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A Warm-Up Program to Reduce Injuries in Youth Field Hockey Players: A Quasi-Experiment

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Context: Field hockey is popular worldwide; however, it entails a risk of injury. Injuries hamper players' participation in the sport and impose a burden on public health.

Objective: To investigate the effectiveness of a structured exercise program among youth field hockey players on the injury rate, severity, and burden.

Design: Quasi-experimental study.

Setting: On field during 1 season of field hockey (October 2016 through June 2017).

Patients or Other Participants: A convenience sample of 22 teams (291 players): 10 teams (135 players, mean age = 11.5 years [95% confidence interval (CI) = 11.2, 11.7 years]) in the intervention group and 12 teams (156 players, mean age = 12.9 years [95% CI = 12.6, 13.2 years]) in the control group.

Intervention(s): The Warming-up Hockey program, a sex- and age-specific, structured, evidence-informed warm-up program consisting of a preparation phase (ie, agility and cardiovascular warm-up exercises), movement skills (ie, stability and flexibility exercises), and sport-specific skills (ie, speed and strength exercises in field hockey situations). Participants in the control group performed their usual warm-up routines.

Main Outcome Measure(s): Injury rate (ie, the number of injuries per 1000 player-hours of field hockey exposure), severity (ie, days of player time-loss), and burden on athletes' availability to play (ie, days of time loss due to injury per 1000 player-hours of field hockey exposure).

Results: The injury rate was lower in the intervention group (hazard ratio of 0.64 [95% CI = 0.38, 1.07]); however, this result was not statistically significant. The severity of injuries was similar in both groups (*t* statistic $P = .73$). The burden of injuries on players' field hockey participation was lower in the intervention group (difference of 8.42 [95% CI = 4.37, 12.47] days lost per 1000 player-hours of field hockey).

Conclusions: Exposure to the Warming-up Hockey program was not significantly associated with a lower injury rate. No reduction was observed in the severity of injuries alone; however, the burden of injuries on players' field hockey participation was lower in the intervention group.

Key Words: quasi-experimental design, injury prevention, neuromuscular training, athletic injuries, risk management, sports, field hockey, adolescents

Key Points

- Exposure to the Warming-up Hockey program (WUP) was not significantly associated with a lower rate of overall injuries or injury severity. It was associated with lower rates of acute injuries and injuries leading to 1 to 3 days of time loss from field hockey.
- The injury burden on field hockey athletes' availability to play was lower in the group exposed to the WUP.
- Further investigation of the influence of field hockey players' age and sex on injury outcomes, such as injury rate and severity, is needed.
- Future injury-prevention efforts should include strategies to improve adherence to the WUP program during the indoor period of the Dutch season.

Sports and physical activity in youth are widely recommended for a healthy lifestyle and a cornerstone of contemporary public health.[1–3] Despite the well-documented benefits of regular physical activity and participation in sports,[4] engaging in such pursuits also brings a risk of unwanted consequences, including injuries.[5] The negative associations with injury can lead to reduced enthusiasm for participating in sports and physical activity.[6]

This counteracts public health efforts to promote sports participation among youth.[7] Moreover, sports injuries hamper the individual's and the team's athletic success[8] and impose a monetary burden on the public health agenda.[9] Therefore, injury prevention is of great importance.[10]

Field hockey is a popular Olympic sport worldwide[11] and is among the most popular sports in the Netherlands.[12] The Royal Dutch Hockey Association (KNHB) reported a membership increase of 37% between 2005 and 2015, of whom 60% were players younger than 18 years.[13] Despite the safety rules already implemented in field hockey, such as proper protective equipment,[14,15] injuries are still a cause for concern.[16] Most of the injuries in field hockey affect the lower limbs.[16] In the Netherlands, 110 000 field hockey injuries are registered each year.[17] Apart from the negative effects of these injuries at the player and team levels, their annual direct medical cost totals €6.7 million (US $7.6 million).[17]

To reduce injuries in field hockey, the KNHB and the Dutch Consumer Safety Institute (VeiligheidNL, Amsterdam, the Netherlands) have partnered. Together with field hockey and injury-prevention experts, they have developed a structured, evidence-informed, exercise-based injury-prevention program for field hockey: the Warming-up Hockey program (WUP). The systematic development, feasibility assessment, and content of the WUP are described elsewhere.[18,19] The WUP consists of sex- and age-specific, structured, evidence-informed exercises to be conducted before field hockey training and game sessions: (1) a preparation phase (ie, agility and cardiovascular warm-up exercises); (2) movement skills (ie, stability and flexibility exercises), and (3) field hockey skills (ie, speed and strength exercises in field hockey situations). The KNHB and VeiligheidNL officials asked us to evaluate the potential protective effects of the existing WUP on injuries. Accordingly, the aim of our study was to investigate the effectiveness of the WUP in reducing the rate and severity of injuries among youth field hockey players. Secondarily, we assessed the effectiveness of the WUP in reducing the burden of injuries on youth athletes' availability to play.

METHODS

Study Design

Because randomization was not feasible based on the constraints identified by the KNHB and VeiligheidNL (that is, the program had already been released via an online platform when they requested the study), we used a quasi-experimental design. This investigation was conducted during the 2016–2017 Dutch field hockey season (October 2016 to June 2017) with a convenience sample of youth field hockey players (10 to 17 years old). The research was approved by the ethics committee of the university and prospectively registered in the national trial registry.

Sample-Size Calculation

In the Netherlands, 240 000 field hockey players were registered with the KNHB in 2012,[13] and 110 000 field hockey injuries are registered each year based on survey data from VeiligheidNL.[17] The estimated injury incidence (ie, the number of injuries divided by the number of participants per season)[20] of 46% (ie, 110 000/240 000) and potential reduction of 50% in the number of injuries informed the sample-size calculation for this study.[21–23] Based on an α of .05 and a β of 90%, we estimated a required sample size of 67 field hockey players per study group. Considering a team-cluster effect of 0.1[24] and the fact that youth field hockey teams in the Netherlands generally consist of 17 players, a sample of 336 players distributed over 20 teams (ie, 10 teams per study group) was required.

Participants

The KNHB sent an open invitation to all field hockey clubs in the Netherlands with a registered medical staff member (N = 160 clubs). Clubs with teams that consisted of players aged 10 to 17 years were eligible to participate in the study. Responding clubs (n = 13) stated their interest in participating in either the intervention (n = 6) or control (n = 7) arm of the study, according to their convenience. Subsequently, we visited these clubs with a KNHB official to present the aim and methods of the study.

Coaches and athletes' parents were present during the visits. All attendees received a package with a written explanation of the study, their expected roles and responsibilities during the study period, and a participation consent form. Teams were included in the study after returning the consent forms signed by the coach and the parents of the participating players. In addition, for a team to be included in the investigation, the coaches had to return a complete follow-up measure of their team (described later) to us during the study period.

As mentioned, teams were not randomized to the intervention or control group, but allocation was based on each club's preference. Teams interested in implementing the intervention program were allocated to the intervention group (n = 36 teams). These teams were instructed in the use of the WUP and how to incorporate the program into their usual routine before training and match sessions. The control group was composed of teams (n = 43) whose clubs had responded to the study invitation but had no interest in carrying out the intervention program. Control teams were instructed to continue with their regular warm-up routines.

Intervention

The WUP, developed by the KNHB and VeiligheidNL, was designed to reduce the risk of lower limb injuries in field hockey players. The detailed systematic development of the program, its content, and feasibility assessment can be found elsewhere.[18,19] In short, the program consists of structured exercises to be conducted before regular field hockey training and game sessions. The exercise structure delivered over the season is sex and age specific and is divided into 3 main components lasting 4 minutes each (ie, 12 minutes in total): (1) preparation phase (ie, agility and cardiovascular warm-up exercises); (2) movement skills (ie, stability and flexibility exercises); and (3) field hockey skills (ie, speed and strength exercises in field hockey situations). The structure, components, and level of difficulty (ie, intensity, frequency, duration, and complexity) of the exercises are adjusted weekly over the 40-week season. A mobile application with a synchronized Web site delivered the program to the coaches through explanatory

videos and text (http://hockey.warmingupapp.nl; in Dutch).[19]

Measurements

Baseline Questionnaire. After signing the study participation consent form, players' parents received an e-mail with a secure link to an online baseline questionnaire. This questionnaire asked about their child's characteristics, including age, years of hockey experience, and injuries sustained in the previous 3 months. The baseline questionnaire was the same for the intervention and control groups.

Participant Follow-Up. Player-specific exposure to field hockey and injuries were recorded by the coach on an exposure form.[25] Coaches noted the total duration of each training session and match, as well as each player's participation time (ie, full, 3 quarters, 1 half, 1 quarter, or no participation) in relation to the duration of the session. If the player did not participate fully, the coach provided the reason (ie, injury, illness, absent for another reason). Completed exposure forms were returned on a weekly basis. If data were missing on the exposure forms, the coach was contacted for the missing data. If no exposure form was returned within 4 days, the coach received a reminder. Apart from the regular registration of players' exposure to field hockey and injuries, coaches in the intervention group were also asked to register, for every session, their adherence to the warm-up program prescribed for that week.

Injury Registration. An *injury* was defined as any musculoskeletal condition or concussive event that caused the player to stop the field hockey activity or to not fully participate in the next planned field hockey training or game session (ie, time-loss injury).[25] When a coach reported an injury, the player's parent was contacted by e-mail to register the injury details. This e-mail included a secure link to an online version of the Sports Medicine Australia Hockey Specific Injury Reporting Form.[26] This form enabled parents to register the specific injured body location, injury type, injury diagnosis, injury mechanism (eg, ball or stick contact, noncontact), first aid received, and medical attention received. If the parent did not complete the online form, an e-mail reminder was sent after 4 days. In the case of no response to the e-mail reminder, the parent was contacted by phone.

Injury Classification and Outcomes. An injury was classified as *acute* when its onset could be linked to a specific identifiable event; otherwise it was classified as *overuse* (ie, with no specific identifiable onset).[27] A *recurrent injury* was defined as an injury to the same body location and of the same type as a previous injury (ie, index injury), regardless of whether it was a reinjury (ie, after full recovery) or an exacerbation (ie, no full recovery).[28,29]

The main outcomes of this study were the overall rate and severity of injuries. The *injury rate* was the number of injuries, including players' subsequent and overuse injuries, per 1000 player-hours of field hockey exposure.[20] The *severity* of each recorded injury was measured as the number of days of nonparticipation in field hockey training or game sessions due to the injury (ie, cumulative days of time loss). A secondary outcome of this study was the burden of injuries on players' availability to play. The *injury burden* was defined as the number of cumulative days of time loss due to injury per 1000 player-hours of field hockey.[30–32]

Table 1. Characteristics of Youth Players at Baseline and Their Total Exposure to Field Hockey Over the 2016–2017 Season

Characteristic	No. (%)	
	Intervention	Control
Teams	10 (45)	12 (55)
Players	135 (46)	156 (54)
Boys[a]	54 (40)	22 (14)
Girls[a]	81 (60)	134 (86)
Previous injury in the past 3 mo	25 (19)	33 (21)
Unknown[a]	12 (9)	39 (25)
Player exposure over the season, h (sessions)	10 766 (7964)	10 404 (8544)
Training	8083 (5277)	7474 (5459)
Game	2683 (2687)	2930 (3085)
	Mean (95% Confidence Interval)	
Age, y[b]	11.5 (11.2, 11.7)	12.9 (12.6, 13.2)
Field hockey experience, y[b]	5.1 (4.7, 5.4)	5.9 (5.6, 6.2)

[a] Difference between the intervention and control groups (Pearson χ^2 test).
[b] Difference between the intervention and control groups (Mann-Whitney test).

Data Analysis

Baseline Data. Data processing and analyses were performed in R (version 3.4.1; R Foundation, Vienna, Austria) and Excel (version 15.40; Microsoft Corp, Redmond, WA). The primary researcher (S.D.B.) conducted all analyses described herein and was not blinded to each participant's group allocation. Descriptive analyses were performed on players' characteristics at baseline (Table 1): count and continuous variables were compared between groups using the Pearson χ^2 and Mann-Whitney tests, respectively.

Adherence to the Intervention. A descriptive analysis was conducted on the coaches' self-reported adherence to the intervention program, which was summarized as the median and 25% to 75% interquartile range (IQR) of the weekly percentage of sessions with the intervention delivered by the coaches and the actual players' intervention uptake (eg, a player who could not be present for a session during which the intervention program was delivered by the coach would not receive credit for that session).

Injury Rate, Severity, and Burden on Players' Availability to Play. Player-specific time to injury was compared between groups using mixed-effects Cox models and the coxme package for R (version 2.2-5).[33] Injury-free players' exposure time contributed to the analysis. The (random and fixed) mixed effects included in the model accounted for the number of hours players spent in field hockey until the first injury and after recovery from the first injury, the hours spent until the second injury, and so on, when applicable. Players, clustered within teams, were included as Gaussian random effects, which accounted for potential correlations at the intraperson and team levels.[23,33]

Due to the non-Gaussian distribution, the *severity of injuries* (ie, cumulative days of time lost from play) was

summarized as the median time loss of all registered injuries and the 25% to 75% interquartile range.[9] Injury severity was compared between the intervention and control groups using *t* statistics on a bootstrap of 10 000 sampling distributions,[34] and therefore, the mean and 95% confidence interval (CI) were provided for descriptive purposes. The differences in cumulative days of time loss due to injury per 1000 player-hours of field hockey and the 95% CIs were used to compare the burden of injuries on athletes' availability to play between the intervention and control groups.[35]

RESULTS

Flow of Participants, Baseline, and Exposure to Field Hockey

A total of 79 youth field hockey teams were interested in participating in the study and, therefore, received information on the procedures. Coaches and parents from 30 teams (n = 383 players) provided consent forms. Two teams (n = 25 players) did not register any follow-up, and 6 teams (n = 67 players) could not provide complete follow-up data (ie, supplied only game or training data). Ultimately, 22 teams (n = 291 players) were included in the study; of those, 10 teams (n = 135 players) composed the intervention group and 12 teams (n = 156 players), the control group (Figure 1). The baseline questionnaire response rates for the intervention and control groups were 92% and 83%, respectively. Characteristics of the youth players at baseline and summary of their exposure to field hockey over the season are presented in Table 1.

Injury Rates

Injury rates are presented in Table 2. Forty-four injuries were registered in the intervention group, for a rate of 4.09 (95% CI = 2.84, 5.33) injuries per 1000 player-hours of field hockey. In the control group, 67 injuries were reported, for a rate of 6.44 (95% CI = 4.87, 8.01) injuries per 1000 player-hours. The lower limb was the most frequently injured body part in both groups. The intervention and control groups sustained 2.04 (95% CI = 1.14, 2.95) and 3.65 (95% CI = 2.45, 4.85) lower limb injuries per 1000 player-hours of field hockey, respectively.

The overall injury rates were not different between groups based on the mixed-effects Cox model (Table 2). The rates for lower limb injuries were also not different between groups (hazard ratio [HR] = 0.54 [95% CI = 0.29, 1.02]). The rates of acute injuries and injuries leading to 1 to 3 days of field hockey time loss were lower in the intervention group than in the control group (HR = 0.55 [95% CI = 0.31, 0.96] and HR = 0.52 [95% CI = 0.27, 0.98], respectively). Given the uneven distribution of players' sexes and ages between groups, we added a mixed-effects Cox model to control for sex and age, which identified no differences between groups (Table 2).

Injury Severity

Injury severity was not different between the intervention and control groups (Table 3). The *t* statistics on the bootstrap of 10 000 samples resulted in a *P* value of .73. The 44 injuries in the intervention group led to 196 days of

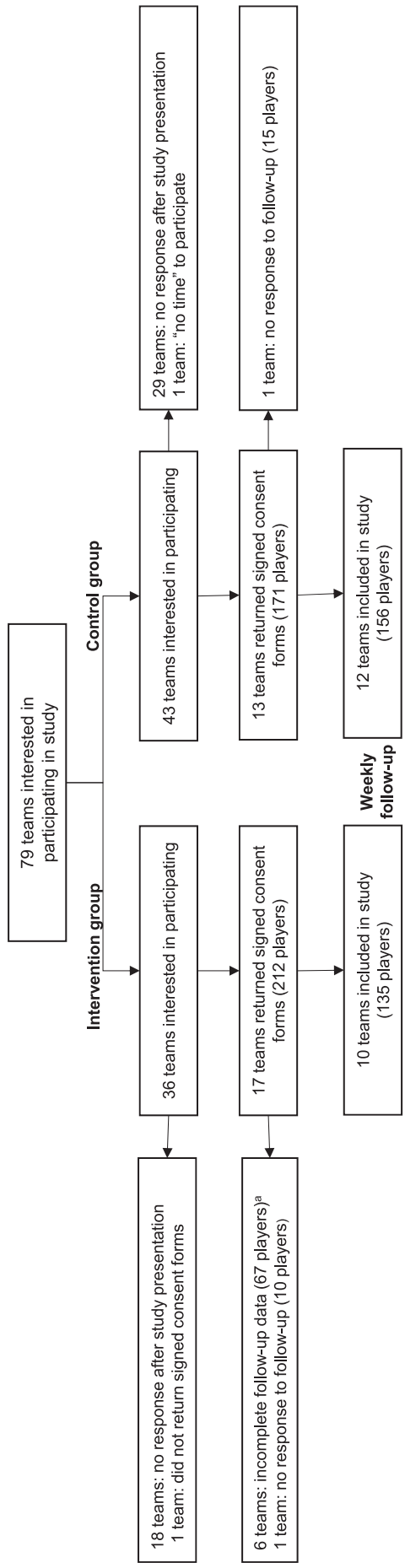

Figure 1. Study design and flow of participants. (Coaches provided training or game data only.)

Table 2. Player-Specific Time-to-Injury Comparison Based on Mixed-Effects Cox Models Between Youth Field Hockey Players in the Intervention and Control Groups

	Intervention (n = 10 Teams, 135 Players)		Control (n = 12 Teams, 156 Players)		Hazard Ratio (95% CI)	
Measure	Injuries (Injured Players)	Injury Rate[a] (95% CI)	Injuries (Injured Players)	Injury Rate[a] (95% CI)	Crude Analysis[b]	Adjusted Analysis[c]
Overall[d]	44 (37)	4.09 (2.84, 5.33)	67 (56)	6.44 (4.87, 8.01)	0.64 (0.38, 1.07)	0.86 (0.51, 1.45)
Severity, d of time loss[d]						
1–3	26 (23)	2.42 (1.44, 3.39)	49 (44)	4.71 (3.36, 6.06)	0.52 (0.27, 0.98)[e]	0.68 (0.35, 1.34)
4–14	15 (14)	1.39 (0.62, 2.16)	12 (12)	1.15 (0.42, 1.89)	1.28 (0.56, 2.91)	1.65 (0.65, 4.18)
15+	3 (3)	0.28 (0.00, 0.97)	6 (6)	0.58 (0.00, 1.18)	0.58 (0.15, 2.33)	1.18 (0.22, 6.22)
Type of exposure[d]						
Training	33 (27)	4.10 (2.64, 5.53)	47 (41)	6.30 (4.44, 8.13)	0.65 (0.36, 1.19)	0.94 (0.51, 1.72)
Game	11 (11)	4.10 (1.35, 6.85)	20 (18)	6.80 (3.63, 10.02)	0.64 (0.28, 1.49)	0.75 (0.29, 1.94)
Onset						
Acute	20 (18)	1.86 (0.99, 2.73)	36 (31)	3.46 (2.29, 4.63)	0.55 (0.31, 0.96)[e]	0.68 (0.36, 1.28)
Overuse	12 (11)	1.11 (0.41, 1.82)	15 (12)	1.44 (0.64, 2.24)	0.77 (0.25, 2.33)	0.96 (0.28, 3.23)
Mechanism						
Noncontact	21 (17)	1.95 (1.06, 2.84)	30 (24)	2.88 (1.81, 3.96)	0.65 (0.30, 1.38)	0.96 (0.44, 2.09)
Contact	11 (11)	1.02 (0.34, 1.71)	21 (19)	2.02 (1.10, 2.94)	0.48 (0.21, 1.14)	0.50 (0.19, 1.30)
Ball or stick	8 (8)	0.74 (0.12, 1.36)	15 (15)	1.44 (0.64, 2.24)	0.48 (0.18, 1.31)	0.43 (0.14, 1.28)
Ground	1 (1)	0.09 (0.00, 1.27)	3 (3)	0.29 (0.00, 1.00)	0.38 (0.04, 3.61)	0.24 (0.02, 2.57)
Player	2 (2)	0.19 (0.00, 1.85)	3 (3)	0.29 (0.00, 1.00)	0.53 (0.09, 3.22)	3.62 (0.31, 41.79)
Body location						
Lower limb	22 (20)	2.04 (1.14, 2.95)	38 (32)	3.65 (2.45, 4.85)	0.54 (0.29, 1.02)	0.81 (0.43, 1.54)
Upper limb	6 (6)	0.56 (0.00, 1.14)	8 (8)	0.77 (0.13, 1.41)	0.72 (0.23, 2.23)	0.52 (0.16, 1.70)
Low back	3 (3)	0.28 (0.00, 0.97)	2 (2)	0.19 (0.00, 1.92)	1.55 (0.26, 9.30)	2.65 (0.30, 23.48)
Head or neck	1 (1)	0.09 (0.00, 1.27)	3 (3)	0.29 (0.00, 1.00)	0.35 (0.04, 3.43)	0.27 (0.02, 3.23)

Abbreviation: CI, confidence interval.

[a] Number of injuries per 1000 player-hours of field hockey.

[b] Mixed-effects Cox model with players clustered within teams.

[c] Mixed-effects Cox model with players clustered within teams, controlled for players' age and sex.

[d] Details of onset, mechanism, and body location were unknown for 12 (27%) and 16 (24%) injuries in the intervention and control groups, respectively. Such injuries were included in the overall calculation and in the categorization by severity and type of exposure only.

[e] Difference between groups.

field hockey time loss, with a mean severity of 4.45 (95% CI = 3.05. 5.86) days of time loss. The 67 injuries in the control group led to 277 days of time loss, resulting in a mean severity of 4.13 (95% CI = 2.52, 5.74) days of time loss.

Injury Burden on Players' Availability to Play

The burden of injuries on players' availability to play was lower in the intervention group (Table 4). The intervention and control groups lost 18.21 (95% CI = 15.64, 20.77) and 26.62 (95% CI = 23.48, 29.77) days of play per 1000 player-hours of field hockey exposure, respectively. The difference between groups was 8.42 (95% CI = 4.37, 12.47) days of time loss per 1000 player-hours. For lower limb injuries, the intervention group had 4.68 (95% CI = 1.33, 8.02) fewer days of play lost per 1000 player-hours of field hockey exposure.

Adherence to the Intervention

The coaches' self-reported adherence in the intervention groups regarding the delivery of the WUP to players and the proportion of players reported to be present during the program delivery for each week of the study are shown in Figure 2. The median of the coaches' weekly adherence to the intervention program was 93.5% (IQR = 73.8%–100.0%). The median of the actual intervention uptake by players was 84.3% (IQR = 58.7%–88.5%).

DISCUSSION

The aim of our quasi-experimental study was to evaluate the effectiveness of the WUP in reducing the rate and severity (ie, in terms of time lost from play) of injuries in a convenience sample of youth field hockey players. In addition, we investigated the effect of the WUP on the burden of injuries on players' participation in field hockey.

Injury Rate

In spite of the statistically nonsignificant difference between groups based on the rate of overall injuries (Table 2), we consider these injury-rate differences between groups to be clinically relevant and important for best-practice considerations. The crude mixed-effects Cox model demonstrated that the intervention group had lower rates of acute injuries and injuries of minor severity (ie, injuries resulting in 1–3 days of lost play time). Comparable findings have been reported by authors investigating the effects of exercise-based injury-prevention programs on diverse youth team sports, such as football (soccer) and basketball. A meta-

Table 3. Severity (ie, Days of Field Hockey Time Loss) of Injuries in Youth Field Hockey Players in the Intervention and Control Groups Over the 2016–2017 Season

	Intervention (n = 10 Teams, 135 Players)			Control (n = 12 Teams, 156 Players)			
Measure	Cumulative Days of Time Loss (Injuries)	Median (IQR)	Mean (95% CI)	Cumulative Days of Time Loss (Injuries)	Median (IQR)	Mean (95% CI)	Comparison (*P* Value)[a]
Overall[b]	196 (44)	2 (1–6)	4.45 (3.05, 5.86)	277 (67)	2 (1–4)	4.13 (2.52, 5.74)	.73
Severity, d of time loss[b]							
1–3	40 (26)	1 (1–2)	1.54 (1.29, 1.79)	69 (49)	1 (1–2)	1.41 (1.23, 1.59)	.26
4–14	102 (15)	6 (4–8)	6.80 (5.42, 8.18)	70 (12)	5 (5–6)	5.83 (5.00, 6.66)	.25
15+	54 (3)	18 (17–19)	18.00 (15.74, 20.26)	138 (6)	19 (18–22)	23.00 (15.79, 30.21)	.08
Type of exposure[b]							
Training	132 (33)	3 (2–8)	5.33 (3.57, 7.10)	191 (47)	2 (1–5)	5.00 (2.78, 7.22)	.79
Game	64 (11)	1 (1–2)	1.82 (0.99, 2.65)	86 (20)	1 (1–2)	2.10 (1.12, 3.08)	.58
Onset							
Acute	113 (20)	3 (1–8)	5.65 (2.97, 8.33)	139 (36)	2 (1–5)	3.86 (2.26, 5.46)	.15
Overuse	59 (12)	4 (2–6)	4.92 (2.95, 6.88)	90 (15)	2 (1–2)	6.00 (0.32, 11.68)	.73
Mechanism							
Noncontact	131 (21)	5 (3–8)	6.24 (4.13, 8.35)	159 (30)	2 (1–4)	5.30 (2.16, 8.44)	.57
Contact	41 (11)	1 (1–2)	3.73 (0.40, 7.05)	70 (21)	1 (1–5)	3.33 (1.50, 5.17)	.79
Ball or stick	11 (8)	1 (1–1)	1.38 (0.64, 2.11)	48 (15)	1 (1–3)	3.20 (0.82, 5.58)	.06
Ground	18 (1)	18 (18–18)	18.00 (18.00, 18.00)	11 (3)	2 (1–5)	3.67 (0.00, 7.95)	NA
Player	12 (2)	6 (3–8)	6.00 (0.00, 15.80)	11 (3)	2 (1–5)	3.67 (0.00, 7.95)	NA
Body location							
Lower limb	139 (22)	5 (2–8)	6.32 (4.21, 8.43)	183 (38)	2 (1–5)	4.82 (2.30, 7.33)	.25
Upper limb	26 (6)	1 (1–3)	4.33 (0.00, 9.78)	35 (8)	1 (1–3)	4.38 (0.00, 8.79)	.99
Low back	6 (3)	2 (1–2)	2.00 (0.87, 3.13)	2 (2)	1 (1–1)	1.00 (1.00, 1.00)	.03
Head or neck	1 (1)	1 (1–1)	1.00 (1.00, 1.00)	9 (3)	2 (1–4)	3.00 (0.01, 5.99)	NA

Abbreviations: CI, confidence interval; IQR, interquartile range; NA, not available.

[a] The *t* statistics on a bootstrap of 10 000 sampling distributions (NA represents injuries with too few observations for bootstrapping).

[b] Details of onset, mechanism, and body location were unknown for 12 (27%) injuries in the intervention group and 16 (24%) injuries in the control group. These injuries were included in the overall calculation and the categorization by severity and type of exposure only.

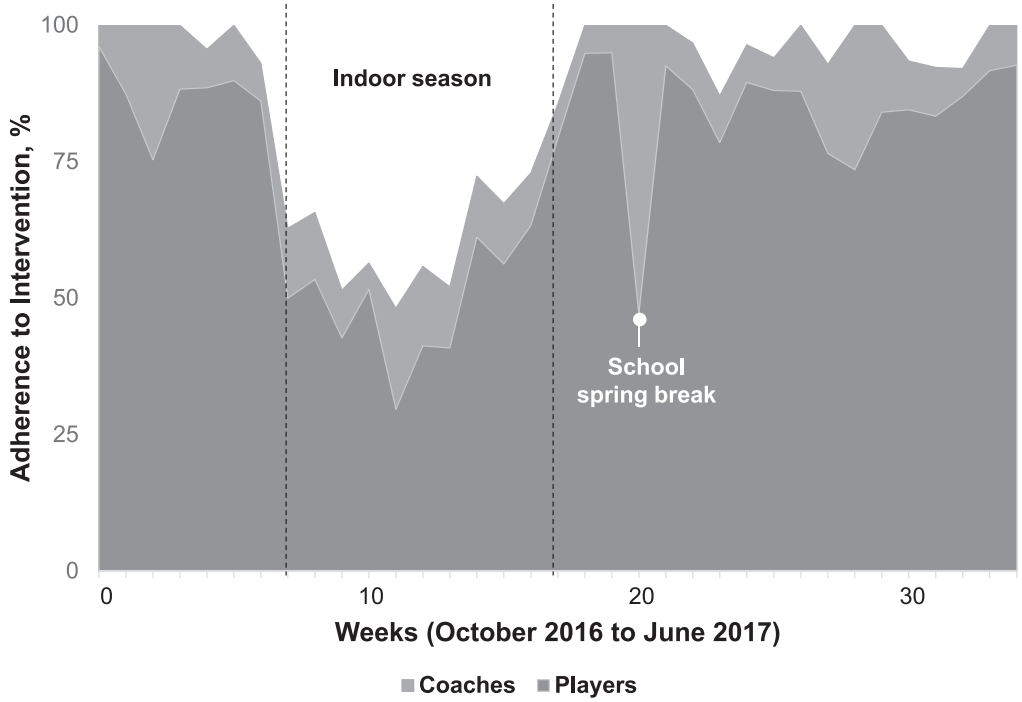

Figure 2. Adherence to the Warming-up Hockey program in youth field hockey teams by week. The light gray area shows the percentage of coaches delivering the program to players. The dark gray area shows the percentage of players present during program delivery. The indoor season is a standard period in the Netherlands due to the winter weather conditions.

Table 4. Burden of Injuries on Youth Players' Field Hockey Participation in the Intervention and Control Groups (95% Confidence Interval) Over the 2016–2017 Season

	Intervention (n = 10 Teams, 135 Players)			Control (n = 12 Teams, 156 Players)			Difference in Injury Burden[c]
Measure	Injury Rate[a]	Mean Severity	Injury Burden[b]	Injury Rate[a]	Mean Severity	Injury Burden[b]	
Overall[d]	4.09 (2.84, 5.33)	4.45 (3.05, 5.86)	18.21 (15.64, 20.77)	6.44 (4.87, 8.01)	4.13 (2.52, 5.74)	26.62 (23.48, 29.77)	8.42 (4.37, 12.47)[e]
Type of exposure[d]							
Training	4.10 (2.64, 5.53)	5.33 (3.57, 7.10)	16.33 (13.52, 19.14)	6.30 (4.44, 8.13)	5.00 (2.78, 7.22)	25.56 (21.91, 29.20)	9.22 (4.64, 13.81)[e]
Game	4.10 (1.35, 6.85)	1.82 (0.99, 2.65)	23.85 (17.90, 29.81)	6.80 (3.63, 10.02)	2.10 (1.12, 3.08)	29.35 (23.06, 35.64)	5.50 (–3.10, 14.09)
Onset							
Acute	1.86 (0.99, 2.73)	5.65 (2.97, 8.33)	10.50 (8.54, 12.45)	3.46 (2.29, 4.63)	3.86 (2.26, 5.46)	13.36 (11.12, 15.60)	2.86 (–0.10, 5.82)
Overuse	1.11 (0.41, 1.82)	4.92 (2.95, 6.88)	5.48 (4.05, 6.91)	1.44 (0.64, 2.24)	6.00 (0.32, 11.68)	8.65 (6.84, 10.46)	3.17 (0.88, 5.46)[e]
Mechanism							
Noncontact	1.95 (1.06, 2.84)	6.24 (4.13, 8.35)	12.17 (10.06, 14.27)	2.88 (1.81, 3.96)	5.30 (2.16, 8.44)	15.58 (12.89, 17.68)	3.11 (–0.06, 6.29)
Contact	1.02 (0.34, 1.71)	3.73 (0.40, 7.05)	3.81 (2.61, 5.010	2.02 (1.10, 2.94)	3.33 (1.50, 5.17)	6.73 (5.12, 8.33)	2.92 (0.94, 4.90)[e]
Ball or stick	0.74 (0.12, 1.36)	1.38 (0.64, 2.11)	1.02 (0.34, 1.71)	1.44 (0.64, 2.24)	3.20 (0.82, 5.58)	4.61 (3.27, 5.95)	3.59 (2.12, 5.06)[e]
Ground	0.09 (0.00, 1.27)	18.00 (18.00, 18.00)	1.67 (0.84, 2.50)	0.29 (0.00, 1.00)	3.67 (0.00, 7.95)	1.06 (0.35, 1.77)	–0.61 (–1.65, 0.43)[e]
Player	0.19 (0.00, 1.85)	6.00 (0.00, 15.80)	1.11 (0.41, 1.82)	0.29 (0.00, 1.00)	3.67 (0.00, 7.95)	1.06 (0.35, 1.77)	–0.06 (–1.00, 0.88)
Body location							
Lower limb	2.04 (1.14, 2.95)	6.32 (4.21, 8.43)	12.91 (10.75, 15.08)	3.65 (2.45, 4.85)	4.82 (2.30, 7.33)	17.59 (15.02, 20.15)	4.68 (1.33, 8.02)[e]
Upper limb	0.56 (0.00, 1.14)	4.33 (0.00, 9.78)	2.42 (1.44, 3.39)	0.77 (0.13, 1.41)	4.38 (0.00, 8.79)	3.36 (2.21, 4.52)	0.95 (–0.53, 5.43)
Low back	0.28 (0.00, 0.97)	2.00 (0.87, 3.13)	0.56 (0.00, 1.14)	0.19 (0.00, 1.92)	1.00 (1.00, 1.00)	0.19 (0.00, 1.92)	–0.37 (–1.01, 0.28)[e]
Head or neck	0.09 (0.00, 1.27)	1.00 (1.00, 1.00)	0.09 (0.00, 1.27)	0.29 (0.00, 1.00)	3.00 (0.01, 5.99)	0.87 (0.20, 1.53)	0.77 (0.07, 1.47)[e]

[a] Number of injuries per 1000 player-hours of field hockey.
[b] Days of play lost due to injury per 1000 player-hours of field hockey.
[c] Positive values favor the intervention group.
[d] Details of onset, body location, and mechanism are unknown for 12 (27%) injuries in the intervention group and 16 (24%) injuries in the control group. These injuries are included in the overall calculation and the categorization by severity and type of exposure only.
[e] Statistically significant difference between groups.

analysis[22] showed that exercise-based injury-prevention programs in organized youth sports could reduce injuries by 46%. Comparing our results with those of other investigators of field hockey is not possible because, to the best of our knowledge, this is the first study to evaluate the effectiveness of a structured, exercise-based, injury-prevention program in the sport.

Due to the nonrandom allocation of participants to the intervention and control groups, the distribution of players' ages and sexes between groups was uneven (Table 1). Therefore, we used a statistical model to adjust for player age and sex. This adjusted model demonstrated no differences in injury rates between groups (Table 2), which suggests that players' ages and sexes may influence injury rates in youth field hockey, as observed in youth soccer.[36] However, it is important to note, that our study was not powered for such an adjusted statistical model. Still, the point-effect estimate favored the intervention program in the adjusted analysis.

Injury Severity

The severity of injuries was not different between groups (Table 3). Descriptively, the median and mean days of lost play time were relatively higher for some measures (eg, lower limb) in the intervention group. This may be explained by the greater effectiveness of the intervention program in preventing injuries leading to 1 to 3 days of lost playing time (Table 2). The injuries in the control group had a more right-skewed distribution regarding lost play time compared with the intervention group, so the summary measure of severity was lower in this group.

Time loss due to injury is arguably the most common severity measure in sports injury research. Yet time loss is only 1 of the important measures of injury severity. The effect of injuries on athletes' performance[27] and the monetary costs to treat such injuries are other severity measures.[37] For logistical reasons, time loss was our only option for estimating the severity of injuries in this study. Future researchers are encouraged to use other severity measures when evaluating the effects of preventive strategies, such as reductions in players' performance and monetary costs to treat the injuries, in field hockey.

Injury Burden on Athletes' Availability to Play

In sports injury prevention, we are interested in reducing the absolute number and the severity of injuries.[38] Although looking at these outcomes separately is useful, they are both descriptors of the injury problem. The burden measure applied in this study is useful, as shown in previous work,[30–32] because it is a cross-product of the injury rate and severity. Using this cross-product is preferable for estimating the risk given the factors that might affect both the rate and severity of injuries.[30] In our study, the burden of injuries on athletes' availability to play was lower in the intervention group (Table 4). This means that, when we considered injury rate and severity together, the negative effect of injuries on players' participation in field hockey, or availability to play, was lower in the intervention group.

Adherence to the Intervention

Coaches' adherence to the intervention during the study period (median = 93.5%) can be considered high. The same can be concluded for the players' intervention uptake (median = 84.3%), which was obviously driven by circumstances beyond the sporting context, such as a school spring break or a player's absence from a session because of personal circumstances. However, an important constraint to the intervention adherence was the indoor season (Figure 2). In the Netherlands, the indoor season is an official period due to the winter weather conditions. During this period, teams play in different and smaller indoor facilities than their usual outdoor field hockey pitch. In addition, teams have limited time slots for training and game sessions as they must share the indoor facilities with other teams. These changes during the indoor season may explain the lower level of adherence to the intervention during this period. Therefore, either the intervention program should be adapted to facilitate execution during the indoor season or the logistics of the indoor season should be adapted to facilitate adherence to the intervention program. Further investigation is needed to verify the feasibility of these potential adaptations and the effects of greater adherence to the intervention during this period on injury outcomes.

Methodologic Considerations

The present study was a quasi-experiment in which we addressed the request of the KNHB to evaluate an existing intervention program. The research design was restricted because the developers of the intervention released the program online before the start of the study, which made a randomized controlled trial design impossible. Thus, the internal validity of the results was constrained given the nonrandom allocation of participants to the intervention and control groups.[39] Yet the approach we took can be considered closer to the real-world context in which the findings are to be applied.[40]

Our study was conducted in the real-world sporting context of participants. We applied the mixed-effects Cox models to handle multilevel data: that is, multiple injuries in a player and multiple players on a team in a team-sport setting. This can be considered a strength of the research. Players were clustered into teams and included in the models as Gaussian random effects, also known as frailty models.[33] Frailty models have been recommended for sports injury data analyses to consider exposure and subsequent injury data after the first injury (ie, not data only until the first injury).[41] Considering the uncontrolled scenario of our study, uncontrolled variables may have affected the outcomes. Because our goal was to measure effectiveness, a crude mixed-effect Cox model was our main statistical analysis. In a secondary analysis, we added a model to adjust for the uneven distribution of players' ages and sexes between the study groups. Although this adjusted analysis can be informative, our study design and statistical power were not fit for a true adjusted analysis.

Teams in the control group were not exposed to the intervention program and used their own warm-up strategies. Therefore, the comparison between the intervention and control groups compared the WUP with the

control team's usual warm-up strategy. The latter may have included some components of the WUP that protected players in the control group against injuries to some degree. For logistical reasons, it was not possible to monitor the content of the warm-up sessions of the control-group teams, which could be considered a limitation of this study.

The close follow-up of participants in this study minimized the effects of recall bias and nonresponse during data collection on player-specific exposures to field hockey and injury details. Still, it did not prevent complete nonresponses from certain participants' parents. Even after several contact attempts, it was not possible to obtain specific information on some injuries. The lack of details on such injuries (ie, onset, mechanism, and body location) may have inflated the injury rate in both groups if those injuries were not related to field hockey. Conversely, injury onset, mechanism, and body location may have been underestimated because the lack of details made it impossible to include these injuries in those categories. Injuries with missing details were included in the overall calculation; the proportions were similar in the intervention and control groups, 27% and 24%, respectively (Tables 2 through 4).

CONCLUSIONS

Exposure to the WUP was not associated with a lower injury rate. However, the program may be meaningful for practice due to a reduction in acute injuries and injuries leading to 1 to 3 days of field hockey time loss. Injury severity was not affected. Yet the burden of injuries on players' participation in field hockey was lower in the intervention group. Such results need to be interpreted with caution, and future studies to investigate the influence of players' ages and sexes on injury outcomes are recommended. Future authors should also investigate how to facilitate teams' adherence to the WUP during the indoor period of the Dutch season and determine the effects of such adherence on injury outcomes.

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