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CHAPTER 6

EFFECTIVENESS OF A WARM-UP PROGRAM TO REDUCE INJURIES IN YOUTH FIELD HOCKEY: A QUASI-EXPERIMENT

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ABSTRACT

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

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

Design: Quasi-experiment.

Setting: One season.

Participants: A convenience sample of 22 teams (291 players) – 10 teams (135 players aged 11.5 [95% CI 11.2–11.7]) in the intervention, and 12 teams (156 players aged 12.9 [95% CI 12.6–13.2]) in the control group (i.e. usual training routine).

Intervention: The Warming Hockey – a sex- and age-specific structured warm-up program consisting of a preparation phase (i.e. agility and cardiovascular warm-up exercises), movement skills (i.e. stability and flexibility exercises), and sport-specific skills (i.e. speed and strength exercises in field hockey situations).

Main outcome measures: Injury rate (i.e. the number of injuries per 1,000 player-hours of field hockey exposure), severity (i.e. days of play time-loss), and burden on players' availability to play (i.e. days of time-loss due to injury per 1,000 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]). The severity of injuries was similar in both groups (p=0.73). 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 1,000 player-hours of field hockey).

Conclusion: The exposure to the warm-up program was associated with a 36% lower injury rate. No reduction was observed in the severity of injuries alone. However, the burden of injuries on players' field hockey participation was significantly lower in the intervention group. It should be borne in mind that the group allocation was not at random, which may restrict the internal validity of the results.

INTRODUCTION

Sports and physical activity promotion in youth is widely recommended for a healthy lifestyle and is a cornerstone of contemporary public health.[1–3] Despite the well-documented benefits of regular physical activity and participation in sport,[4] engaging in such activities also brings a risk of unwanted consequences – i.e. injuries.[5] The negative associations with injuries can make youth lose enthusiasm in partaking in physical activity and sports.[6] This counteracts public health efforts to promote sports participation among youth.[7] Moreover, sports injuries hamper the individual's and team's athletic success,[8] and pose a monetary burden on the public health agenda.[9] Therefore, 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 an increase of 37% in membership between 2005 and 2015, of which 60% regarded to players aged below 18.[13] Despite safety rules already put in place 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 impact of these injuries on the player and team level, their annual direct medical cost sums up to €6.7 million.[17]

In order to reduce injuries in field hockey, the KNHB and the Dutch Consumer Safety Institute (VeligheidNL) have partnered. Together with field hockey and injury prevention experts, they have developed a structured exercise-based injury prevention program for field hockey – the Warming-up Hockey program. The systematic development, feasibility assessment, and content of the Warming-up Hockey program can be found elsewhere.[18,19] The KNHB and VeligheidNL officials have requested the authors of this study to evaluate the potential preventative effect of this already existing Warming-up Hockey program. Accordingly, the aim of the present study was to investigate the effectiveness of the Warming-up Hockey program regarding its potential to reduce the rate and severity of injuries in youth field hockey. Secondarily, this study

assesses the effectiveness of the of the Warming-up Hockey program on the burden of injuries on youth players' availability to play.

METHODS

Study design

As mentioned, this study was a request of the KNHB and VeiligheidNL. Due to their constraints, the only option was a quasi-experimental study. The developers of the program under investigation were already releasing the program in its online platform when they requested the study. This study was conducted during the 2016–2017 Dutch field hockey season (October 2016 to June 2017) and included a convenience sample of youth field hockey players (10 to 17 years old). The study was approved by the ethics committee of the VU University Medical Center Amsterdam and has been prospectively registered in the Dutch National Trial Register (NTR6035).

Sample size calculation

In the Netherlands, 240,000 field hockey players were registered with the Royal Dutch Hockey Association (KNHB) in 2012,[13] and 110,000 field hockey injuries are registered each year based on survey data from Dutch Consumer Safety Institute (VeiligheidNL).[17] These figures lead to a clinical incidence (i.e. number of injuries divided by the number of participants)[20] of 46% (i.e. 110,000/240,000). A potential reduction of 50% in the number of injuries was estimated for this study.[21–23] A power calculation with these numbers, with an alpha of 0.05 and a beta of 90%, resulted in a required sample size of 67 field hockey players per study group. Considering a team-cluster effect of 0.1, and that youth field hockey teams in the Netherlands generally consist of 17 players, a sample of 336 players distributed over 20 teams (i.e. 10 teams per study group) was required for the present study.

Participants

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

Coaches and parents of players were present during the presentation of the study aim and methods. All present received a package with a written explanation of the study, their expected roles and responsibilities during the study period, as well as a participation consent form. Teams from the respondent clubs were included in the study after returning the consent form signed by the coach and by the parents of the participating players. In addition, for a team to be included in the study, coaches had to return a complete follow-up measure of their team (see below) to the researchers during the period of the study.

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

Intervention

The Warming-up Hockey program was developed by KNHB and VeiligheidNL, and aimed to reduce the risk of lower limb injuries in field hockey. The detailed systematic development of the program, its content, and feasibility assessment can be found

elsewhere.[19] In short, the program consists of structured exercises designed to be conducted before regular field hockey training and game sessions. The exercise structure delivered over the season is sex- and age-specific, and are divided in three main components that last four minutes each (i.e. 12 minutes in total); (1) preparation phase (i.e. agility and cardiovascular warm-up exercises); (2) movement skills (i.e. stability and flexibility exercises); and (3) field hockey skills (i.e. speed and strength exercises in field hockey situations). The exercise structure and components are dynamic; i.e. they are adjusted weekly together with the level of difficulty of the exercises over the 40-week season. A mobile application with a synchronized website delivered the program to coaches through explanatory videos and text (http://hockey.warmingupapp.nl; in Dutch).[19]

Measurements

Baseline questionnaire

Players' parents received an email with a secure link to an online baseline questionnaire after signing the study participation consent form. This questionnaire asked about their children's characteristics, including age, years of hockey experience, and information on injuries sustained in the past 3 months. The baseline questionnaire was the same for the intervention and control group.

Participant follow-up

Player-specific exposure to field hockey and injuries were recorded by the coach on an exposure form.[24] Coaches noted the total duration time of each training session and match as well as the participation of each player (i.e. full, three quarters, one half, one quarter, or no participation). If the player did not participate fully, the coach noted the reason – injury, illness, or absence for other reasons. 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. In case no exposure form was returned within 4 days, coaches received a reminder. Apart from the regular registration, coaches in the

intervention group were also requested 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 caused the player not to fully participate in the next planned field hockey training or game session (i.e. time-loss injury).[24] In case of a reported injury by the coach, the parent of the player was contacted by email to register the injury details. This email included a secure link to an online version of the Sports Medicine Australia Hockey Specific Injury Reporting Form.[25] This form enabled parents to register the specific injured body location, injury type, diagnosis of the injury, direct mechanism of the injury (e.g. ball/stick contact, non-contact), first aid received, and received medical attention. If parents did not complete the online form, a reminder was sent after 4 days by email. In case of no response to the email reminder, parents were 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 (i.e. with no specific identifiable onset).[26] A recurrent injury was defined as an injury to the same body location and type as a previous injury (i.e. index injury), regardless of being a re-injury (i.e. after full recovery) or an exacerbation (i.e. no full recovery).[27,28]

The main outcomes of this study were the overall rate and severity of injuries. The injury rate is described as the number of injuries, including players' subsequent and overuse injuries, per 1,000 player-hours of field hockey exposure.[20] The severity of each recorded injury was measured as the number of days of non-participation in field hockey training/game sessions due to such injury (i.e. 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 operationalised as the number of cumulative days of time-loss due to injury per 1,000 player-hours of field hockey.[29–31]

Data analysis

Baseline data

Data processing and analyses were performed in R version 3.4.1 and Microsoft® Excel version 15.40. The primary researcher conducted all analyses described below and was not blinded to the participants' group allocation. Descriptive analyses were conducted to present players' characteristics at baseline (Table 1), where count and continuous variables were compared between groups using the Pearson's chi-squared and Mann-Whitney tests, respectively.

Adherence to the intervention

A descriptive analysis was conducted to present the coaches' self-reported adherence to the intervention program, which was summarised as the median and its 25%–75% interquartile range (IQR) of the weekly percentage of sessions with the intervention delivered by coaches as well as the actual players' intervention 'uptake' (e.g. a player could not have been present in a session during which the intervention program was delivered by the coach).

Injury rate, severity, and burden on players' availability to play

Player-specific time-to-injury was compared between groups through mixed effects Cox models using the coxme package for R, version 2.2-5.[32] Injury free players contributed their exposure time to the analysis. The (random and fixed) mixed effects included in the model accounted for the number of hours that players spent on 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 on intra-person and team level.[23,32]

The severity of injuries (i.e. cumulative days of time-loss from play) was summarized as the median of time-loss of all registered injuries and its 25%–75% interquartile range due to its non-Gaussian distribution.[9] Injury severity was compared between intervention and control group through *t*-statistics on a bootstrap of 10,000 sampling distributions,[33] and therefore, its mean and 95% confidence interval (95% CI) are described for descriptive purposes. The difference in cumulative days of time-loss due to injury per 1,000 player-hours of field hockey and its 95% CI were used to compare the burden of injuries on players' availability to play between intervention and control group.[34]

RESULTS

Flow of participants, baseline, and exposure to field hockey

Seventy-nine youth field hockey teams showed an interest in participating in the study and, therefore, received information on the procedures. Coaches and parents from 30 teams (383 players) provided consent forms to participate in the study. Two teams (25 players) did not register any follow-up, and 6 teams (67 players) could not provide complete follow-up data (i.e. only game or training data). Ultimately, 22 teams (291 players) were included in the study, of which 10 teams (135 players) composed the intervention group and 12 (156 players) the control group (Figure 1). The characteristics of youth players at baseline and the summary of their exposure to field hockey are presented in Table 1.

Injury rate

The injury rate was 36% lower in the intervention group (Table 2). Forty-four injuries were registered in the intervention group, which led to a rate of 4.09 (95% CI 2.84–5.33) injuries per 1,000 player-hours of field hockey. In the control group, 67 injuries

were reported, which resulted in a rate of 6.44 (95% CI 4.87–8.01) injuries per 1,000 player-hours of field hockey. The lower limb was the most frequently injured body part in both groups. The rate of lower limb injuries was 46% lower in the intervention group (Table 2).

No significant differences between groups were detected by the mixed effects Cox models in the overall and overuse injury rates, neither for main body parts and mechanisms of injury (Table 2). The injury rate for acute injuries was significantly lower in the intervention group (hazard ratio of 0.55 [95% CI 0.31–0.96]), as well as for injuries leading to 1–3 days of field hockey time-loss (hazard ratio of 0.52 [95% CI 0.27–0.98]).

Table 1. Characteristics of youth players at baseline and their exposure to field hockey over the 2016–2017 season.

	Intervention	**Control**
Teams, n (%)	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 months	25 (19)	33 (21)
Unknown[a]	12 (9)	39 (25)
Age, mean (95% CI)[b]	11.5 (11.2–11.7)	12.9 (12.6–13.2)
Years of field hockey experience, mean (95% CI)[b]	5.1 (4.7–5.4)	5.9 (5.6–6.2)
Total players-exposure over the season, hours (sessions)	10,766 (7,964)	10,404 (8,544)
Training	8,083 (5,277)	7,474 (5,459)
Game	2,683 (2,687)	2,930 (3,085)

95% CI: 95% confidence interval
[a] Difference between intervention and control group (Pearson's chi-squared test)
[b] Difference between intervention and control group (Mann-Whitney test)

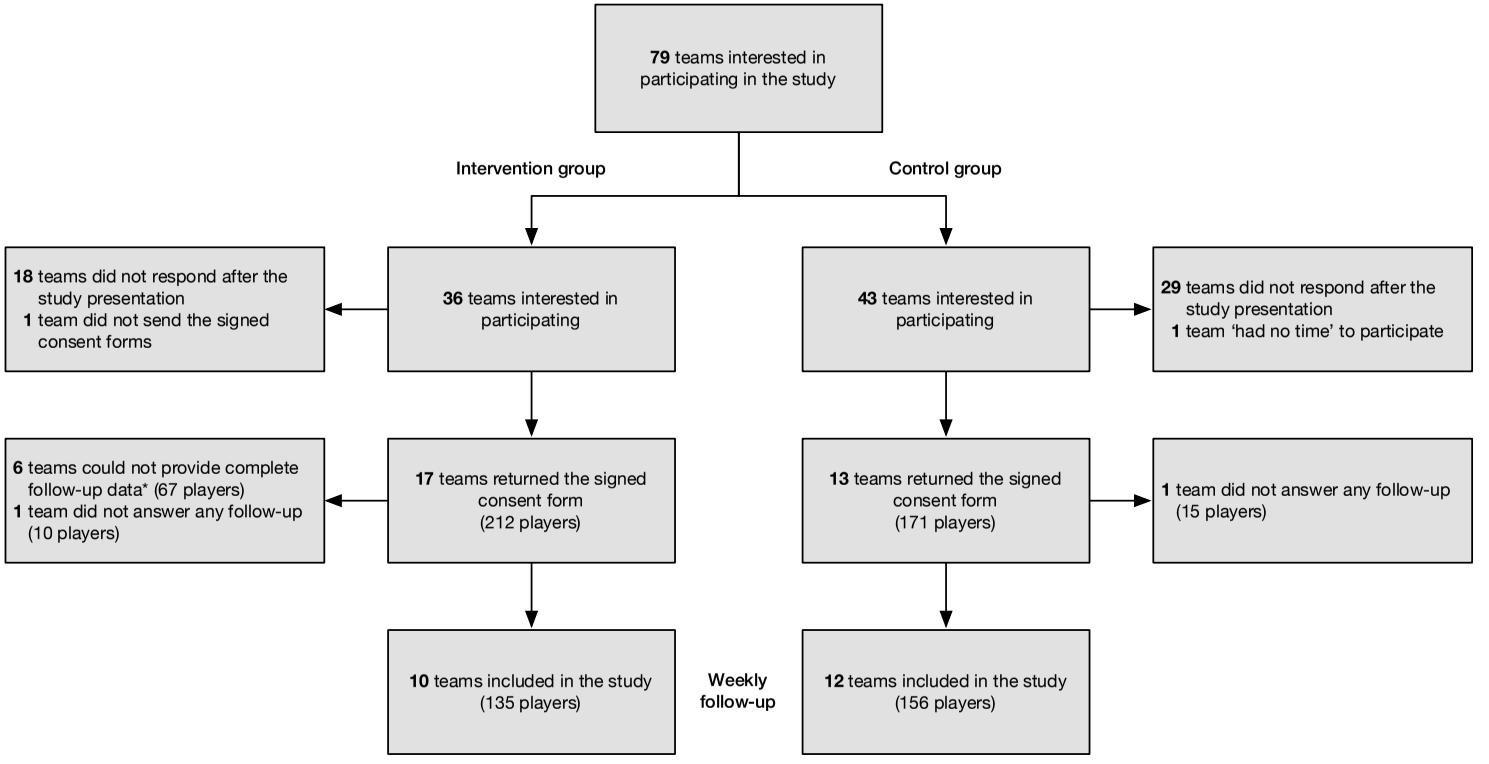

Figure 1. Study design and flow of participants. *Coaches would provide training or game data only.

Injury severity

The severity of injuries was not significantly different between intervention and control group (Table 3). The *t*-statistics on the bootstrap of 10,000 samples resulted in a *p*-value of 0.78. The 44 injuries in the intervention group led to 196 days of field hockey time-loss, with a mean of 4.45 (95% CI 3.05–5.86) days. The 67 injuries in the control group led to 277 days of field hockey time-loss, resulting in a mean of 4.13 (95% CI 2.52–5.74) days.

Injury burden on players' availability to play

The burden of injuries on players' availability to play was significantly lower in the intervention group (Table 4). The intervention and control group lost 18.21 (95% CI 15.64–20.77) and 26.62 (95% CI 23.48–29.77) days of play per 1,000 player-hours of field hockey exposure, respectively. The difference between groups was of 8.42 (95% CI 4.37–12.47) days of playing time-loss per 1,000 player-hours. For lower limb injuries, the intervention group had 4.68 (95% CI 1.33–8.02) fewer days of play lost per 1,000 player-hours of field hockey exposure.

Adherence to intervention

Figure 2 depicts the percentage of self-reports of coaches in the intervention group regarding the delivery of the warm-up program to players, and the percentage of players reported to be present during the program delivery for each week of the study. The median of the weekly adherence to the intervention program by coaches 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%).

Table 2. Player-specific time-to-injury comparison through mixed effects Cox models between youth field hockey players in the intervention and control group.

	Intervention (n = 10 teams, 135 players)		Control (n = 12 teams, 156 players)		
	Injuries (injured players)	Injury rate[b] (95% CI)	Injuries (injured players)	Injury rate[b] (95% CI)	**Hazard ratio (95% CI)**
Overall[a]	44 (37)	4.09 (2.84–5.33)	67 (56)	6.44 (4.87–8.01)	0.64 (0.38–1.07)
Severity[a]					
1–3 time-loss days	26 (23)	2.42 (1.44–3.39)	49 (44)	4.71 (3.36–6.06)	0.52 (0.27–0.98)
4–14 time-loss days	15 (14)	1.39 (0.62–2.16)	12 (12)	1.15 (0.42–1.89)	1.28 (0.56–2.91)
15+ time-loss days	3 (3)	0.28 (0.00–0.97)	6 (6)	0.58 (0.00–1.18)	0.58 (0.15–2.33)
Type of exposure[a]					
Training	33 (27)	4.10 (2.64–5.53)	47 (41)	6.30 (4.44–8.13)	0.65 (0.36–1.19)
Game	11 (11)	4.10 (1.35–6.85)	20 (18)	6.80 (3.63–10.02)	0.64 (0.28–1.49)
Onset					
Acute	20 (18)	1.86 (0.99–2.73)	36 (31)	3.46 (2.29–4.63)	0.55 (0.31–0.96)
Overuse	12 (11)	1.11 (0.41–1.82)	15 (12)	1.44 (0.64–2.24)	0.77 (0.25–2.33)
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)
Upper limb	6 (6)	0.56 (0.00–1.14)	8 (8)	0.77 (0.13–1.41)	0.72 (0.23–2.23)
Low back	3 (3)	0.28 (0.00–0.97)	2 (2)	0.19 (0.00–1.92)	1.55 (0.26–9.30)
Head/neck	1 (1)	0.09 (0.00–1.27)	3 (3)	0.29 (0.00–1.00)	0.35 (0.04–3.43)
Mechanism					
Non-contact	21 (17)	1.95 (1.06–2.84)	30 (24)	2.88 (1.81–3.96)	0.65 (0.30–1.38)
Contact	11 (11)	1.02 (0.34–1.71)	21 (19)	2.02 (1.10–2.94)	0.48 (0.21–1.14)
Ball/stick	8 (8)	0.74 (0.12–1.36)	15 (15)	1.44 (0.64–2.24)	0.48 (0.18–1.31)
Ground	1 (1)	0.09 (0.00–1.27)	3 (3)	0.29 (0.00–1.00)	0.38 (0.04–3.61)
Player	2 (2)	0.19 (0.00–1.85)	3 (3)	0.29 (0.00–1.00)	0.53 (0.09–3.22)

95% CI: 95% confidence interval.

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

[b] Number of injuries per 1,000 player-hours of field hockey.

Table 3. Severity (i.e. days of field hockey time-loss) of injuries in youth field hockey players in the intervention and control group over the 2016–2017 season.

	Intervention (n = 10 teams, 135 players)			**Control (n = 12 teams, 156 players)**			
	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)**[b]
Overall[a]	196 (44)	2 (1–6)	4.45 (3.05–5.86)	277 (67)	2 (1–4)	4.13 (2.52–5.74)	0.73
Severity[a]							
1–3 time-loss days	40 (26)	1 (1–2)	1.54 (1.29–1.79)	69 (49)	1 (1–2)	1.41 (1.23–1.59)	0.26
4–14 time-loss days	102 (15)	6 (4–8)	6.80 (5.42–8.18)	70 (12)	5 (5–6)	5.83 (5.00–6.66)	0.25
15+ time-loss days	54 (3)	18 (17–19)	18.00 (15.74–20.26)	138 (6)	19 (18–22)	23.00 (15.79–30.21)	0.08
Type of exposure[a]							
Training	132 (33)	3 (2–8)	5.33 (3.57–7.10)	191 (47)	2 (1-5)	5.00 (2.78–7.22)	0.79
Game	64 (11)	1 (1–2)	1.82 (0.99–2.65)	86 (20)	1 (1–2)	2.10 (1.12–3.08)	0.58
Onset							
Acute	113 (20)	3 (1–8)	5.65 (2.97–8.33)	139 (36)	2 (1–5)	3.86 (2.26–5.46)	0.15
Overuse	59 (12)	4 (2–6)	4.92 (2.95–6.88)	90 (15)	2 (1–2)	6.00 (0.32–11.68)	0.73
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)	0.25
Upper limb	26 (6)	1 (1–3)	4.33 (0.00–9.78)	35 (8)	1 (1–3)	4.38 (0.00–8.79)	0.99
Low back	6 (3)	2 (1–2)	2.00 (0.87–3.13)	2 (2)	1 (1–1)	1.00 (1.00–1.00)	0.03
Head/neck	1 (1)	1 (1–1)	1.00 (1.00–1.00)	9 (3)	2 (1–4)	3.00 (0.01–5.99)	-
Mechanism							
Non-contact	131 (21)	5 (3–8)	6.24 (4.13–8.35)	159 (30)	2 (1-4)	5.30 (2.16–8.44)	0.57
Contact	41 (11)	1 (1–2)	3.73 (0.40–7.05)	70 (21)	1 (1–5)	3.33 (1.50–5.17)	0.79
Ball/stick	11 (8)	1 (1–1)	1.38 (0.64–2.11)	48 (15)	1 (1–3)	3.20 (0.82–5.58)	0.06
Ground	18 (1)	18 (18–18)	18.00 (18.00–18.00)	11 (3)	2 (1–5)	3.67 (0.00–7.95)	-
Player	12 (2)	6 (3–8)	6.00 (0.00–15.80)	11 (3)	2 (1–5)	3.67 (0.00–7.95)	-

IQR: 25%–75% interquartile range; 95% CI: 95% confidence interval.

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

[b] *t*-statistics on a bootstrap of 10,000 sampling distributions (dashes represent injuries with not enough number of observations for bootstrapping).

Table 4. Burden of injuries on youth players' field hockey participation in the intervention and control group over the 2016–2017 season.

	Intervention (n = 10 teams, 135 players)			Control (n = 12 teams, 156 players)			
	Injury rate[b] (95% CI)	Mean severity (95% CI)	Injury burden[c] (95% CI)	Injury rate[b] (95% CI)	Mean severity (95% CI)	Injury burden[c] (95% CI)	Difference on injury burden[d]
Overall[a]	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)
Type of exposure[a]							
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)
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)
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)
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)
Head/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)
Mechanism							
Non-contact	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)
Ball/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)
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)
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)

IQR: 25%–75% interquartile range; 95% CI: 95% confidence interval.
[a] Details on onset, body location, and mechanism are unknown for 12 (27%) and 16 (24%) injuries in the intervention and control group, respectively. Such injuries are included in the overall calculation, and in the categorization by severity and type of exposure only.
[b] Number of injuries per 1,000 player-hours of field hockey.
[c] Days of play time-loss due to injury per 1,000 player-hours of field hockey.
[d] Positive values favour the intervention group.

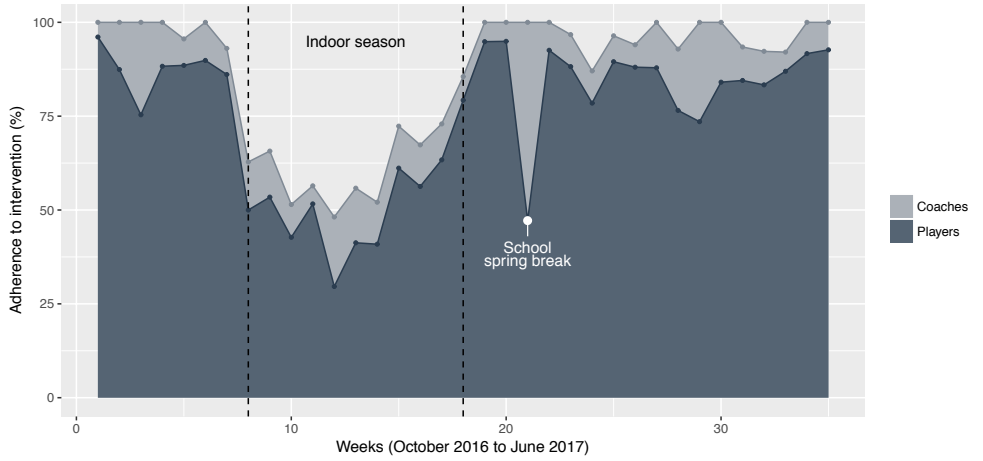

Figure 2. Adherence to the Warming-up Hockey program over in youth field hockey teams by week. The light grey area shows the percentage of coaches delivering the program to players. The dark grey area shows the percentage of players present during the program delivery. The indoor season is a standard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

DISCUSSION

The aim of this study was to evaluate the effectiveness of a structured warm-up program (i.e. Warming Hockey) regarding its potential to reduce the rate and severity (in terms of time-loss from play) of injuries in a convenience sample of youth field hockey. This was pursued in a quasi-experimental design. In addition, this study investigated the effect of the Warming-up Hockey program on the burden of injuries on players' participation in field hockey.

Injury rate

The overall injury rate was lower in the intervention group during the study, but this was not statistically significant (Table 2). However, we did observe a significant reduction of acute injuries and minor injuries (i.e. injuries with 1–3 days of play time-loss). In spite of the non-statistical-significance of the overall finding, we do consider the 36% reduction in overall injury rate meaningful for practice. We follow the same

reasoning for lower limb injuries, which are the most common injured body location in field hockey.[16] Despite the non-significant difference, the injury rate was 46% lower in the intervention group. Comparable findings have been reported by studies investigating the effect of exercise-based injury prevention programs on diverse youth team sports, such as football (soccer) and basketball. A meta-analysis showed that exercise-based injury prevention program in youth organized sports can reduce injuries by 46%.[22] Comparing our results with other studies on field hockey is not possible since, to the best of our knowledge, this is the first study evaluating the effectiveness of a structured exercise-based injury prevention program in the sport.

Injury severity

The severity of injuries was not significantly different between groups (Table 3). Descriptively, the medians and means of days of play time-loss were relatively higher for some measures in the intervention group (e.g. lower limb). This may be explained by the higher effectiveness of the intervention program in preventing injuries leading to 1-3 days of play time-loss (Table 2). Since the injuries in the control group had a more right-skewed distribution regarding play time-loss compared to the intervention group, 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. However, it should be noted that time-loss is only one of the important measures of injury severity. The impact of injuries on athletes' performance[26] and/or the monetary costs to treat such injuries are examples of other severity measures.[35] Due to logistic reasons, time-loss was the only option for estimating the severity of injuries in this study. Future studies are encouraged to use other severity measures when evaluating the effect of preventative strategies in field hockey, such as reduction in players' performance and monetary costs to treat the injuries at hand.

Injury burden on players' availability to play

In sports injury prevention, one is interested in reducing the absolute number *and* the severity of injuries.[36] 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 research,[29–31] because it is a cross-product of the injury rate *and* severity. Using this cross-product is preferable in order to estimate 'risk' given that factors might affect both the rate and severity of injuries.[29] In the present study, the burden of injuries on players' availability to play was lower in the intervention group (Table 4). This means that, when considering injury rate and severity altogether, the negative impact of injuries on players participation in field hockey, or availability to play, was lower in the intervention group.

Adherence to intervention

The adherence to the intervention by coaches during the study period (i.e. median of 93.5%) can be considered high. The same can be concluded for the actual players' intervention 'uptake' (i.e. median of 84.3%), which is obviously driven by circumstances that go beyond the sporting context, such as a school spring break, or players' absence to a session due to personal circumstances. An important constraint to the intervention adherence was, however, the indoor season period (Figure 2). The indoor season is an official period in the Netherlands due to the weather conditions during winter. During this period, teams play in different and smaller indoor facilities than their usual outdoor field hockey pitch. In addition, teams have tighter time slots for training and game sessions since they need to share the indoor facilities with other teams. This change in the context during the indoor season may explain the lower adherence to the intervention during this period. Therefore, the intervention program should be adapted in order to facilitate its execution during the indoor season; or the logistics of the indoor season should be adapted in order to facilitate the adherence to the intervention program. Further investigation is needed to verify the feasibility of these potential adaptations, as well as the effect of higher adherence to the intervention during the indoor season period on injury outcomes.

Methodological considerations

The present study was a quasi-experiment in which we had to deal with the request of the Royal Dutch Hockey Association (KNHB) to evaluate an already existing intervention program. We were also restricted by them regarding the research design, which made a randomised controlled trial design impossible. This has restricted the internal validity of the results due to the non-random allocation of participants to intervention and control group.[37] However, the approach taken in our study can be considered closer to a real-world context in which the findings are to be applied.[38]

We applied the mixed effects Cox models to handle multi-level data – multiple injuries in a player, and multiple players in a team – which happens to be the case in a team-sport setting. This can be considered a strength of this study. Players were clustered into teams and included in the models as Gaussian random effects, also known as frailty models.[32] Frailty models have been recommended for sports injury data analyses in order to consider exposure and subsequent injuries data after the first injury (i.e. not data until first injury only).[39]

The close follow-up of participants in this study was conducted to minimise recall bias, as well as non-response during data collection on player-specific exposure to field hockey and injury details. However, it did not prevent complete non-responsiveness from participants. Due to non-response of players' parents, even after several contact attempts, it was not possible to register specific information on some injuries. The lack of details on such injuries (i.e. onset, mechanism, and body location) may have inflated the injury rate in both groups, in case those injuries were not related to field hockey. Conversely, the figures of injury onset, body location, and mechanism may have been underestimated since the lack of details made it impossible to include these injuries in such categories. These injuries with missing details were included in the overall calculation given that their proportion was similar in the intervention and control group – 27% and 24%, respectively (Table 2–4).

CONCLUSION

The exposure to the program was associated with a 36% lower injury rate. Although this difference did not reach statistical significance, we consider this result meaningful for practice. The lower injury rate was mainly due to a reduction of acute injuries and injuries leading to 1–3 days of field hockey time-loss, where significant differences are observed. No reduction was observed in the severity of injuries alone. However, the burden of injuries on players' participation in field hockey was significantly lower in the intervention group. Stakeholders interested in reducing the injury rate in youth field hockey, as well as players' availability to play, can implement the Warming-up Hockey program in their team. Further investigation is needed in order to facilitate teams' adherence to the Warming-up Hockey program during the indoor period of the Dutch season, as well as the effect of such adherence on injury outcomes.

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