This warm-up program consists of three parts. The first part is jogging exercises, combined with active stretching and ball control exercises. The second part has six different sets of exercises, including strength, balance, and jumping exercises, each with three levels of increasing difficulty. The last part is a special exercise for sprint running combined with soccer sports techniques.	The FIFA11+ Kid comprehensive warm-up is an injury prevention exercise specifically developed by the F-MARC international panel of experts for children ages 7 - 13. This warm-up exercise is designed to improve coordination and balance, increase core and unilateral leg stability, and optimize drop technique. The warm-up consists of a total of 7 exercises that take approximately 15 - 20 minutes; the coach ensures that all athletes can perform each exercise correctly, divided into 5 levels, and all exercises should start at the first level of each movement and not move on to the next level until they are completed [11] [12] [13].	Each exercise of NMT warm-up lasts 15 - 25 min, and the main exercises include warm-up, muscle activation, balance training, strength training, and core stability training, which is a training method that emphasizes the use of proprioception to promote the coordination of muscle and joint power.	This includes aerobic exercises, dynamic stretching exercises, and soccer-specific exercises.

2.1.3. Comparative Factors (C)

Control group was one of the regular warm-ups, FIFA 11+ combined warm-ups, FIFA 11+ Kids comprehensive warm-up, and neuromuscular training warm-up.

2.1.4. Outcome Indicator (O)

Effectiveness in preventing knee injuries.

2.1.5. Study Design (S)

The included study designs were all randomized controlled trials (RCTs).

2.1.6. Exclusion Criteria

1) The full text could not be downloaded; 2) The literature was in a language other than Chinese or English; 3) The data were incomplete; 4) The study was conducted on college students.

2.2. Literature Search

Two researchers searched Chinese and foreign language databases according to a pre-defined search strategy, and the Chinese databases searched were: China National Knowledge Infrastructure, China Biomedical Database, and Wanfang Database. English database repositories for Web of Science, PubMed, SPORTDiscus. The search period was from the establishment of each database to February 2022; the Chinese search terms were: soccer, adolescent, juvenile, injury prevention, lower limb injury, sports injury, knee injury; the English search terms were:

soccer, adolescent, juvenile, sports injury, Injury Prevention, Knee injury. The references included in the study were also searched to ensure that the search was comprehensive and scientific.

2.3. Literature Screening and Data Extraction

Two researchers conducted literature screening and data extraction in strict accordance with the inclusion and exclusion criteria, respectively, and cross-checked after completion, and discussed and resolved any divergent literature and data, and in case of disputes, through third-party discussions, and contacted the authors through their email addresses for incomplete information, if possible, to ensure the integrity of the data. The process of literature screening was performed by reading the title and abstract to exclude literature that was incompatible with the study, and then by reading the full text to further identify the included studies. The main contents of the data extraction included: 1) authors' names and publication dates; 2) characteristics of the subject population: age and gender; 3) description of the intervention: intervention period, duration, intensity, and frequency; 4) main contents of the risk evaluation of biased chairs; and 5) evaluation results of effectiveness.

2.4. Evaluation of the Risk of Biased Chairs in the Literature

The risk of bias in the included studies was evaluated comprehensively by two researchers according to the Cochrane Handbook, and in case of disagreement between the two evaluations, an agreement was reached through discussion with a third author.

2.5. Statistical Analysis

Statistical analysis of the included data was performed using Stata 14.0 software, OpenBUGS. Since the outcome indicators were dichotomous variables, the effect size was evaluated using the ratio of ratios (OR) and 95% confidence intervals, and the effectiveness of each intervention was ranked for comparison using SUCRA values, with higher SCURA values indicating better effectiveness of the interventions and vice versa. Since this study was a comparison of each intervention with a conventional warm-up, and there was no closed structure, then no consistency test was required [14]. Published bias chairs are inspected using calibration funnel charts.

3. Results

3.1. Literature Search Process and Screening Results

According to the pre-defined search strategy, Chinese and foreign language databases were searched, and a total of 489 kinds of literature were retrieved, and 8 literature were retrieved through other means. According to the inclusion and exclusion criteria, the literature that was not relevant to this study was excluded in EndNote X9 software, and a total of 10 studies were finally included.

3.2. Basic Characteristics of the Included Studies

A total of 10 English-language publications were included, all of which were randomized controlled trials containing four types of warm-up: FIFA 11+ Kids integrated warm-up, neuromuscular training warm-up, FIFA 11+ integrated warm-up, and conventional warm-up, with a total of 17,143 subjects, spanning the age range of 7 - 19 years, mainly concentrated in Switzerland, the Netherlands, Germany, and the Czech Republic, and the United States; the intervention time was mostly concentrated in 15 - 25 min, the training frequency was mainly focused on 2 times per week, and the intervention period was 1.5 - 9 months; the main index was a knee injury. The specific characteristics are shown in **Table 2**.

3.3. Methodological Quality of the Included Studies

The quality of the included RCT studies was evaluated according to the Cochrane Handbook, and a total of six studies used the random number method or computer-automated randomized group generation for the grouping of experiments, which were not influenced by human intervention and evaluated as low risk; the blinding of the included studies was not described in detail, and other sources of bias could not be determined. The risk of bias for the included literature is shown in **Table 3**.

3.4. Evidence Network Diagram and Consistency Analysis of the Included Studies

The size of the dots in the evidence network diagram represents the number of samples for each intervention, and the thickness of the line connecting the two dots represents the number of studies for both interventions. Evidence network map for the effectiveness of knee injury prevention involve a total of 10 RCT studies, of which 3 RCT studies directly compare the FIFA 11+ Kids integrated warm-up with the conventional warm-up, containing 5859 subjects. There were three RCT studies with direct comparisons between FIFA 11+ integrated warm-up and conventional warm-up, containing 4328 subjects; four RCT studies with direct comparisons between neuromuscular training warm-up and conventional warm-up, containing 6956 subjects; there were no studies with direct comparisons between the three interventions, FIFA 11+ Kids integrated warm-up, FIFA 11+ integrated warm-up, and neuromuscular integrated warm-up, making no closed structure in the reticulation diagram between the four interventions and therefore no consistency test was performed (**Figure 1**).

3.5. Mesh Meta-Analysis Ranking

A total of 10 RCT studies reported knee injury indicators, containing 17,143 subjects, and the results of the reticulated Meta-analysis are shown in **Table 4** and **Table 5**. The results showed that the combined warm-up for FIFA 11+ Kids (OR = 2.45, 95% CI [1.11, 4.84]) and neuromuscular training warm-up (OR = 1.97, 95% CI [1.07, 3.86]) were both more effective than conventional warm-up

Table 2. Basic characteristics of the included studies.

Study/Year	Nationality	Age	Gender	Sample size		Intervention Cycle	Interventions		Intervention Time	Intervention Frequency	Conclusion Indicators
				Experimental group	Control group		Experimental group	Control group			
Zarei, Abbasi <i>et al.</i> 2020 [9]	Iran	T: 12.1 ± 1.8 C: 12.2 ± 1.7	Female	443	519	9	FIFA 11+ Kids	Regular warm-up	20	2	Knee Joint Injuries
Rössler, Verhagen <i>et al.</i> 2019 [10]	Switzerland, the Netherlands, the Germany, Czech Republic	7 - 12	Female, male	614	388	2	FIFA 11+ Kids	Regular warm-up	15	2	Knee Joint Injuries
Rössler, Junge <i>et al.</i> 2018 [15]	Switzerland, the Netherlands, the Germany, Czech Republic	7 - 13	Female, male	2066	1829	3	FIFA 11+ Kids	Regular warm-up	15 - 20	2	Knee Joint Injuries
Foss, Thomas <i>et al.</i> 2018 [16]	United States	14.0 ± 1.7	Male	74	68	3	NMT	Regular warm-up	20 - 25	3	Knee Joint Injuries
Waldén, Atroshi <i>et al.</i> 2012 [11]	Sweden	12 - 17	Male	2479	2085	6	NMT	Regular warm-up	15	2	Knee Joint Injuries
Emery and Meeuwisse 2010 [12]	Canada	13 - 18	Male	380	364	1.5	NMT	Regular warm-up	15 - 20	2	Knee Joint Injuries
Owoeye, Akinbo <i>et al.</i> 2014 [17]	Nigeria	14 - 19	Female	212	204	6	FIFA 11+	Regular warm-up	15 - 20	2	Knee Joint Injuries
Steffen, Myklebust <i>et al.</i> 2008 [18]	Norway	13 - 17	male	1073	947	8	FIFA 11+	Regular warm-up	15	2	Knee Joint Injuries
Soligard, Myklebust <i>et al.</i> 2008 [19]	Norway		Male	1055	837	8	FIFA 11+	Regular warm-up	20	2	Knee Joint Injuries
Kiani, Hellquist <i>et al.</i> 2010 [20]	Sweden	13 - 19	Male	777	729	9	NMT	Regular warm-up	20	1 - 2	Knee Joint Injuries

FIFA 11+ Kids: FIFA 11+ Kids comprehensive warm-up; NMT: neuromuscular training warm-up; FIFA 11+: FIFA 11+ comprehensive warm-up.

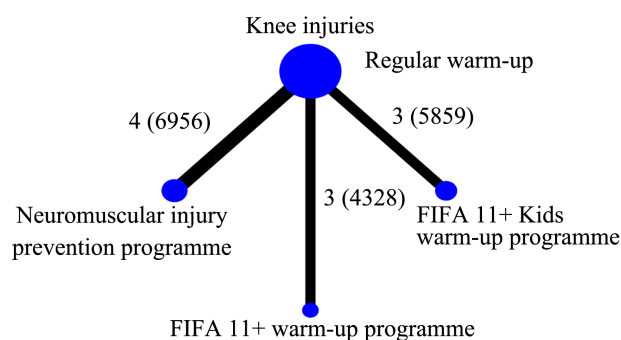


Figure 1. Evidence network diagram for the effectiveness of each intervention in preventing sports injuries.

Table 3. Risk of bias evaluation results of included studies.

Study/Year	Random method	Assign hidden	Blind method	The integrity of result data	Selective reporting of study results	Other bias Source
Zarei, Abbasi <i>et al.</i> 2020 [9]	Low Risk	Not clear	Not clear	Low Risk	Low Risk	Not clear
Rössler, Verhagen <i>et al.</i> 2019 [10]	Low Risk	Not clear	Not clear	Not clear	Not clear	Not clear
Rössler, Junge <i>et al.</i> 2018 [15]	Low Risk	Not clear	Not clear	Not clear	Not clear	Not clear
Foss, Thomas <i>et al.</i> 2018 [16]	Not clear	Not clear	Not clear	Low Risk	Low Risk	Not clear
Waldén, Atroshi <i>et al.</i> 2012 [11]	Low Risk	Not clear	Not clear	Not clear	Low Risk	Not clear
Emery and Meeuwisse 2010 [12]	Not clear	Low Risk	Not clear	Low Risk	Low Risk	Not clear
Owoeye, Akinbo <i>et al.</i> 2014 [17]	Low Risk	Not clear	Not clear	Low Risk	Not clear	Not clear
Steffen, Myklebust <i>et al.</i> 2008 [18]	Not clear	Not clear	Not clear	Low Risk	Low Risk	Not clear
Soligard, Myklebust <i>et al.</i> 2008 [19]	Not clear	Not clear	Not clear	Low Risk	Not clear	Not clear
Kiani, Hellquist <i>et al.</i> 2010 [20]	Low Risk	Not clear	Not clear	Low Risk	Low Risk	Not clear

Table 4. Results of cross-comparisons across interventions.

Effectiveness in preventing knee injuries (OR, 95% CI)	FIFA 11+ Kids comprehensive warm-up	Neuromuscular Training Warm-up (NMT)	FIFA 11+ Comprehensive warm-up	Regular warm-up
	1.83 (0.6, 4.19)			
		1.45 (0.57, 3.44)		
	2.45 (1.11, 4.84)*	1.97 (1.07, 3.86)*	1.52 (0.78, 2.75)	

*a significant difference ($P < 0.05$)

Table 5. SUCRA values for the effectiveness of each intervention.

Interventions	SUCRA	PrBest	Mean Rank	Ranking
FIFA 11+ Kids comprehensive warm-up	85.3	72.5	1.3	1
Neuromuscular Training Warm-up (NMT)	66.7	21.6	2.1	2
FIFA 11+ Comprehensive warm-up	44	5.8	2.7	3
Regular warm-up	0.4	0	3.9	4

in preventing knee injuries, with a significant difference ($P < 0.05$). FIFA 11+ combined warm-up (OR = 1.52, 95% CI [0.78, 2.75]) was more effective than conventional warm-up in preventing knee injuries, with no significant difference ($P > 0.05$); FIFA 11+ Kids comprehensive warm-up was more effective than neuromuscular training warm-up (OR = 1.83, 95% CI [0.6, 4.19]) and FIFA 11+ combined warm-up (OR = 1.39, 95% CI [0.43, 3.02]), with no significant difference ($P > 0.05$); the preventive effect of neuromuscular training warm-up was better than that of FIFA 11+ combined warm-up (OR = 1.45, 95% CI [0.57, 3.44]), with no significant difference ($P > 0.05$). Combining OR and SUCRA values to rank the effectiveness of the four warm-up activities in reducing knee injuries in children and adolescents, the most effective intervention was probably the FIFA 11+ Kids comprehensive warm-up (SCURA = 85.3), the second intervention was probably neuromuscular training (SCURA = 66.7), the third intervention was probably the FIFA 11+ Kids comprehensive warm-up (SCURA = 44), and conventional warm-up (SUCRA = 0.4) came last (Table 4 and Table 5).

3.6. Published Bias Chair Test

Comparison-corrected funnel plots were used to identify small sample effects and publication bias in the included studies, and comparison-corrected funnel plots plotted with a knee injury as the effect indicator showed that the symmetry of the included studies was fair, indicating a possible small sample effect (Figure 2).

4. Discussion

4.1. The Relative Effectiveness of the Comprehensive Warm-Up of FIFA 11+ Kids

A total of 10 RCT studies involving four types of warm-up exercises were included in this study, and the results of the mesh Meta-analysis showed that the

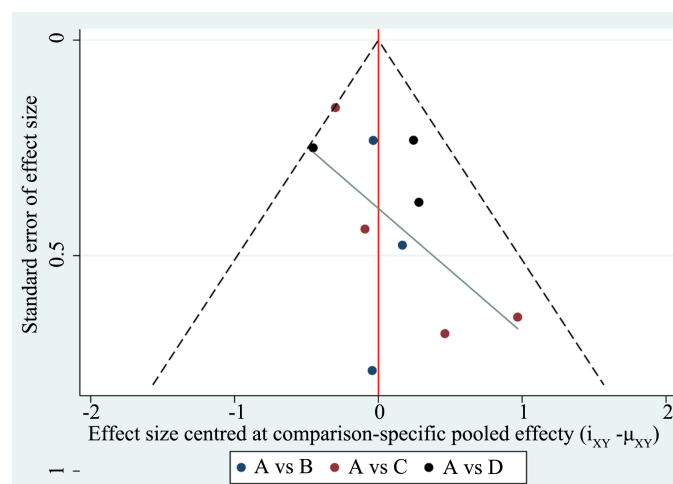


Figure 2. Comparison-correction funnel diagram of effectiveness in preventing knee injuries. A: regular warm-up; B: NMT: neuromuscular training warm-up; C: FIFA 11+ Kids comprehensive warm-up; D: FIFA 11+ comprehensive warm-up.

FIFA 11+ Kids comprehensive warm-up, the neuromuscular training warm-up, and the FIFA 11+ warm-up exercises were more advantageous compared to the traditional conventional warm-up in preventing knee injuries; the neuromuscular training warm-up (NMT) had a greater advantage compared to the FIFA 11+ warm-up exercises. Judged by OR magnitude and SUCRA values, the FIFA 11+ Kids comprehensive warm-up became the most effective warm-up exercise to reduce knee injuries in junior soccer players, with the others in order of priority being neuromuscular training warm-up (NMT), FIFA 11+ comprehensive warm-up, and conventional warm-up.

Currently available for soccer players between the ages of 7 - 14, the FIFA 11+ Kids comprehensive warm-up is an exercise that prevents injury and improves performance by increasing stability in the legs and core area as well as improving coordination and balance. FIFA 11+ Kids comprehensive warm-up is simple and easy to operate without additional equipment, the exercise is divided into 7 parts, mainly including: running game exercises, alternate leg jumping, single-leg straight-line jumping, single-leg standing two-handed passing, Spider-Man movements, push-ups, falling technique exercises, each exercise can be divided into 5 levels, and the coach can use the actual number and quality of completed movements as the criteria for evaluating the entry into the next level [15]. In addition, the warm-up exercises have significant advantages in terms of reducing the associated medical costs, with a study by Roland showing that performing the FIFA 11+ Kids comprehensive warm-up reduced medical costs by 51% compared to performing the regular warm-up exercises, which is a crucial boost to the development of children's and youth soccer [16].

4.2. Advantages of Various Warm-Up Exercises

The three warm-up exercises have different advantages for reducing knee injuries in children and youth soccer players. The FIFA 11+ Kids comprehensive warm-up takes into account the developmental characteristics and injury types of soccer players at lower ages, focusing on improving spatial perception, body stability, and proper movement techniques at different ages [21]. The FIFA 11+ comprehensive warm-up mainly includes 10 movements to improve the core stability, balance, and other qualities of soccer players as well as the concept of fair play, applied to professional and amateur soccer players over 13 years old, with the main objective of reducing the occurrence of sports injuries while improving athletic ability. In neuromuscular warm-up exercises (NMT), athletes change the wrong movement patterns through strength training, core stability training, explosive power training, and other ways to enhance their perceptual ability of space, thus achieving a training method to prevent injuries and improve athletic ability, which is also effective for preventing sports injuries in volleyball and basketball for middle school students [22]. According to the SUCRA results of various warm-up exercises, the FIFA 11+ Kids comprehensive warm-up, as an emerging warm-up, may be the optimal warm-up for preventing knee in-

juries in children and adolescents, followed by the FIFA 11+ comprehensive warm-up and neuromuscular warm-up exercises (NMT).

4.3. Shortcomings of the Study and Outlook

Although the current study showed that the effectiveness of FIFA 11+ Kids integrated warm-up was better than the other three warm-up exercises in preventing sports injuries in children and adolescents, due to the age span, the population of subjects included in this study for FIFA 11+ Kids integrated warm-up was mainly aged 7 - 14 years old, with fewer studies on adolescents in the adolescent stage, while the study population for neuromuscular warm-up exercises (NMT), FIFA 11+ integrated warm-up was mainly aged 12 - 19 years old, so the application of this finding has to be reviewed. Coaches should be more flexible in the use of warm-up exercises to reduce the occurrence of injuries, improve athletic performance and reduce related medical expenses according to the age and gender characteristics of the participant group. More experiments on the two warm-up exercises should be conducted in future studies to increase the evidence for direct comparison and to take advantage of the net Meta-analysis to further explore the optimal warm-up for this special group of children and adolescents, thus enriching the research in this area of school soccer warm-up exercises and promoting the development of school soccer.

5. Conclusion

Compared to the other three warm-up exercises, the FIFA 11+ Kids comprehensive warm-up exercise was the most effective warm-up for preventing knee injuries in junior and child soccer players, but the results of this study need further in-depth validation due to the quantity and quality of the literature.

Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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