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Neuromuscular exercises prevent severe knee injury in adolescent team handball players

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Abstract
Purpose Team handball is associated with a high risk of severe knee injury that needs to be reduced, particularly at the youth level. The purpose of this study was to show how an injury-prevention programme effectively reduces severe knee injury in adolescent team handball players.
Methods Of 23 adolescent handball teams of both sexes, 13 were randomly allocated into the intervention group (168 players) and 10 into the control group (111 players). Players of the intervention group regularly participated in an injury-prevention programme for one season. Handball exposure and sustained injuries were documented for both groups on a monthly basis. The primary outcome parameter of the injury-prevention programme was the incidence of severe knee injury.
Results Of the 279 included players, 68 (24%) sustained 82 injuries yielding an overall incidence of 1.85 injuries per 1000 h handball exposure (intervention group: 50 injuries/incidence: 1.90/1000 h; control group: 32 injuries/incidence: 1.78/1000 h). Knee injury was the second most frequent injury in adolescent team handball. The primary outcome parameter, severe knee injury occurred significantly more often in the control group [mean age (SD) 15.1 (1.0), injury incidence 0.33/1000 h] than in the intervention group [mean age (SD) 14.9 (0.9), injury incidence 0.04/1000 h]. The odds ratio was 0.11 (95% CI 0.01–0.90), $p = 0.019$. Other injuries to the lower extremities showed no significant difference between the two groups.
Conclusions Frequent neuromuscular exercises prevent severe knee injury in adolescent team handball players and should thus be included in the practical routine as well as in the education of team coaches.

Keywords Team handball · Handball · Adolescent · Injury · Prevention · Knee · Anterior cruciate ligament

Introduction

Team handball is one of the most popular team sports worldwide, particularly in Europe. Thus, team handball has become of increasing interest to sports physicians and orthopaedic surgeons [23]. Injuries in team handball are common and hence well published in the literature but most of these studies have focussed on the injuries of adult and elite team players [4, 11, 22, 28]. Yet, knee injury—mainly tearing of the anterior cruciate ligament (ACL)—is also the most frequent severe injury in team handball in the age group of 15 to 19 years [5, 22]. Prevention programmes for ACL injury have been shown to be effective in other team sports, such as football and senior team handball [17, 25]. However, little evidence exists regarding the potential benefits for the high-risk injury group of adolescent team handball players, especially that of men.

The purpose of this study was to implement and analyse an injury-prevention programme for adolescent team

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handball players that included sufficient and practicable exercises to reduce injury rates. Based on previous findings, it was hypothesized that frequent neuromuscular exercises decrease the incidence of severe knee injury in adolescent team handball players of both sexes [17, 18, 20, 21, 29, 30].

Materials and methods

Team handball players of both sexes aged under 16 (u-16) and under 18 (u-18) years were included in this study. The registration of each participating team and player started at the beginning of the season 2015/16. We used block randomisation in which teams were allocated into one of four groups for each sex and age group. Within each group, blocks of two teams were assigned into the intervention or control group. Severe knee injury was defined as the primary outcome parameter and injury to the lower extremities as the secondary outcome parameter. A secondary analysis of injuries to the ankles and upper extremities was also included.

All participants received detailed instructions about the study design and the planned study protocol. Team coaches in the intervention group received detailed informations on the implemented injury-prevention programme. Apart from the instructions on each exercise by means of pictures and videos, the team coaches were informed about the aims of the injury-prevention programme as well as the typical injury profiles and mechanisms in team handball. The study coordinator additionally informed the team coaches about the mechanisms of injuries to the upper and lower extremities and the typical injury mechanisms in team handball, such as ankle sprain and dynamic knee valgus. Similar to other studies, instructions also included the correct landing technique and alternative handball-specific landing techniques [27]. The teams of the control group continued their usual training modules over the study season. The personal and anthropometric data of the players were collected by means of a standardised questionnaire at the beginning of the season.

Injury-prevention programme

The injury-prevention programme consisted of 15 min training exercises two to three times per week during the 10- to 12-week preseason and of 15 min training exercises once per week during the competition period. A handball-specific injury-prevention programme developed for the daily routine in adolescent team handball consisted of two different sets of exercises. Each set comprised five exercises which progressed in three steps from easy to more difficult. After a player's progression to the most difficult level of an exercise module, the team coaches were free to choose between the different exercise levels available (Fig. 1, 2, 3, 4).

The programme included jump exercises, landing exercises, proprioceptive exercises, plyometric exercises and strength exercises for the quadriceps, hamstring and core muscles (Table 1). Most exercises had already been shown to prevent injury to the lower extremities in previous studies [3, 7, 10, 13, 17, 25, 27]. All exercises could be executed without using any additional equipment.

Injury definition

Injury was defined as time-loss injury if it was caused by playing handball during training or competition and if it resulted in absence from at least one training session or match. Injuries were graded into five categories of severity, i.e. minimal (absence from team handball of 0 days), slight (1–3 days), mild (4–7 days), moderate (8–28), and severe (> 28 days) [2, 19, 25, 27]. Primary outcome parameters for severe knee injury were defined as intraarticular fracture, patella luxation, rupture of the collateral or cruciate ligament, meniscus tear or cartilage injury. An injury was categorised as overuse injury if no traumatic event could be identified and as re-injury if the injury occurred at the same body site.

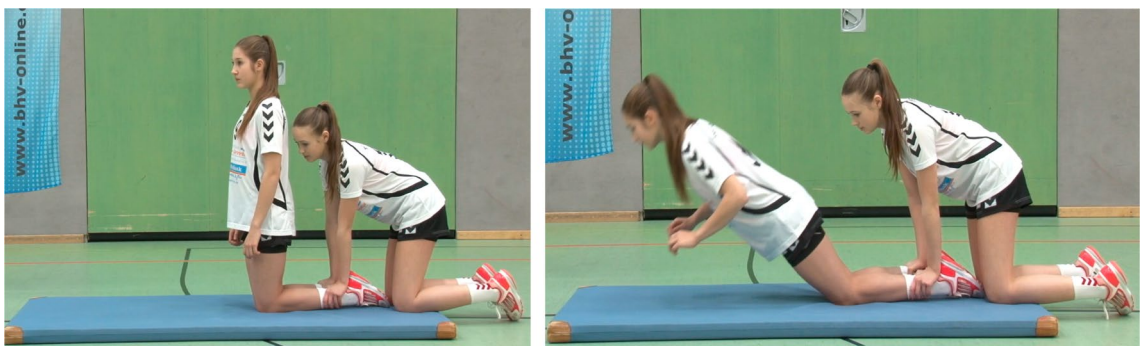

Fig. 1 Module 1: strengthening exercises: eccentric strengthening of the hamstring muscles

Fig. 2 Module 2: plyometric exercises: single-leg multidirectional jumps with short ground contact time

Fig. 3 Module 3: jump and landing exercises: single-leg jump and contraleral single-leg landing exercise

Data assessment

Diagnoses were made by a member of the medical staff. Every month, the coaches had to document the training and match exposure of each player in minutes and had to report injury details such as diagnosis and treatment by means of an online questionnaire or by directly contacting the study team [2, 15, 16]. The injury report questionnaire had been adapted to the commonly used injury report protocols used in team sports and previous studies [2, 16,

Fig. 4 Module 4: proprioceptive exercises: single-leg stabilisation exercise

17, 19, 27]. Injury incidence was calculated per 1000 h of team handball exposure during matches and training as well as the sum of training and matches. According to the official match duration in each age group, 60 min was calculated for each match for u-18 players and 50 min for u-16 players.

An informed written consent was obtained from all study participants and their parents. The study design was approved by the Ethics Committee of the University of Regensburg (ID: 15-101-0137).

Statistical analysis

Continuous data are expressed as mean and standard deviation (SD) and categorical data as frequency counts (percentages). The primary endpoint 'incidence of severe injuries to the knee' was compared between the two study groups by means of an exact test based on the Poisson distribution. Logistic regression models were calculated to estimate the effect of the training programme on different types of injury. Odds ratio (OR) and corresponding 95% confidence intervals (CI) are reported. The significance level was set to $p < 0.05$ and high significance to $p < 0.01$. No sample size was calculated for the investigation of lower extremity injuries because the aim of the study was to recruit as many youth teams of the regional handball association as possible for the season of intervention. All analyses were conducted using IBM SPSS Statistics, version 24.

Results

Of the 30 initially registered teams, 7 dropped out because of the inability to provide the required monthly documentation. Nine more players dropped out because they stopped playing for their team during the study period or because their parents withdrew their consent. Twenty-three teams (13 teams in the intervention group with 168 players and 10 teams in the control group with 111 players) participated in the study until the end of the season; 98 female and 70 male players of the intervention group and 76 female and 35 male players of the control group showed similar anthropometric data and were homogenous with regard to handball exposure and the position on field (Table 2). The mean age for the intervention group was 14.9 years [SD (0.9)] and 15.1 years [SD (1.0)] for the control group.

Overall exposure to team handball in training and matches was 44,207 h for the complete study population and 158.4 h per player. Sixty-eight (24%) of the 279 players sustained 82 injuries resulting in an overall injury incidence of 1.85 injuries per 1000 h handball exposure. U-18 players had a higher handball exposure per player than u-16 players—225.9 h vs. 146.8 h—but the same injury incidence of 1.85 injuries vs. 1.86 injuries per 1000 h handball exposure.

The comparison of the injury incidence between the two sexes showed 1.91 injuries per 1000 h handball exposure for male players and 1.78 injuries for female players (p = n.s.). The injury incidence was 1.0 per 1000 h training

Table 1 Intervention programme

Exercise module	Exercise examples
Module 1: strength exercises	Plank, side plank, Nordic hamstring
Module 2: plyometric exercises	Multidirectional single-leg jumps
Module 3: jump and landing exercises	'Ice-skater' jump, jump run
Module 4: proprioceptive exercises	Standing on one leg with closed eyes, trying to destabilise the partner by pressing against their body

Table 2 Anthropometric and handball-specific data

	Intervention group ($n = 168$)	Control group ($n = 111$)
Anthropometric data	Mean ± SD (range)	Mean ± SD (range)
Age (years)	14.9 ± 0.9 (13–18)	15.1 ± 1.0 (13–18)
Height (cm)	171.2 ± 9.2 (156–198)	173.8 ± 9.9 (152–203)
Weight (kg)	64.3 ± 9.7 (49–94)	65.5 ± 11.3 (40–93)
BMI (kg/m^2)	21.1 ± 2.1 (17.9–28.0)	21.8 ± 2.7 (17.3–29.0)
Handball-specific data	*n* (%)	*n* (%)
Position on field		
Goalkeeper	23 (13.7)	12 (10.8)
Wing player	33 (19.6)	33 (29.7)
Back court player	53 (31.5)	43 (38.7)
Pivot	16 (9.5)	13 (11.7)
Variable	43 (25.6)	10 (9.0)
Handball exposure		
Overall handball exposure over the season (h)	26,278 (100)	17,929 (100)
Overall match exposure (h)	3,327 (12.7)	1,787 (10.0)
Overall training exposure (h)	22,952 (87.3)	16,142 (90.0)
Overall handball exposure per player (mean in h)	156.4 ± 84.8	161.5 ± 54.7
Match exposure per player (mean in h)	19.8 ± 9.0	16.1 ± 7.1
Training exposure per player (mean in h)	136.6 ± 82.5	145.4 ± 48.5

SD standard deviation

exposure and 8.2 per 1000 h match exposure. Sixty-eight (83%) of all injuries were traumatic injuries and 14 (17%) were overuse injuries. Nine players of the study population sustained more than one injury per season. Five players had two injuries and four players had three injuries per season. The most affected body site was the lower extremities with 59% ($n = 48$). The ankle was the most frequently injured body site in both groups, followed by the knee (Table 3). The prevalence of severe knee injury was 2.5%. Anatomic sites for fractures were the lower arm, thumb, tibia, ankle, foot, and toe. Dislocations occurred at the dominant shoulder and the dominant thumb and finger.

The primary outcome parameter 'severe knee injury' occurred significantly more often in the control group (injury incidence 0.33/1000 h) than in the intervention group (injury incidence 0.04/1000 h) with an odds ratio of 0.11 (95% CI 0.01–0.90), $p = 0.019$. Four male and three female players sustained a severe knee injury (Table 4).

For secondary parameters, no difference could be found. The intervention group did not significantly differ from the control group with regard to the incidence of injury to the lower extremities (intervention group: 1.03 injuries per 1000 h handball exposure; control group: 1.17 injuries per 1000 h handball exposure; n.s.), ankle injuries (intervention group: 0.42 injuries per 1000 h handball exposure, control group 0.45 injuries per 1000 handball exposure, OR 0.82, 95% CI 0.34–2.02; n.s.) or injuries to the upper extremities (intervention group: 0.61 injuries per 1000 h handball exposure, control group 0.39 injuries per 1000 h handball exposure, OR 1.47, 95% CI 0.580–3.731; n.s.) (Table 5).

In the intervention group, 42 players (25%) sustained 50 injuries; in the control group, 27 players (24%) sustained 32 injuries.

Discussion

The most important finding of this study is that frequent neuromuscular exercises prevent severe knee injury in adolescent team handball players of both sexes.

Severe knee injuries, such as ACL tears, represent a serious problem in youth team sports because of their association with long absence from sports, decrease in physical performance and potential posttraumatic long-term consequences because of the injured joint [5, 12, 24]. For this reason, injury-prevention programmes and all other measures to avoid severe knee injury should start at the youth level [8, 9, 13]. The injury-prevention programme used in this study focussed on the lower extremities and consisted of training modules to prevent severe knee injury typical for team handball [11, 20, 30]. The

Table 3 Overall injury pattern

Injury pattern	Intervention group (n = 168)		Control group (n = 111)	
	Number of injuries (%)	Injuries from 1000 h exposure	Number of injuries (%)	Injuries from 1000 h exposure
Injury localisation				
Head/neck	3 (6%)	0.11	3 (9%)	0.17
Chest	1 (2%)	0.04	0	0
Back	2 (4%)	0.08	0	0
Shoulder	4 (8%)	0.15	2 (6%)	0.11
Elbow/forearm	3 (6%)	0.11	0	0
Wrist/hand	4 (8%)	0.15	4 (13%)	0.22
Finger	5 (10%)	0.19	1 (3%)	0.06
Hip/groin	2 (4%)	0.08	1 (3%)	0.06
Thigh	2 (4%)	0.08	0	0
Knee	8 (16%)	0.30	7 (22%)	0.39
Calf/Achilles	2 (4%)	0.04	0	0
Ankle	11 (22%)	0.42	8 (25%)	0.45
Foot	3 (6%)	0.11	6 (19%)	0.33
Injury severity				
Minimal	8 (16%)		0	
Slight	15 (30%)		0	
Mild	10 (20%)		6 (19%)	
Moderate	9 (18%)		10 (31%)	
Severe	8 (16%)		16 (50%)	
Type of injury				
Abrasion/cut	1 (2%)		0	
Contusion	10 (20%)		2 (6%)	
Sprain	16 (32%)		11 (34%)	
Strain	6 (12%)		1 (3%)	
Fracture	3 (6%)		3 (9%)	
Dislocation	2 (4%)		1 (3%)	
Rupture	2 (4%)		4 (13%)	
Concussion	0		3 (9%)	
Other	10 (20%)		7 (22%)	

exercises and modules employed are suitable for the daily routine of youth team handball players of both sexes. As shown in other team sports, exercises that require no or low financial investment may help achieve the continuous implementation of such modules [6, 18, 26, 27]. This fact was confirmed by the present level-1 study that did not use any additional equipment in adolescent team handball. Because of the low compliance at adolescent age levels, team coaches should monitor the implementation of these prevention exercises in the daily routine of team training sessions. The principles of handball-specific injury prevention should be included in the education of team coaches, which is the task of national and international handball associations.

The incidence of severe knee injury in this study was comparable to that in the previous literature [11, 20, 22]. No potential differences in injury occurrence between the sexes were found. Further analysis of risk factors for sustaining ACL injury in youth team handball may be useful to further improve injury prevention [5].

This study also analysed other typical team handball injuries. The overall injury incidence in youth team handball players in this study was lower than that of senior male and female team handball players but similar to epidemiological studies of the same age groups [11, 22, 23, 29]. Ankle sprains were the most common type of injury but no difference could be found between the intervention group and the control group. The injury rate for the upper extremities also showed a high injury incidence. Further research should evaluate the effectiveness of injury-prevention programmes for the upper extremities in youth team handball [1, 14].

This randomised controlled intervention study has some limitations. Several teams and players had dropped out before the start of the study period. Data were recorded monthly by the team coaches, but self-reported injuries may lack adequate medical information in comparison to injury reports directly compiled by medical staff. No sample size was calculated for the investigation of injuries to the lower extremities because we recruited as many youth teams of the regional handball association as possible for the season of intervention. Future studies should include larger samples to confirm the effect of the training modules on preventing other types of injuries and injuries to other body sites, such as the shoulders.

This study showed the effectiveness of simple injury-prevention exercises during training sessions. Thus, the results can be considered clinically relevant for team handball routines. The exercises do not require any equipment and can easily be implemented in the subpopulation of adolescent handball players who are often less inclined to comply with training and warm-up exercises.

Conclusion

This study showed that the frequent implementation of training modules with specific neuromuscular exercises may help prevent severe knee injury in adolescent team handball.

Table 4 Knee injuries

Knee injuries	Intervention group ($n = 168$)		Control group ($n = 111$)	
	Number of injuries (%)	Injuries from 1000 h exposure	Number of injuries (%)	Injuries from 1000 h exposure
All knee injuries	8 (16%)	0.30	7 (22%)	0.39
Severe knee injuries	1 (2%)	0.04*	6 (19%)	0.33
ACL injuries	1 (2%)	0.04	2 (6%)	0.11
PCL injuries	0	0	1 (3%)	0.06
MCL/LCL injuries	0	0	2 (6%)	0.11
Meniscus injuries	0	0	1 (3%)	0.06
Less severe injuries	7 (14%)	0.27	1 (3%)	0.06

*$p < 0.05$, **$p < 0.01$

Table 5 Ankle injuries

Ankle injuries	Intervention group ($n = 168$)		Control group ($n = 111$)	
	Number of injuries (%)	Injuries from 1000 h exposure	Number of injuries (%)	Injuries from 1000 h exposure
All ankle injuries	11 (22%)	0.42	8 (25%)	0.45
Ankle sprains	10 (20%)	0.38	7 (22%)	0.39
Ankle fractures	0	0	1 (3%)	0.06
Other	1 (2%)	0.04	0	0

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Ethical approval The study was approved by the Ethical committee of the University of Regensburg.

Informed consent Players and parents were informed, and they consented to conduct the study.

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