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ORIGINAL ARTICLE

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Neuromuscular training warm-up in the prevention of overuse lower extremity injuries in children's football: A cluster-randomized controlled trial

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Abstract

The objective of this study was to examine the effect of a neuromuscular training (NMT) warm-up on the prevalence of overuse lower extremity (LE) injuries in children's football. Twenty Finnish U11-U14 youth football clubs (n = 1409 players; females 280, males 1129; age range 9-14) were randomized into intervention and control groups containing 10 clubs each (intervention: 44 teams, n = 676 players; control: 48 teams, n = 733 players). The intervention group performed a structured NMT warm-up operated by team coaches for 20 weeks. The main outcome measure was the prevalence of football-related overuse LE injuries and injuries were tracked via weekly text messages. The average weekly prevalence of overuse LE injuries was 11.6% (95% CI: 11.0%-12.2%) in the intervention group and 11.3% (10.7%-11.9%) in the control group. The most common anatomical locations were the knee (weekly prevalence 6.0% in the intervention group and 5.7% in the control group) and heel (2.4% and 2.6%). There was no difference in the prevalence of overuse LE injuries between the groups: odds ratio (OR) 1.01 (95% CI: 0.99-1.03). In conclusion, NMT warm-up was equal to standard practice warm-up in preventing overuse LE injuries in children's football during a follow-up of 20 weeks.

Trial registration: ISRCTN14046021

KEYWORDS
children, football, injury prevention, neuromuscular training, overuse injuries, youth

1 | INTRODUCTION

Participation in sports activities such as football is beneficial for overall health but involves a risk for injuries. In football injury research, acute and traumatic injuries have traditionally received most of the attention, while the knowledge on overuse injuries is limited.[1,2] Especially, randomized-controlled trials (RCT) focusing on the prevention of overuse lower extremity (LE) injuries are in few in youth football.[2,3] Methods on football injury research have earlier focused largely on *time-loss from training and playing* or *the need for medical attention* on defining injuries.[4] These standard methods are more appropriate when examining acute injuries, but reveal only the tip of the iceberg in overuse injuries.[5] Overuse injuries do not always result in time-loss from sports or in a medical appointment—especially in youth players.[6,7] The Oslo Sports Trauma Research Centre Overuse injury questionnaire (OSTRC-O) has been introduced as a more complete approach on tracing the occurrence and consequences of overuse injuries.[8] The questionnaire has been validated and used in many previous studies.[5,9-12]

Overuse injuries result from repetitive microtrauma and usually without a single identifiable event responsible for the injury (gradual onset), although sudden onset debut can occur.[4,13] Overuse injuries are often thought to be prevalent only in long duration and monotonous sports such as endurance running, or technical sports that require repetition of same movements such as handball. However, there is increasing evidence suggesting a high prevalence of overuse injuries in team sports, including children's football.[14] In children playing football, neuromuscular training (NMT) can prevent LE injuries overall[15,16] and acute non-contact LE injuries,[17] but there has been little focus on the effect of NMT warm-up on overuse injuries. A RCT in under 13-year-old (U13) children reported a nonsignificant reduction in overuse injury incidence and another RCT with 13-17-year-old female players reported a significant 53% decrease in overuse LE injury incidence in favor for the NMT warm-up group.[15,18] In another RCT with 13-17-year-old females, the overuse injury incidence was the same for both the NMT warm-up group and the control group.[19] These studies used time-loss and/or medical appointment definitions for injuries and both reported a relatively low incidence of overuse injuries. With the OSTRC-O questionnaire and data collection methods, an RCT of 12-17-year-old floorball players reported a 45% decrease in the rate of acute injuries but no beneficial effect was seen in the prevalence of overuse injuries.[10] This study also reported that as many as two-thirds of all injuries were overuse-related, suggesting that most of the overuse injury burden is left unnoticed with the more traditional research methods.

The aim of this RCT was to examine whether the prevalence of overuse LE injuries could be reduced with a NMT warm-up in 9-14 year-old children playing football.

2 | METHODS

2.1 | Study design and participants

This was a two-armed cluster-randomized controlled trial conducted according to the Consolidating Standards for Reporting Clinical Trials (CONSORT).[20] The Ethics Committee of Pirkanmaa Hospital District (ETL-code R13110) approved the study.

The follow-up period was dated January-June 2015. In August 2014, we invited all 20 U11-U14 clubs (92 teams, n = 1643 players) in the Finnish youth football player development monitoring program Sami Hyypiä Academy (SHA) to take part in the study. The program includes competitive level youth soccer clubs across Finland. Every official player of the participating teams was eligible to enter the study. After an informed consent from each player's legal guardian, altogether 1424 players agreed to participate (Figure 1). Players with any injury at baseline were also included in the study.

Computer-generated randomization of participants into intervention and control group was performed 1 month prior to the start of follow-up by a statistician who was not further involved in the study. Home cities of the clubs were used as the unit of randomization to avoid intracity contamination of warm-up methods. Cities with more than two clubs (n = 1, 4 clubs), cities with two clubs (n = 4) and cities with one club (n = 8) were allocated in different randomization blocks aiming to adjust the groups by city size. The three blocks were randomized separately with an even number of clubs in both groups (10 clubs each). Concealment of allocation was followed during randomization process.

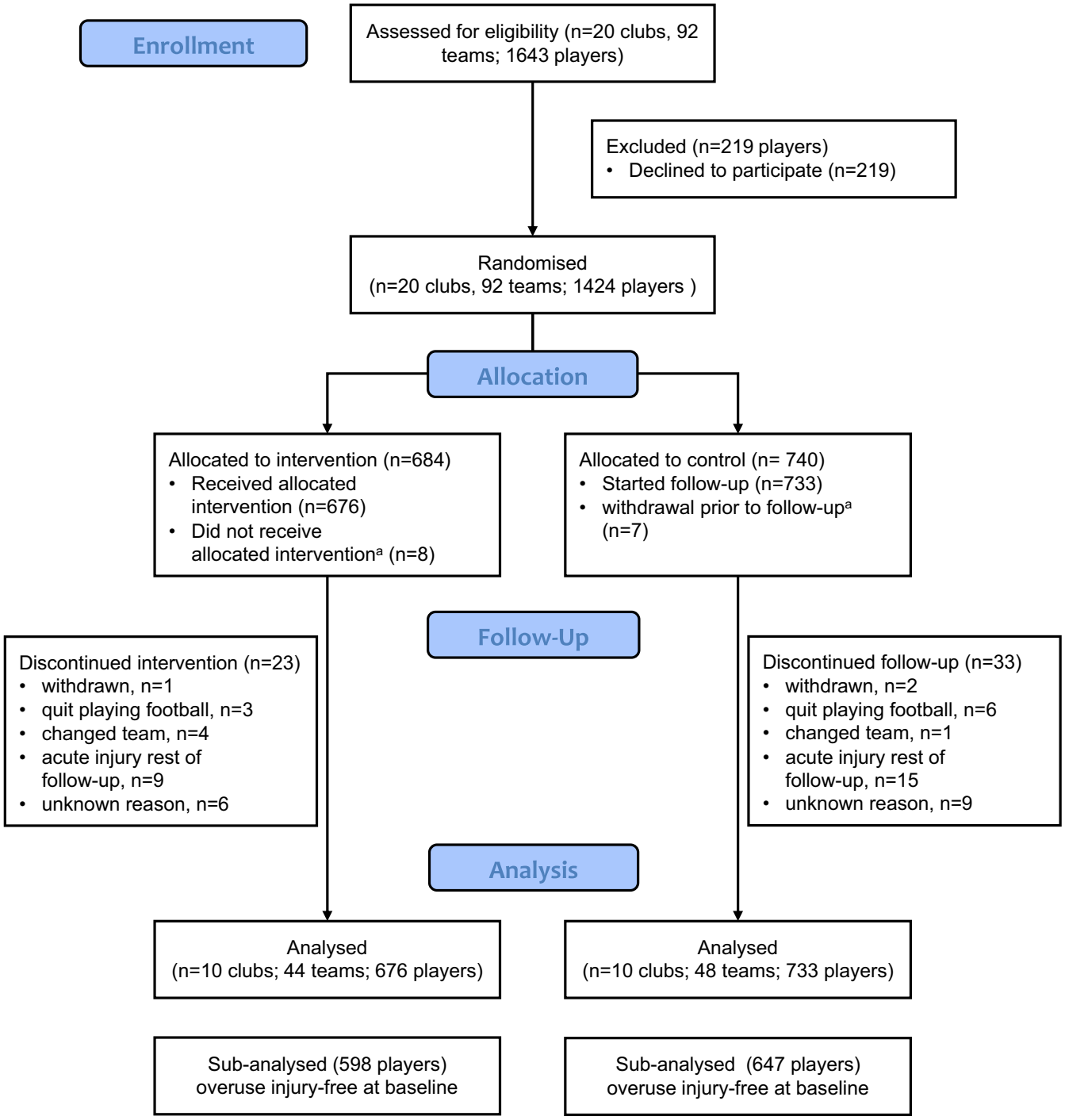

FIGURE 1 Flow chart

2.2 | Intervention

We conducted a 20-week intervention from January to June 2015 when football is played mainly on artificial turf in Finland. Prior to the start of the intervention, we invited coaches from the intervention group to a weekend workshop for theoretical and practical education in football injury prevention and the study NMT warm-up. Each coach received a tablet including instructions and videos of the exercises and completion of the warm-up in team practices. The videos are available at Video S1.

The NMT warm-up (Figure S1) was developed based on the senior investigator's earlier NMT warm-up with proven efficacy in female floorball.[21] We modified the existing warm-up in collaboration with experienced football coaches for the purpose of this study. We instructed the

teams in the intervention group to replace their standard warm-up with NMT warm-up 2-3 times a week. During the intervention, we researchers visited each intervention team randomly 2-3 times to oversee training, and to support and help coaches in case they needed help in exercise technique or other aspects of the program.

In a 1-hour pre-study meeting, we introduced the teams in the control group to the data collection methods and advised them to continue their usual warm-up methods during follow-up. We conducted random check-ups to the control clubs for evaluating the warm-up routines in the control arm during study. The control teams were informed to receive the same education as the intervention group after the study.

2.3 | Outcome measure

As the primary outcome, we analyzed the prevalence of football-related overuse LE injuries (gradual onset injuries). Acute injuries have been analyzed in an earlier publication.[17]

We defined injuries following the Fuller consensus statement[4] as any physical complaints resulting from football activities, irrespective of time-loss or the need for a medical appointment. Overuse injuries were defined as being caused by repeated microtrauma without a single identifiable event responsible for the injury. Secondarily we analyzed overuse injuries separately for different body parts and by sex. Sub-analyses were also conducted for substantial overuse injuries defined as injuries leading to moderate or severe reductions in sports performance or participation in the OSTRC-O questionnaire or time-loss from sports entirely.[5]

2.4 | Data collection

Studied teams took part in baseline player monitoring events arranged by the SHA within 5 months prior to follow-up (Sep 2014-Jan 2015). The players' guardians were asked to complete baseline questionnaires surveying basic information (age, sex) and injuries during the last 12 months (Table 1).

Players were asked to report weekly exposure hours for training and games once a month on a web-based training diary as a routine procedure in the SHA program (Table 1). However, the reports were inadequate and credible individual-level data could not be retrieved. Thus, we deviated from trial protocol and report team-based exposure instead of individual exposure hours. Mean player practice hours within teams were calculated from individuals reporting exposure data and the mean player exposure was used for all players in the team. Team game exposure was estimated using number of games, standard game durations and number of players on field.[4] Number of games was obtained from the SHA and the Finnish Football Association. Team game exposure was divided even for the players in the team.

We collected overuse injury data via weekly text messages to players' guardians surveying injury symptoms: has your child had any musculoskeletal complaint or injuries during the previous 7 days (yes/no)? Whenever players or their guardians answered "yes," they were contacted by a blinded study physical therapist for a structured phone interview with the guardian and/or the player. Overuse LE injuries were registered using the OSTRC-O questionnaire,[5] which measures the effects of an overuse injury in four categories: sports participation, training volume, performance and perceived pain. Each item is scored with either a 4-point or a 5-point scale, ranging from 0 (no problem, no reduction, no effect and no pain, respectively) to 25 (cannot participate at all). The OSTRC-O questionnaire was filled for each anatomical area separately had the player suffered from more than one injury during the week.

The coaches in the intervention group submitted monthly a diary of all NMT warm-up sessions conducted in their teams. At the end of the follow-up period, the coaches in the control group completed a questionnaire concerning their teams' possible injury prevention strategies during the study period.

TABLE 1 Participant characteristics

	Intervention	Control
Players, N	676	733
Females, N (%)	117 (17)	163 (22)
Age (y), mean (SD)	12.2 (1.2)	12.3. (1.1)
Height (cm), mean (SD)	151.4 (10.1)	151.7 (9.8)
Weight (kg), mean (SD)	41.4 (8.7)	41.2 (8.5)
Previous injuries (yes/no), N	302	291
Injured players[a] at baseline, N	79	85
Weekly exposure (h), mean (SD)	5.4 (1.4)	4.5 (0.9)

[a]lower extremity overuse injury.

2.5 | Power calculation and statistical analysis

We conducted a cross-sectional pilot study in 2014 for the SHA players (n = 1400) to estimate optimal sample size. We did not base power calculations on overuse LE injuries specifically as there was no previous experience of the use of OSTRC-O data collection in youth football at the time. Instead, the sample size was based on the seasonal incidence of acute LE injuries and the hypothesis of 20% reduction in those injuries.[17] We considered statistical significance at 0.05.

We performed statistical analyses using IBM SPSS Statistics for Windows, version 27.0 (IBM Corp.). We calculated weekly overuse injury prevalence by dividing the number of players reporting injury that week by the number of players answering to the text message in the group. We compared the prevalence of overuse LE injury between the intervention and control groups with generalized linear mixed model (GLMM) using binomial distribution. The model was based on repeated measures conducted on the players as subjects. Overuse injuries were set as the outcome variable and the follow-up week, study group and interaction between follow-up week and study group as the explanatory variables. The club was used as random effect. Autoregressive moving average (ARMA11) as repeated measures covariance structure was used to assess the dependency between several measurements from a single player. The results are expressed as odds ratios (OR) from the interaction with 95% confidence intervals having the control group as reference.

We conducted the primary analysis unadjusted for any covariates and by the intention to treat (ITT) principle following the trial protocol. We also made two supplementary analyses: first, an analysis adjusting the groups for age, sex, and exposure to football practice and games (included as additional explanatory variables in the model) following the ITT principle; and second, an efficacy analysis accounting for the subgroup of overuse injury-free players at baseline. The statistician performing the analyses was blinded.

3 | RESULTS

3.1 | Player characteristics and response rate

The flow of players through study is shown in Figure 1 following the CONSORT guidelines. All approached clubs agreed to participate, resulting in 1424 players for randomization. Fifteen players stopped playing in the participating teams between study recruitment and start of follow-up, and so, the final sample consisted of 1409 players (676 in the intervention group, 733 in the control group). During the intervention period, 56 players (3.9%) dropped-out for reasons specified in Figure 1. Data from these players were included in the analyses for the time they participated. Complete overuse injury data (20/20 weeks) were obtained from 1019 players.

The average response rate for the 20 text messages was 96% in the intervention group and 95% in the control group. Seventy-two percent of the players answered every week and 95% responded 15 times or more.

The data collection for individual exposure failed and, instead, we, therefore, report team-based exposure. Exposure to practice and games was 5.4 hours per week in the intervention group and 4.5 hours per week in the control group. Exposure was significantly higher in the intervention group ($P < .001$).

3.2 | Injury characteristics

A total of 615 (44%) players reported at least one overuse LE injury during the 20-week follow-up and 171 of these had more than one overuse injury (Table 2). The median duration of overuse LE injuries was 2 weeks (range 1-20) and the number of injuries per player ranged from 0 to 5. Overuse injuries were reported in a total of 3070 player-weeks and the injury was classified as substantial in 31% of these weeks. In 14% of these weeks the overuse LE injury resulted in complete time-loss from sports participation ("cannot participate at all" in OSTRC-O question 1).

The most common injury location was the knee (51% of all reported overuse LE injuries) followed by the heel (22%), the hip/groin (7%) and the ankle (6%; Table 2).

3.3 | Primary outcome: all overuse LE injuries

The average weekly prevalence for overuse LE injuries was 11.6% (95% CI: 11.0%-12.2%) in the intervention group and 11.3% (10.7%-11.9%) in the control group (Table 3, Figure 2). In the GLMM analysis, no difference was observed in the prevalence of all overuse LE injuries between groups: OR 1.01 (95% CI: 0.99-1.03; Table 3).

3.4 | Secondary outcomes

The weekly prevalence of overuse heel injuries was significantly higher in the intervention group than in the control group: OR: 1.05 (95% CI: 1.00-1.10).

The weekly prevalence of substantial overuse LE injuries was 6.0% (95% CI: 5.6%-6.5%) in the intervention group and 5.0% (95% CI: 4.7%-5.4%) in the control group, being similar between groups: OR: 1.00 (95% CI 0.97-1.03).

In analyses adjusted for age, sex, and exposure to football practice and games, no major differences were observed compared to unadjusted primary analyses (Table S1).

In the subgroup, analysis including only overuse injury-free players at baseline, the prevalence of substantial LE injury was decreased in females by 8% in the intervention group compared to the controls: OR: 0.92 (95% CI: 0.85-1.00). This difference was not seen in the analysis of males or both sexes combined. In opposite, the intervention group had a higher prevalence of heel (6%) and substantial heel (10%) injuries than the controls, and the differences were even greater examining males only (10% and 13%, respectively; Table S2).

TABLE 2 Injury characteristics

	Intervention	Control
No. of injured players (%)	297 (44%)	318 (43%)
No. of players with >1 injuries	84 (12%)	87 (12%)
No. of new injuries	395	411
Median weeks suffering from a single injury	2	2
Reported weeks of injury	1502	1568
Reported weeks of substantial injury	784	699
Time-loss injury weeks (%)	271 (18%)	169 (11%)
Injury sites, No. (%)		
Knee	774 (52%)	793 (51%)
Heel	307 (20%)	367 (23%)
Ankle	134 (9%)	55 (4%)
Hip/groin	72 (5%)	131 (8%)

3.5 | Team adherence

In an average follow-up week, 63% of the teams conducted the NMT warm-up at least twice.[17] In January, the adherence to the program was higher compared later in the study period. Almost all teams (95%) conducted one or more sessions on 75% of weeks, which was considered moderate adherence overall. Mean session length was 25 min (range 10-70 min).

A total of 34 out of 48 teams (71%) in the control group responded to the questionnaire on injury preventive measures during the study period. Twenty-five teams (74% out of 34 teams answering) reported having conducted some sort of weekly injury prevention strategy bearing similarity to the NMT examined in this study. Most control teams included in their weekly training core planks (94%), single-leg lunges and jumps (82%), while hip muscle strength exercises were less popular (41%).

4 | DISCUSSION

4.1 | Main findings

We examined the effects of a NMT warm-up on the prevalence of overuse LE injuries in a large cohort of 9-14-year-old children playing football competitively. No significant differences were seen between the groups in the overall prevalence of overuse LE injuries. Opposite to what we expected, statistically significant differences

TABLE 3 Lower extremity injury prevalence generalized linear mixed model (GLMM) analysis between intervention and control groups

	Mean weekly prevalence, % (95% CI)		GLMM analysis
	Intervention	Control	Odds ratio (95% CI)
All injuries			
LE	11.6 (11.0-12.2)	11.3 (10.7-11.9)	1.01 (0.99-1.03)
Knee	6.0 (5.6-6.4)	5.7 (5.3-6.1)	0.99 (0.96-1.02)
Heel	2.4 (2.1-2.6)	2.6 (2.4-2.9)	**1.05 (1.00-1.10)**
Substantial injuries			
LE	6.0 (5.6-6.5)	5.0 (4.7-5.4)	1.00 (0.97-1.03)
Knee	2.9 (2.6-3.2)	2.4 (2.2-2.7)	0.97 (0.93-1.02)
Heel	1.2 (1.1-1.5)	1.1 (1.0-1.3)	1.06 (0.99-1.13)

Note: All analyses are performed using the control group as reference value.
All analyses are unadjusted for any variables.
Significant result is in bold.

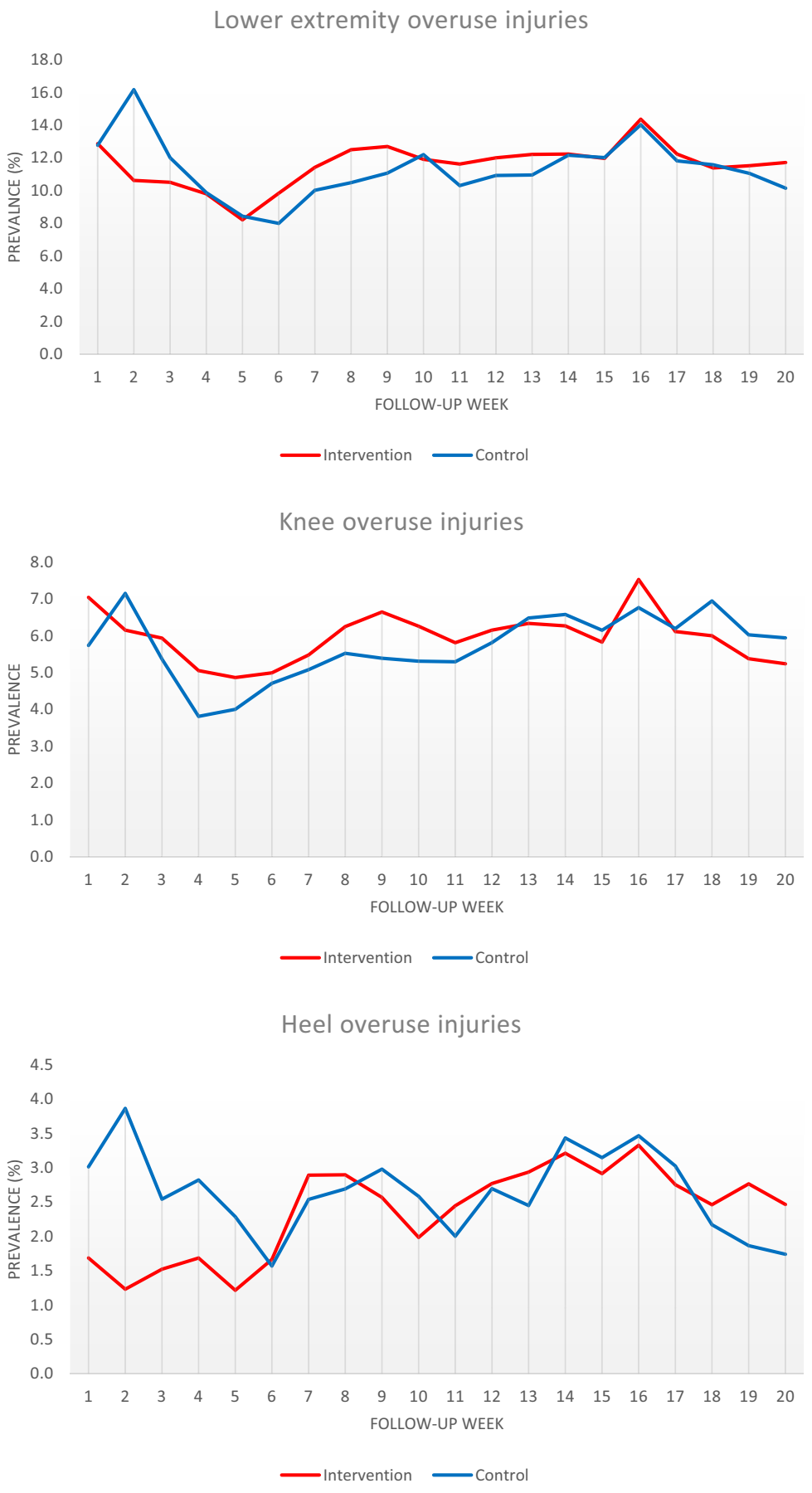

FIGURE 2 Weekly overuse injury prevalence

in favor of not performing NMT warm-up was found in the subanalyses of heel injuries, particularly in males. However, the change in absolute risk was negligible in the current follow-up. Importantly, we witnessed that overuse LE injuries seem to be a big problem affecting one in 10 players at any given time, but most of the overuse LE injury complaints do not lead to time-loss acutely.

The results are much in line compared to earlier research in youth team sports with similar methods on 12-17-year-old Swedish floorball players, where a significant and a major reduction in acute injuries but no difference at all in overuse injuries was seen using a NMT warm-up as intervention.[10] This Åkerlund et al's study reported adverse effects of the NMT program on overuse knee injuries in female players. No such effect was seen in our study on knee injuries, but instead, we observed a small increase in the prevalence of heel injury in the NMT group. Knee injuries may become a bigger problem later on adolescence than in our study population.

Three relevant RCTs have examined the effect of NMT warm-up on overuse injuries in youth football, all using time-loss and/or medical attention definition for injuries. In one study, the result was similar to ours: no difference in overuse injury incidence between NMT warm-up intervention group and the control group in female youth football.[19] Soligard et al,[18] however, found a significant 53% reduction in overuse injuries in favor for the NMT warm-up group in female youth football. Rössler et al[15] reported low number and incidence of overuse injuries resulting in nonsignificant comparison between groups, but the NMT warm-up was concluded as likely beneficial in the protection of overuse injuries in 7-12-year-old children. In our study, time-loss resulted from overuse LE injuries in only 18% and 11% of the cases in the intervention and control groups, respectively, making these studies less comparable with the current study. The short- and long-term impact of the many mild overuse injuries not leading to acute time-loss would be wise to be investigated in future, as these have not been previously assessed sufficiently.

An aspect to consider in the interpretation of this study is that the children may not have been used to NMT training and when starting new practice routines the injury risk could temporarily rise due to underpreparedness and increase in training workload before the body adapts to new exercise-specific stimuli.[22,23] Starting new training interventions should be done gradually to avoid overuse injuries. However, we did not see a declining trend in the prevalence of overuse injuries during the 20-week study period. Thus, a more plausible explanation may be that NMT training is not better than standard practice in the prevention of overuse injuries.

Also, the intervention group had 20% more weekly exposure hours than the control group, making the interpretation more difficult. The coaches in the intervention group were instructed to perform the NMT warm-up instead of their usual warm-up and not to lengthen their practice sessions while starting the new warm-up method but this might have failed. The increase in training load may predispose for injuries.[22,23] No between-group differences in the prevalence of overuse LE injuries was seen when the analysis was made adjusting for exposure hours, but we see the relative risk increase in training load may overcome the relative risk decrease in adjusting for exposure.

Existing or latent overuse injuries may diminish the benefits from doing any injury prevention strategies. Especially growth-related overuse injuries, such as apophysitis, are prevalent in this age group.[2] In our data, knee injuries were the most common injuries in our population. Especially, injuries such as Osgood-Schlatter disease do not ease with training including jumps and squats, but by restricting workload.[24] It could be speculated that new training routines for players already suffering from an imminent overuse injury would worsen their symptoms. However, whether or not taking into account these players, the NMT warm-up did not have significant impact on the injury prevalence.

This study warrants further research with longer follow-up on NMT warm-up and its effects on long-term overuse injury prevalence in children. For now, NMT cannot be seen conclusively effective in the prevention of overuse injuries in children's football. Also, football overuse injuries should be studied in older adolescent population with modern self-report methods. The short- and long-term impact of the mild overuse injuries not leading to acute time-loss should also be further investigated. In addition to controlled trials, future focus is needed on the implementation of the recommended interventions in a real-life setting.[25]

In this trial, NMT warm-up was found to be equal to standard warm-up in overall overuse LE injury prevention and a small adverse effect was observed in overuse heel injuries. However, we encourage NMT to be implemented in the weekly training schedule of children playing football for the established efficacy in the prevention of acute injuries.

4.2 | Strengths and limitations

This study was a large RCT conducted in a unique children's study population including both male and female players. The coach-led intervention was designed applicable for future implementation as the NMT warm-up was

only introduced to team coaches before the start of follow-up and after that was operated by team coaches with minimal support from the study personnel.

The strengths of this study included the good response rate to the injury survey via text messages and the study provided positive feedback to the use of these data collection methods in future research also. The exposure time data collection would perhaps be wise to be included in the text message data collection: a clear limitation in the current methods was that children this young were noncompliant in reporting individual exposure via online diary and team-based exposure had to be used instead. Another limitation in the data collection is that the OSTRC-O has not been validated in children this young and not when completed by the players' guardians.

Unfortunately, the adherence to the intervention was observed to decrease during the follow-up as is earlier reported in similar trials.[19,26] We believe that the length of the program may have been an obstacle limiting teams from continuing the intervention as regularly as expected. The increasing evidence on the utility of NMT on injury risk reduction may in future motivate team coaches to engage in this type of training better, although it is clear that successful implementation is a complicated process.[25,27,28]

A limitation in interpreting the study results is that the control teams reported utilizing components of NMT in their warm-ups and/or supportive training sessions.[17] It may be that the most relevant difference in the warm-ups between intervention and control teams was not in the exercises themselves, but in the systematic and structured execution of the NMT in the intervention group.

Other limitations in the study methods include that we did not include power calculations for overuse injuries in the trial protocol, and later we had to deviate from the trial protocol in estimating individual exposure hours from team-based data. We did not make adjustments for multiple analyses when examining the supplementary analyses, and thus, the reported significant results should be interpreted with caution. Due to the multifactorial nature of overuse injuries, non-football-related injuries were not identified or excluded from analysis in the current study. Also, a limitation is that the measured weekly prevalence as an outcome did not account for the specific duration of the symptoms in days.

5 | PERSPECTIVE

Overuse LE injuries are prevalent in children's football as we observed one in 10 players to report symptoms of these injuries every week. NMT warm-up was equal to standard practice warm-up in preventing overuse LE injuries in children's football during a follow-up of 20 weeks. The statistical but clinically negligible increase in the risk for heel pain in the players performing NMT warm-up in the current study should be noted and further investigated. Despite this, we encourage neuromuscular training to be included in weekly practice in children's football for its established beneficial effects in the prevention of acute injuries.

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CONFLICT OF INTEREST

None declared.

ETHICS APPROVAL

Ethics Committee of Pirkanmaa Hospital District (ETL-code R13110).

DATA AVAILABILITY STATEMENT

Data available on request from the authors according to trial protocol.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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