The effectiveness of a Warm-up Program to reduce injuries in Youth Volleyball Players: A Quasi-Experiment

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ABSTRACT

Objectives

To establish the effectiveness of the 'VolleyVeilig' programme on reducing injury rate, injury burden, and injury severity in youth volleyball players.

Methods

We conducted a quasi-experimental prospective study over one volleyball season. After randomisation by competition region, we instructed 31 control teams (236 children, average age 12.58 ± 1.66) to use their usual warming-up routine. The 'VolleyVeilig' programme was provided to 35 intervention teams (282 children, average age 12.90 ± 1.59). This programme had to be used during each warm-up before training sessions and matches. We sent a weekly survey to all coaches, collecting for each player their volleyball exposure data and any injuries sustained. Multilevel analyses estimated differences in injury rates and burden between both groups, and we used nonparametric bootstrapping to compare the differences in injury numbers and injury severity.

Results

We found an overall reduction in injury rates of 30% for intervention teams (HR 0.72; 0.39 – 1.33). Detailed analyses revealed significant differences for acute (HR 0.58; 95%CI: 0.34 – 0.97) and upper extremity injuries (HR 0.41; 95%CI: 0.20 – 0.83). Compared to control teams, the intervention teams had a relative injury burden of 0.39 (95%CI: 0.30 – 0.52) and a relative injury severity of 0.49 (95%CI: 0.03 – 0.95).

Conclusion

We established that the 'VolleyVeilig' programme was associated with reduced acute and upper extremity injury rates and lower injury burden and severity in youth volleyball players. Based on these outcomes, we advise implementation of the programme, while, at the same time, programme updates should improve adherence and, subsequently, the preventive effect of the programme.

WHAT IS ALREADY KNOWN ON THIS TOPIC

- Despite being a non-contact sport, volleyball is an injury prone sport with a high number of participants globally, and around 25% of all volleyball related injuries occur among youth players.
- Exercise-based warm-up programmes to prevent injuries in volleyball have been systematically developed and evaluated successfully. However, the available evidence on injury risk reduction in youth volleyball is lacking.

WHAT THIS STUDY ADDS

- The 'VolleyVeilig' warm-up programme is associated with reduced injury rates in youth volleyball players, specifically acute injuries and injuries to the upper extremity.
- The 'VolleyVeilig' programme had a positive impact on the severity of injuries, as measured by a reduction in the number of sports days missed due to injury.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- 'VolleyVeilig' provides a youth-specific, feasible and effective warm-up programme that can have significant impact on injuries and their severity.
- Implementation of the programme is recommended, but programme updates should improve adherence and, subsequently, the preventive effect of the programme.

INTRODUCTION

The international literature has shown that injuries are common among volleyball players, with an incidence rate ranging from 1.7 to 10.7 injuries per 1,000 playing hours [1]. In the Netherlands, volleyball is in the top 5 sports with the highest absolute number of injuries, with an annual average of 170,000 injuries between 2006 and 2014 [2]. Around 25% of the total number of volleyball related injuries occur among youth volleyball players (aged <19 years) [2]. As a consequence of both the number and the severity of injuries occurring in volleyball, the Dutch Volleyball Federation (Nevobo) and its partners systematically developed an exercise-based warm-up programme to prevent or reduce injuries among youth and adult volleyball players [3]. The effectiveness of this 'VolleyVeilig' programme was recently assessed in adult Dutch recreational volleyball [4]. The programme led to a trend in lower acute injury rates in adult players. However, the effect interventions need to be examined considering their context [5]. When compared to the structure and organisation of adult sports participation, the structure and organisation of youth sports, such as the availability of coaches and the structure of competitions, are generally different. Also, it has been well described in the scientific literature that the injury risks faced by young athletes are different from those faced by adults [6-8]. As a result, the subsequent step that should be taken would be to determine whether the intervention is also successful among young volleyball players. Therefore, the current study's objective was to evaluate 'VolleyVeilig''s effectiveness in recreational youth volleyball players. We hypothesised that over one season, the 'VolleyVeilig' programme would be associated with reductions in injury rate, injury severity, and injury burden among youth volleyball players.

METHODS

Study Design & participants

We conducted a quasi-experimental prospective study over one volleyball season in The Netherlands (September 2019 - March 2020). We based our study design on previous studies looking at effectiveness of injury prevention programs in sport [9, 10]. This study and its procedures were approved by the Medical Ethical Committee of Amsterdam UMC (2019.109).

The Nevobo hosts 4 competition regions, North, South, East and West. Through simple randomisation with random numbers, we allocated these regions into a control group (CG; West & North) and an intervention group (IG; East & South). Participating teams were subsequently

allocated according to the region they play. The competition regions are comparable in (level of) competition and youth divisions.

For our study, the Nevobo invited all coaches with a team in the B (14-17 years), C (12-14 years), or D (10-12 years) youth divisions to participate. This was done with an open call through the association's media channels and directly contacting all licensed trainers and clubs (n = 1,080). For all coaches interested in partaking, we hosted explanatory meetings during which we provided written and oral explanations on the purpose and procedures of the study. These meetings were organized separately for each competition region, and we revealed study allocation during these meetings. We obtained informed consent from participating coaches and their teams' players and/or parents. Parents signed the informed consent form for players under 12 years of age; if a player was between 12 and 16, both the player and the parents were asked to sign the consent form. Players 16 years or older signed the informed consent form themselves. We only registered data for team members after we received consent from both the coach and the (parent of the) player.

Sample size

Around 500,000 Dutch athletes play volleyball, and between 2006 and 2014, 170,000 volleyball injuries occurred annually[2]. These figures correspond to a population prevalence of volleyball related injuries of 36%. In Dutch youth sports, warming-up programmes similar to 'VolleyVeilig' were found to lead to a 50% reduction in injury rates [10, 11]. We estimated a similar potential reduction of injury rates for our study. Using these numbers and assuming a two-sided alpha of 0.05 and a beta of 80%, we calculated a required sample size of 164 volleyball players per study group. Further, we considered that youth volleyball teams generally consist of 10 players and took a team intracluster correlation coefficient (ICC) of 0.05 and the subsequent design effect of 1.45 into account. In the absence of available ICC data, we had to consider this value based on our previous experience with preventive trials in youth team sports. In the end, our calculations showed for our study a required sample of 480 players distributed over 48 teams (i.e., 24 teams per study group).

'VolleyVeilig' youth programme

We instructed CG teams to use their usual warming-up routine and asked IG teams to use the 'VolleyVeilig' programme during each warm-up before training sessions and matches. The

Nevobo and VeiligheidNL developed the 'VolleyVeilig' intervention with sports physiotherapists, volleyball coaches and other injury prevention experts. The development process and the resulting programme for adults (16+ years) are described elsewhere [3]. Together with paediatric physiotherapists, the exercises from the adult programme were made suitable for children aged 9-11 and 12-15 into the 'VolleyVeilig' youth programme. For the youngest age group, the programme paid specific attention to playful elements. The programme further included a gradual increase in training load and strength exercises throughout the season, and the use of elastic bands was restricted to children aged over 12 only.

The 'VolleyVeilig' programme was to be performed at least twice a week, and each session lasted approximately 15 minutes consisting of different exercises. The programme was designed to span a volleyball season and consisted of six phases, lasting five to six weeks each. These phases followed the course of the volleyball season and considered regular holiday breaks, running from the end of the summer break (Phase 1), through the end of the competition season (Phase 5), to the post-competition (Phase 6).

- Phase 1 Start season: end summer break (calendar week 40)
- Phase 2: Autumn (calendar weeks 41-45)
- Phase 3: Before the Christmas break (calendar week 46-51)
- Phase 4: Before the spring break (calendar weeks 2-7)
- Phase 5: Before end of season (calendar weeks 9-13)
- Phase 6: Post-competition (calendar weeks 14-18)

Each session had the same preparatory cardiovascular and core stability components, and exercises focused on the knee, shoulder, and ankle. The exercises progressively increased in frequency, duration, and complexity throughout the season.

A mobile application with a synchronized Web site delivered the programme to the IG coaches through explanatory videos and textual descriptions (www.volleyveilig.nl; in Dutch). The 'VolleyVeilig' youth programme was not publicly accessible before and during the study period. After providing consent, only IG coaches were granted access to the programme.

Data Collection

Baseline & demographic variables

At baseline (September 2019), we sent the players' parents an email with a link to an online questionnaire. This questionnaire asked about their child's characteristics, including age and gender, sports participation, years of volleyball experience, and information on injuries sustained in the previous season. The questionnaire was the same for the IG and CG. At baseline, we also sent coaches a questionnaire collecting information on their experience as a (youth) trainer, motivation to participate in the study, characteristics of their team (age category, training routine, competition level), and their usual (regular) warm-up routine.

Weekly exposure and injury registration

We sent a weekly online survey to all coaches, collecting for each player their volleyball exposure data. The same procedure has been used successfully in previous trials on sports injury prevention by our research group [4, 9, 10]. Coaches would report the full duration for each training session and match, as well as the participation of each player (0%, 25%, 50%, 75%, 100% of the session) and the reason in case of incomplete participation (injury or other). Individual players' exposure was calculated based on their participation in each session. In addition, we asked coaches from the IG to report for each session whether the 'VolleyVeilig' youth programme was used and to what extent (not used, partially used, or fully used). The CG coaches reported similarly whether they performed any type of structured warm-up (yes or no).

An injury was defined as any musculoskeletal condition or concussive event that caused the player to stop the current volleyball session or not fully participate in the next planned volleyball session (i.e., time-loss injury). When a coach reported an injury in the weekly survey, we asked the coach to provide injury information, if possible, with input from the parents and the injured player. We used the Australian Sports Injury Data Dictionary to register the specific injured body location, injury type, injury diagnosis, injury mechanism, first aid received, and medical attention [12]. If we did not receive this information after 4 days, we sent a reminder. In the case of no response to the reminder, we contacted the coach by phone.

Data Analysis

Data processing and analyses were performed in IBM SPSS Statistics for Mac, version 28 (IBM Corp., Armonk, N.Y., USA)[13-15] and Microsoft Excel for Mac (version 16.52; Microsoft Corp, Redmond, WA). The primary researcher (EV) conducted all analyses. He was not blinded to each participant's group allocation. We conducted the analyses for overall, acute, and overuse injuries and upper and lower extremity injuries separately.

We performed descriptive analyses on players' characteristics at baseline. Discrete and continuous variables were compared between groups using the Pearson X^2 and Mann-Whitney tests, respectively. Adherence to the intervention was calculated by week as no adherence (<25%), partial adherence (25% to 75%), or full adherence (>75%). We assessed adherence per week and categorised adherence by training and match session.

Injury incidence rate

The injury incidence rate and the corresponding 95% confidence interval (95% CI) was calculated as the number of new injuries per 1,000 exposure hours of volleyball activities [16, 17]. In this calculation, we only took the exposure hours until the time of injury into consideration. We performed a shared-frailty Cox proportional hazard regression analysis to estimate between the IG and CG the hazard ratios (HRs) and 95% confidence intervals (CIs). Teams were used as cluster levels. We decided a-priori to adjust the analyses for gender, age, and previous injury based on previous literature describing these variables to be potential confounders. Further, we checked whether competition level, years of volleyball experience or participation in other sports were confounders or effect modifiers. None of these, however, affected the analyses.

Injury severity and burden

The severity of injuries (i.e., the cumulative days lost from play) was summarized as the median time loss of all registered injuries and the range. We calculated the burden of injuries and the corresponding 95% CI as the number of cumulative days of time-loss due to injury per 1,000 hours of volleyball exposure following previously proposed methods [16, 18, 19].

Injury rate vs severity

Finally, we compared the differences in injury rate against injury severity between the IG and CG [20]. This analysis followed a standard approach as would be used in a cost-effectiveness analyses, under the assumption that injury severity follows a similar skewed distribution as injury related costs. To account for the skewed nature of injury severity, we used simple nonparametric bootstrapping with 1,000 replications to acquire a bootstrapped sample of data sets. In each of the resulting data sets we calculated, while considering the clustered nature of our data, 95% confidence intervals (CIs) around the relative severity and injury rate differences. Uncertainty surrounding these differences is shown in a severity-effectiveness plane with the CG at the origin.

RESULTS

Study population

Initially, 82 coaches responded to our invitation for participation, of whom 65 met our inclusion criteria (Figure 1). Eventually, 6 coaches and 60 players could not commence the study for various reasons (e.g., change of team or personal reasons), which gave us a total sample of 36 IG teams (298 players) and 32 CG teams (246 players). After follow-up, 2 coaches and 10 players were lost in our sample, which gave us 35 IG teams (282 players) and 31 CG teams (236 players) for our analyses. In total, 79 boys and 439 girls playing in 66 teams participated in this study (Figure 1). Their age was between 8 and 17 years, with an average of 12.76 years (SD = 1.63). The players had between 0 and 12 years of volleyball experience, which a median of 4.0 years (IQR = 4.0). Characteristics of participating teams and players are presented in Table 1.

The percentage of teams that fully adhered to the intervention was on average 44% (SD ± 16%; range: 19% in week 26, 78% in week 6) for training sessions and 51% (SD ± 18%' range: 0% in weeks 16 and 17, 75% in week 1) for matches (Figure 2).

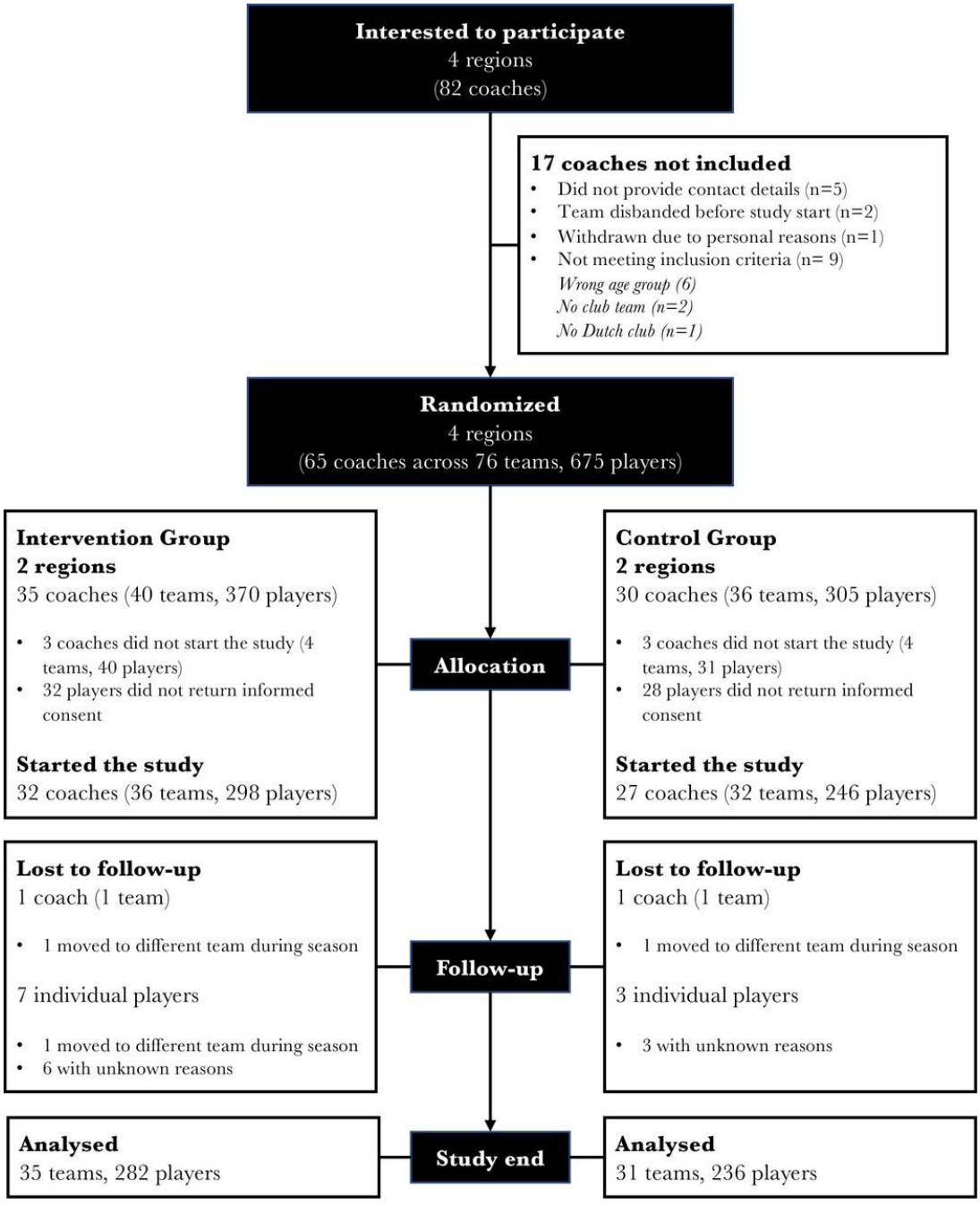

Figure 1 Study design and flow of participants.

Table 1 Characteristics of participating teams and players.

	Total	IG	CG	P value
Coaches (N)	57	31	26	
Teams (N)	66	35	31	
Number of players (N, %)				
Overall	518	282	236	
Boys	79 (15,3%)	33 (11.7%)	46 (19.5%)	0.020
Girls	439 (84.7%)	249 (88.3%)	190 (80.5%)	
Player age (mean ± SD)				
Overall	12.76 ± 1.63	12.90 ± 1.59	12.58 ± 1.66	0.024
Boys	11.77 ± 1.42	11.45 ± 1.23	12.00 ± 1.52	0.082
Girls	12.39 ± 1.60	13.10 ± 1.53	12.72 ± 1.66	0.016
Years of volleyball experience (median; interquartile range)				
Overall	4.0; 4.0	4.0; 3.5	3.5; 3.0	0.002
Boys	3.0; 2.3	3.0; 3.0	3.0; 2.0	0.893
Girls	4.0; 3.5	4.5; 3.0	4.0; 3.0	0.005
Players with an injury in the previous season (N)				
Any injury	180	103	77	0.404
Lower extremity	89	48	41	0.992
Upper extremity	73	44	29	0.341
Average hours of volleyball exposure per player (mean ± SD)				
Overall	69.73 ± 26.14	71.32 ± 25.08	67.84 ± 27.29	0.135
Training	49.78 ± 19.91	50.79 ± 20.11	48.55 ± 19.62	0.201
Match	19.96 ± 9.16	20.53 ± 8.49	19.29 ± 9.88	0.132

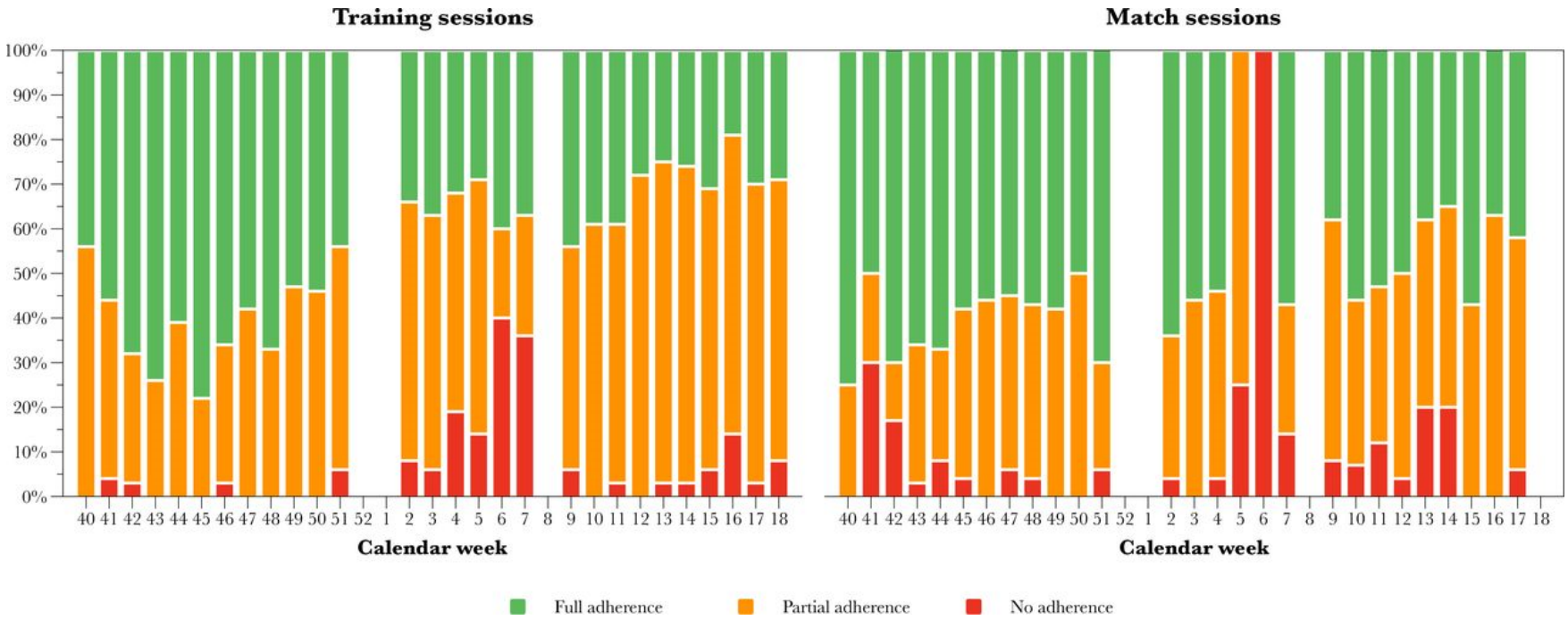

Figure 2 Adherence to the 'VolleyVeilig' programme in IG teams by calendar week of the study, During the weeks 52, 1, and 8 no volleyball sessions were planned due to the Christmas and spring breaks. The left figure represents use of the programme before training sessions, on the right the use before match sessions.

Injury incidence rate

Overall, 76 injuries were reported by the participating players. Of these, 43 were in the CG and 33 in the IG. These numbers corresponded to injury rates of 2.69 injuries per 1,000 hours (95%CI: 1.88 – 3.49) in the CG and 1.64 injuries per 1,000 hours (95%CI: 1.08 – 2.20) in the IG (Table 2). Cox regression analysis revealed overall a reduction in injury rates, which were significant only for acute injuries (HR 0.58; p = 0.037) and upper extremity injuries (HR 0.41; p = 0.013).

Severity and burden of injury

The severity of reported injuries was highly skewed, with a median time loss of 1 day and a range of 1 to 43 days (Table 3). The intervention group had a 61% lower burden of overall injuries. A significant lower burden of injuries in the IG was found for overall, acute, and upper extremity injuries.

Injury rate vs severity

Nonparametric bootstrapping to calculate the relative severity and injury rate differences revealed in the IG an injury rate of 0.76 (95%: 0.46 – 1.25) and an injury severity of 0.49 (95%CI: 0.03 – 0.95) times the rates in the CG (Figure 3). Of all bootstrapped samples, 87% showed lower injury rates and lower injury severity in the IG.

Table 2 Number of incident injuries and corresponding injury rates (number of injuries per 1,000 hours of volleyball exposure) for the CG and IG. Hazard Ratio's between groups were analysed using a Mixed-Effects Cox regression Model, accounting for team cluster effects and corrected for Gender, Age, and Previous injury.

	Control Group		Intervention Group			
	Number incident injuries	Injury Rate (95%CI)	Number incident injuries	Injury Rate (95%CI)	Hazard Ratio (95%CI)	P value
Overall	43[#]	2.69 (1.88 – 3.49)	33[$]	1.64 (1.08 – 2.20)	0.72 (0.39 – 1.33)	0.290
Acute	33	2.23 (1.47 – 2.99)	26	1.35 (0.83 – 1.88)	0.58 (0.34 – 0.97)	0.037
Overuse	2	0.13 (0.00 – 0.30)	7	0.35 (0.09 – 0.61)	2.68 (0.55 – 12.99)	0.224
Upper extremity	22	1.44 (0.84 – 2.04)	12	0.61 (0.27 – 0.96)	0.41 (0.20 – 0.83)	0.013
Lower extremity	15	0.97 (0.48 – 1.46)	18	0.93 (0.50 – 1.36)	0.90 (0.45 – 1.78)	0.753

[#] Of all CG injuries, 8 were with unknown onset and 6 with unknown location

[$] Of all IG injuries, 3 were with unknown location

Table 3 Median and range of time loss in days. Injury burden is expressed as the number of days lost per 1,000 hours of exposure. The relative burden between groups is calculated as the injury burden of the IG divided by the CG.

	Control Group		Intervention Group			
	Median days lost (range)	Injury Burden (95%CI)	Median days lost (range)	Injury Burden (95%CI)	Relative Burden (95%CI)	P value
Overall	2 (1 - 43)	9.74 (8.22 – 11.27)	1 (1 – 12)	3.83 (2.97 – 4.68)	0.39 (0.30 – 0.52)	<0.001
Acute	2 (1 – 43)	8.99 (7.46 – 10.51)	1 (1 – 8)	2.45 (1.75 – 3.15)	0.27 (0.20 – 0.38)	<0.001
Overuse	11.5 (1 – 22)	1.45 (0.86 – 2.04)	6 (1 – 12)	1.66 (1.09 – 2.23)	1.15 (0.67 – 1.95)	0.623
Upper extremity	1 (1 – 5)	2.03 (1.32 – 2.75)	1.5 (1 – 5)	0.76 (0.38 – 1.15)	0.38 (0.20 – 0.70)	0.003
Lower extremity	1 (1 – 23)	3.37 (2.45 – 4.28)	1 (1 – 12)	2.99 (2.22 – 3.76)	0.89 (0.61 – 1.29)	0.553

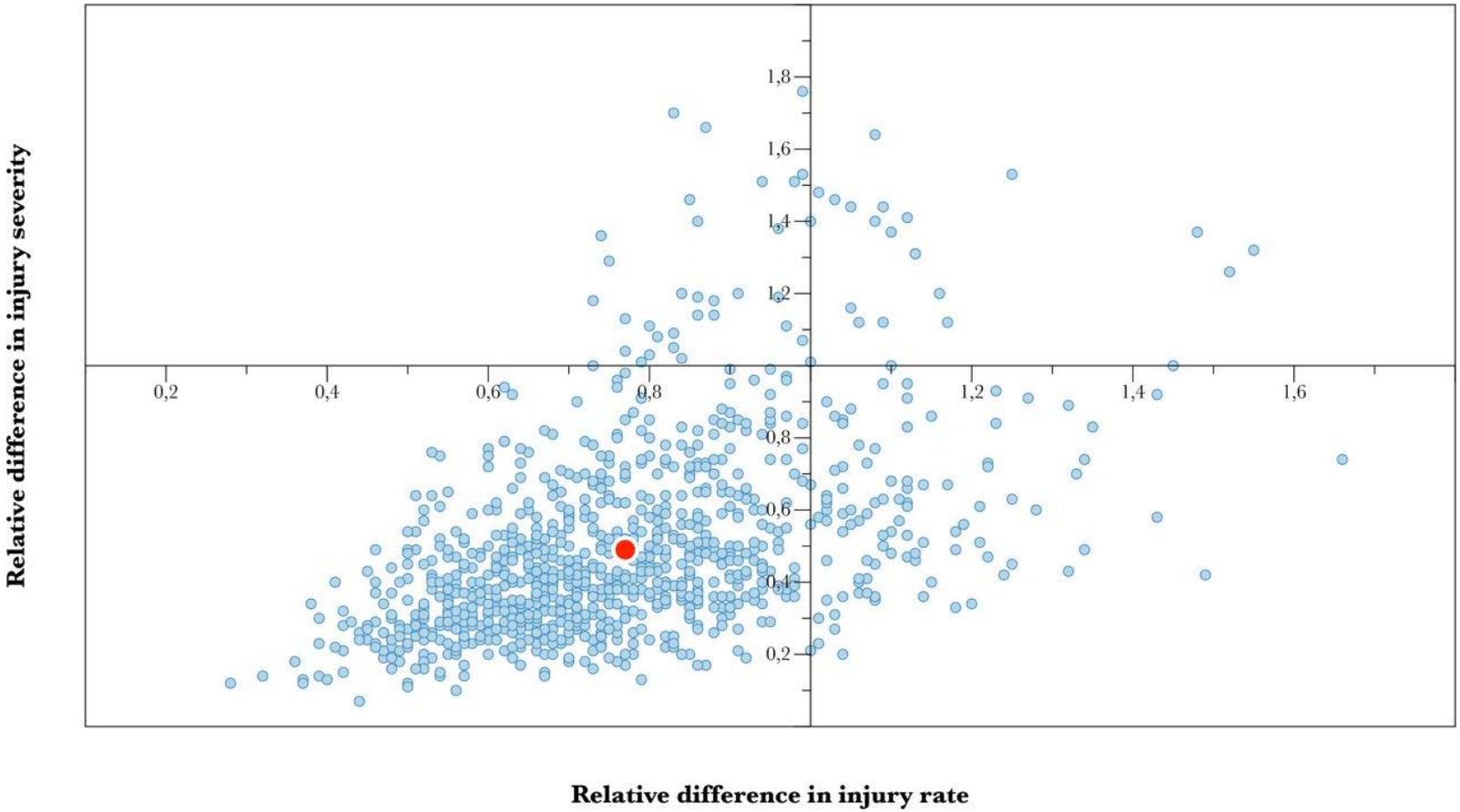

Figure 3 Plane presenting injury-severity pairs estimated through bootstrapping (1,000 samples) for the relative differences in the injury risk between IG and CG. Each dot represents one bootstrapped injury-severity pair and the relative difference in injury rate and injury severity of the IG compared to the CG. The red dot presents the average across all bootstrapped outcomes, showing averaged across all bootstrapped sample in the IG compared to the CG, a 24% lower injury rate (RR 0.76; 95%: 0.46 – 1.25) and 51% lower injury severity (RR 0.49; 95%CI: 0.03 – 0.95). The outcomes of the samples are spread over four quadrants, with 87% of the bootstrapped pairs in the south-west "dominant" quadrant (less injury and lower severity).

DISCUSSION

This quasi-experimental study with a prospective design evaluated the effectiveness of the 'VolleyVeilig' programme to reduce the rate and severity of injuries among youth volleyball players. In addition, we investigated the effect of the 'VolleyVeilig' programme on the burden of injuries.

Injury rates

We found an overall reduction in injury rates for IG teams of 30%. Although relevant, this effect was not significant. We found significantly lower incidence rates when looking at acute injuries (42% reduction) and upper extremities (59% reduction) separately. However, we must note that our sample size calculation was based on overall injury rates and not on sub-analyses. As such, one must be cautious with the interpretation as the sub-analyses may not reflect a true effect.

Other researchers reported that preventive exercise programmes significantly reduced injury rates in youth rugby [21], and youth football [11, 22]. Their outcomes showing strong significant injury rate reductions contrast our findings, despite similarities in the population and the exercise programmes' frequency, duration, and components. We believe that the lesser controlled nature of our design has contributed to this difference. In our study, just about half of the IG teams fully adhered to the 'VolleyVeilig' programme, by which one could logically expect a lower effect when comparing our outcomes to those of controlled trials.

We also need to point out that over the years, evidence showed the general value of warm-up and targeted exercises for the prevention of injuries in sports [23]. The fact that these preventive programmes in volleyball focus mostly on lower extremities could explain why we find no effects on lower extremity injuries. The available evidence has led to changes in coaching practice and made the use of a structured warm-up common practice. Especially the Nevobo has a strong history of implementing preventive evidence through their coaching education. Although a youth volleyball specific programme has not been developed before, it is not unlikely that our CG teams also employed a structured, effective warm-up programme. Consequently, our results represent the value of the 'VolleyVeilig' youth programme compared to current standard practice instead of the absolute effect of the programme.

We found a significant reduction in upper extremity injury rates. In volleyball, the most common upper extremity injuries are to the shoulder [1, 24]. Nonetheless, in previous prevention programmes, the Nevobo focused predominantly on – acute – lower extremity injuries. Hence,

the inclusion of upper extremity exercises in the current programme was new to most coaches. Also, some of the general 'VolleyVeilig' exercises put an additional demand on the players' shoulder complex, such as planks, bear crawls and exercises with elastic bands. In the absence of targeted upper extremity strengthening programmes, these exercises may have benefited these young players specifically.

Burden of injury

The injury burden followed a similar pattern as the injury rates we discussed above. However, we found a significantly lower overall injury burden in the IG (61% reduction). This was in addition to a significantly lower injury burden for acute injuries (73% reduction) and upper extremity injuries (62% reduction). These outcomes indicate that besides lowering the number of injuries, the 'VolleyVeilig' programme also positively affected the severity of injuries in fewer sports days lost due to injury.

We cannot make this claim, however, based on injury burden alone. Injury burden is a combined group measure that is also responsive to reducing injury numbers [19]. Therefore, we also compared the differences in injury numbers and injury severity between our study groups through a method derived from economic evaluations [20]. This analysis showed lower injury rates and lower injury severity in the IG compared to the CG. Admittedly, this analytical approach was not used for this purpose nor for severity outcomes before. However, when looking at sports injuries, severity data closely resemble the highly skewed nature of cost data, and this approach is logically warranted.

Methodologic considerations

For our study, we employed a quasi-experimental design. The internal validity of the results could be constrained, given that participants were not blinded for group allocation at the time of inclusion [25]. We used a similar design in previous comparable studies [4, 10] and experienced this design close to the real-world context where the findings are to be applied [26].

We specifically aimed to conduct our study as close to the real-world sporting context of participants as possible. This implied limited control as a research team over the IG teams throughout the study's follow-up. Although many would consider the resulting low level of adherence a limitation, we consider this a strength. We would have inflated our results if we had pushed IG coaches to implement the programme in a non-realistic study setting. We would be

unable to make well-informed, practical recommendations. Nonetheless, the adherence rates do suggest room for improvement, and future analyses should look into the reasons for non-adherence and point to improvements for the programme or education thereof.

It should also be noted that we report our outcomes in a single HR that is averaged over the duration of our study's follow-up. This assumes that any effect of the 'VolleyVeilig' programme was constant during our follow-up. Although this approach is commonly used in injury prevention studies, we should consider that a preventive effect of exercise programmes may be subject to time dependent factors like training periodisation, match schedule, etc. Our results should, as such, be interpreted as an outcome over the full season of follow-up.

Although we registered previous injuries at baseline, the retrospective nature of this recollection limited the detail of information that we could derive. The nature, severity and location of previous injuries logically could impact their relevance to our study. For our analyses, we have considered previous injury as a confounder in the analyses. Those previous injuries that do not affect our outcomes, in principle will not have influenced our analyses. For those previous injuries with characteristics that impact our outcomes, the analyses are corrected.

Our choice to employ a weekly follow-up by coaches will have minimized the effects of recall bias and non-response during data collection on player-specific exposures to volleyball and injury details. However, our injury reports still rely on self-reported data, despite using a standardised injury report form specifically designed to report injuries in volleyball [12]. It was simply not feasible to have trained personnel available to collect weekly data from all teams. This made us rely on time-loss injury in our registration, and even though we report overuse injuries we should consider that mane of these injuries do not lead to time-loss. This could explain our non-significant findings in overuse injuries.

Also, the weekly follow-up did not prevent occasional non-responses from certain teams or players. Even after several contact attempts, it was not possible to obtain specific information on some injuries. Injuries with missing details were included in the overall calculations but could not be included in all sub-analyses, as shown in Table 2.

CONCLUSIONS

The 'VolleyVeilig' programme was associated with reduced injury rates and lower injury burden in youth volleyball players. Based on these outcomes, we advise implementation of the

programme, while, at the same time, programme updates should improve adherence and, subsequently, the preventive effect of the programme.

CONTRIBUTORSHIP STATEMENT

VG and EV drafted the design of this study. VG, EK and JdW led the development of the studied intervention. IV, JN and EV drafted the study protocol. IV, DZ, JN and EV conducted data collection. EV performed the analyses and drafted the manuscript. All authors supported interpretation of the data and provided their final approval of the manuscript. EV is this study's guarantor and accepts full responsibility for the conduct of the study and the finished work.

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COMPETING INTEREST

EK was employed at the Dutch Consumer Safety Institute (VeiligheidNL). JdW was employed at the Dutch Volleyball Federation (Nevobo). VeiligheidNL and Nevobo own the "VolleyVeilig" intervention.

ETHICAL APPROVAL

The medical ethics committee of the Amsterdam UMC gave permission for the study with an exempt status (qualified as non- WMO obliged research), protocol number 2019.109. The study protocol was registered in the Dutch trial register (NL7651).

PATIENT & PUBLIC INVOLVEMENT

The 'VolleyVeilig' intervention was developed in cooperation with sports physical therapists and volleyball coaches.

DATA AVAILABILITY

Data are available upon reasonable request

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