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Original Research

Could a specific exercise programme prevent injury in elite orienteerers? A randomised controlled trial

Bodil Halvarsson, Philip von Rosen*

Karolinska Institutet, Department of Neurobiology, Care Sciences, and Society, Division of Physiotherapy, Huddinge, Sweden

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ABSTRACT

Objectives: To determine the effect of a specific exercise programme on preventing lower extremity injury in adult elite orienteerers.
Design: Randomised controlled trial.
Setting: Elite orienteering.
Participants: Sixty-two orienteerers (n = 32/30, male/female) were randomized and followed over 14 weeks. The intervention group completed an exercise programme 4 times per week.
Main outcome measures: Number of substantial injuries, average substantial injury prevalence and incidence of ankle sprains over the competitive season. In per-protocol analyses, compliance rate to exercise programme was considered.
Results: No significant differences between control and intervention group were found for substantial injured orienteerers (OR 0.50, 95% CI 0.19–1.34), number of substantial injuries (OR 0.46, 95% CI 0.18 –1.13) and incidence of ankle sprains (p = 0.775). In per-protocol analyses, significant differences in substantial injured orienteerers (difference −7.9%, OR 0.25, 95% CI 0.06–0.97) and number of substantial injuries (difference −8.5%, OR 0.26, 95% CI 0.07–0.92) in favour for the orienteers completing the exercises at least twice a week, compared to the control group, were found.
Conclusions: An exercise programme, consisting of balance and jump exercises, is suggested to be performed at least twice per week in order to reduce the risk of lower extremity injury in elite orienteerers.
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1. Introduction

Elite orienteerers run through rough terrain while making route choices in order to complete a course as fast as possible, covering racing time for a long distance race up to 100 min. Therefore, it is not hard to imagine that the physical and mental aspects of orienteering are highly challenging. Orienteerers are at high risk of lower extremity injury and across a season as more than 8% of young elite orienteerers have been found to be substantially injured each week (von Rosen, Flostrom, Frohm, & Heijne, 2017). The injury risk is higher during competitions, where the injury incidence is reported to be 7.3–15.4/1000 competition hours (Ekstrand, Roos, & Tropp, 1990; Linko, Blomberg, & Frilander, 1997), compared to 2.2–3.0/1000 training hours (Johansson, 1986; Roos, Taube, Zuest, Clenin, & Wyss, 2015). One of the most frequent reported injuries is ankle sprains (Ekstrand et al., 1990; Hintermann & Hintermann, 1992; Linde, 1986; Linko et al., 1997; Mclean, 1990), with an incidence proportion between 8% and 37% (Johansson, 1986; Linde, 1986; Roos et al., 2015). Other common injuries found in this population are medial shin pain, Achilles peritendinitis and iliotibial band friction syndrome. Although injury prevalence/incidence number, injury risk factors have been explored in this sport (von Rosen et al., 2017; Linde, 1986; von Rosen, Heijne, & Frohm, 2016; Leandersson, Heijne, Flodstrom, Frohm, & von Rosen, 2018), to date, no study has tested the effect of an intervention in reducing number of injuries in orienteerers.

Specific exercise programs have been found to be successful in reducing number of injuries, mainly in team sports. Shoulder injuries, groin injuries, anterior cruciate ligament injuries and ankle sprains are example of injuries that have been prevented in a general sporting population based on exercise programme (Andersson, Bahr, Clarsen, & Myklebust, 2016; Emery, Rose, McAllister, & Meeuwisse, 2007; Hagglund, Atroshi, Wagner, &

* Corresponding author. Division of Physiotherapy, Department of Neurobiology, Care Sciences, and Society, Karolinska Institutet Alfred Nobels Allé 23, SE-141 83, Huddinge, Sweden.
E-mail address: philip.von.rosen@ki.se (P. von Rosen).

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Walden, 2013; Haroy et al., 2019). These programmes have typically been performed between two to fives times/week. The high stress exposure in elite orienteerers due to running on uneven terrain suggests that a specific exercise programme, adjusted to the challenging characteristics of elite orienteering, is needed. In addition, in order to motivate and keeping a high compliance to an exercise protocol in elite athletes, the programme need to be attractive and not interfering with normal training.

The exercise programme this trial wants to test requires no equipment and is developed with the purpose to be performed in the training routine of the elite orienteerer. In specifically, it was developed by the medical team of the Swedish national orienteering team based on other successful exercise programs (Hubscher et al., 2010). The exercise programme has also been tested by runners in the Swedish national orienteering team, that perceived the programme to be feasible and challenging for an elite orienteerer. Therefore, it is believed to have good potential to be successful in elite orienteering. The purpose of this randomised controlled trial (RCT) was to determine the effect of a specific exercise programme on preventing lower extremity injury in adult elite orienteerers.

2. Method

2.1. Study design and participants

This study is a RCT, registered at the US National Library of Medicine ClinicalTrials.gov database (4–1645/2017), and took place from March 2018 to June 2018. During the 2018 preseason (January to March), adult elite orienteerers in Sweden were contacted at four sites with organised training facilities for elite male and female orienteerers. All orienteerers who agreed to participate were visited to receive more information of the trial. To be eligible the orienteerer had to be in age 18–40 and be an elite orienteerer, defined as an orienteerer participating in at least one competition in the highest national orienteering league (Swedish League). Athletes not able to complete the initial screening tests (heel-rise test, square hop test) or have not been able to run the last week due to injury were excluded. The orienteerer received verbal and written information about the study purpose and procedures and provided written consent to participation in accordance with a study protocol (von Rosen & Halvarsson, 2018). The study design and reporting follows the CONSORT recommendations for the conducting and reporting of randomized controlled trials and is approved by the Regional Ethical Committee in Sweden (dnr 2018/135–32). The report is prepared according to the Consort Statement recommendations (Turner et al., 2012).

2.2. Baseline measures

At baseline, demographic data, injury history, training volume were registered as well as two questionnaires, Hassles and Uplifts Scale and the Self-Perceived Stress (Fawkner, McMurrary, & Summers, 1999; Nordin & Nordin, 2013), were completed by the orienteerers. The orienteerers also performed two screening tests, the heel-rise test and the square hop test (Hebert-Losier, Wessman, Alricsson, & Svantesson, 2017; Ostenberg, Roos, Ekdahl, & Roos, 1998). All tests were monitored by test personnel from the medical staff of the Swedish National Federation of Orienteering. Data on the screening tests and the Hassles and Uplifts Scale and the Self-Perceived Stress are not presented in this report.

2.3. Randomisation

A computer-generated stratified random assignment by sex was used to randomise orienteerers to the control or exercise group. This was done to keep the sex distribution equal across groups. One of the authors, blinded to group allocation, performed the randomisation and prepared the sealed envelopes. After an orienteerer agreed to participate and had completed the baseline tests, the orienteerer opened a sealed envelope revealing their group assignment. After the data collection was completed the blinding was revealed.

2.4. Blinding

It was not possible to blind the elite orienteerers or the test personnel responsible for demonstrating the exercise protocol to the orienteerers. However, the data collector, managing all data collection over the study period, was blinded without knowing group allocation until all data had been collected.

2.5. Sample size

We estimate the effect size between the intervention and the control groups for the number of substantial injuries in the lower extremity, allowing for multiple injuries per individual including both acute and overuse injuries, to be 0.3. With two-sided testing, a significance level of 0.05 and a power of 0.8, each study group was estimate to include 33 athletes. However, by the time of recruitment closure only 63 elite orienteerers, fulfilling the study criteria, had agreed to participate. One orienteerer withdrew shortly after randomisation. Consequently, 62 elite orienteerers were enrolled in the study (Fig. 1). This deviation from the study protocol resulted in a slight reduction of power (power of 0.75).

2.6. Data collection

Injury data was collected using the valid version of the *Oslo Sports Trauma Research Center* (OSTRC) Overuse Injury Questionnaire (Clarsen, Myklebust, & Bahr, 2013). The injury questionnaire was provided to the participating orienteerers using text messages, distributed throughout the software Questback online survey (Questback V. 9.9, Questback AS, Oslo, Norway). The text messages were delivered each second week for a total period of 14 weeks, including both preseason (week 1–4) and competitive season (week 5–14). In case of non-response, a reminder was sent three days later. If still no response, the orienteerer was interviewed by phone another two days later.

The OSTRC Overuse Injury Questionnaire has been shown to have acceptable content and construct validity with a Cronbach's alpha of 0.91 and measures injury consequences on sports participation, performance, training and pain based on four questions with alternative responses. It assesses the effect of injuries on participation (question 1 with four responses ranging from "full participation" to "cannot participate"), reduction in training volume (question 2 with five responses ranging from "no reduction" to "cannot participate"), reduced sporting performance (question 3 with five responses ranging from "no effect" to "cannot participate") and experience of pain (question 4 with four responses ranging from "no pain" to "severe pain"). The OSTRC Overuse Injury Questionnaire was adjusted to orienteering by including questions about training volume, occurrence of ankle sprains and how often the exercise programme had been completed. Every second distributed questionnaire also included the Self-Perceived Stress questionnaire.

2.7. Intervention

The exercise programme consisted of four exercises addressing

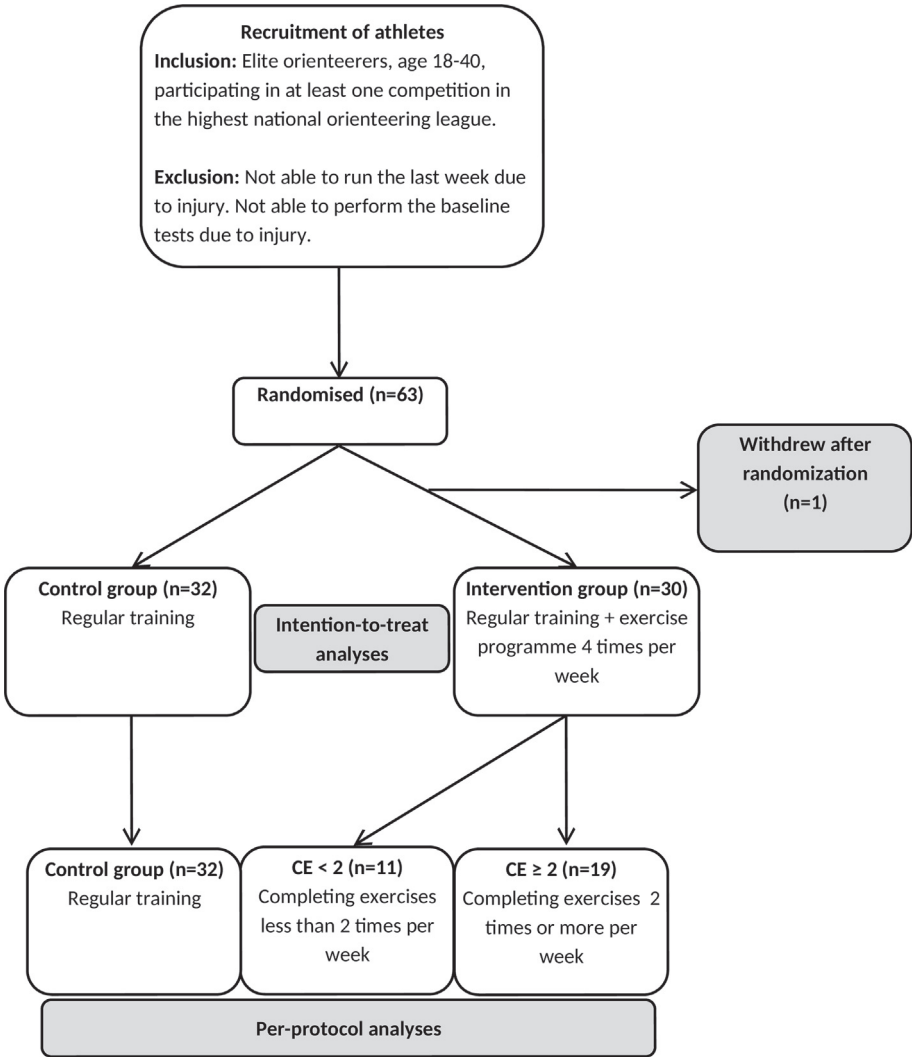

Fig. 1. Flowchart of included elite orienteerers.

the neuromuscular control of the lower extremity and included balance and jump exercises. It was developed by the medical team of the Swedish national orienteering team, based on the injury profile of elite orienteering and previous research (Doherty et al., 2016; Drewes, McKeon, Kerrigan, & Hertel, 2009; Halabchi, Angoorani, Mirshahi, Pourgharib Shahi, & Mansournia, 2016; Mailuhu et al., 2015; Verhagen et al., 2004). The four exercises used in this trial are the one-leg stance, runner's pose, one leg heel raise and one leg side hop with three difficulty levels, previously described in detailed (von Rosen & Halvarsson, 2018). The orienteerers were asked to perform the exercises four times a week throughout the entire study period. Every second week the exercises' difficulty level was increased. The first level of the four exercises was explained and demonstrated to the orienteerers after the randomisation process. Thereafter, the orienteerers were provided pictures of the exercises as well as verbal explanation on exercise performance quality.

2.8. Compliance

Compliance to the exercise programme was determined based on orienteerers' self-reported number of sessions completed. This information was collected bi-weekly using an online web-based questionnaire (see above).

2.9. Outcome measures

The primary outcome is number of substantial injuries in the lower extremity. The secondary outcomes are the average substantial injury prevalence and the incidence of ankle sprains. Substantial injury was defined as "any physical complaint resulting in moderate or severe reductions in training volume, or moderate or severe reduction in performance, or complete inability to participate in sports" (i.e. alternative responses "to a moderate extent", "to a major extent" or "cannot participate at all" in either Question 2 or Question 3 of the OSTRC Overuse Injury Questionnaire) (Clarsen et al., 2013). An orienteering reporting a substantial injury in the lower extremity, defined as the area from the foot to the hip, was reported as primary outcome.

2.10. Exposure

Bi-weekly, the orienteer reported their exposure to orienteering training (hours), including competition time.

2.11. Statistical analyses

The average weekly response rate was 97.7% and only ten questionnaires were missing over the 14 weeks. Multiple

imputations were used to handle the missing data. The missing data were deemed to be "missing at random", and a total of five datasets were imputed based on a so called Chained Equation algorithm in SPSS (V.22, IBM Corporation, New York, NY, USA). The average value of these five datasets was used.

Bi-weekly, the substantial injury prevalence was calculated by dividing the number of substantial injuries by the number of questionnaire respondents. Number of substantial injuries and ankle sprains were presented per 1000 h of exposure to orienteering. Average values were presented for the complete period and the competitive season.

To assess the effect of the intervention over the competitive season, two generalised estimating equation (GEE) analyses were performed using an exchangeable covariance matrix, with number of substantial injuries and substantial injured as dependent variables. Odds ratio (OR) values were presented.

Primary analyses were performed using an ITT principle. In secondary per-protocol (PP) analyses, the intervention group were divided in two groups based on average compliance over the complete study period to the exercise programme. Specifically, to present a clinically understandable value, the group were divided based on compliance rate to the closest integer (2 times/week) while keeping the group size as similar as possible. Injury data was also presented for orienteerers performing the programme; 1–2 times/week, 2–3 times/week and 3–4 times/week.

Differences in number of ankle sprains were explored based on 95% confidence intervals. We also assessed differences in baseline characteristics between the intervention and control group using independent *t*-test or Chi-square test. All analyses were performed using SPSS Statistics for Windows, V.24.0 (SPSS) with the level of significance set at a p value 0.05 for all tests.

3. Results

3.1. Baseline data, response rate and compliance to exercise protocol

No significant differences were found between the intervention and control group regarding baseline characteristics for the 62 included elite orienteerers (Table 1). The intervention group completed the exercise protocol in average 2.2 (SD 0.6) times/week, with 19 (63%) orienteerers completing the exercise two times or more per week and 11 (37%) orienteerers less than two times per week. No reports on any adverse events related to performing the study intervention were recorded.

3.2. Primary analyses

A total of 64 substantial injuries were reported over the 14 weeks, where approximately two thirds (n = 44, 66%) occurred during the competitive season (Table 2). In the intervention group, more than half of all injuries (n = 15, 54%) occurred during the competitive season, whereas for the control group, three quarters occurred in the same period (n = 27, 75%). The majority of injuries was located in the foot (n = 33, 52%), followed by injuries in the lower leg (n = 14, 22%). The average bi-weekly substantial injury prevalence for the competitive season was 12% and 9% in the control and intervention group, respectively, whereas the number of substantial injuries across the competitive season was 12 and 8 per 1000 h training exposure in the control and intervention group, respectively (Table 3). In ITT analyses, the GEE models showed no significant differences between groups for substantial injured orienteerers (OR 0.50, 95% CI 0.19–1.34) and number of substantial injuries (OR 0.46, 95% 0.18–1.13) (Table 4) (Fig. 2). Number of ankle sprains did not significantly (p = 0.775) differ between intervention (5.1/1000 h of training exposure) and control group (3.6/1000 h of training exposure).

3.3. Secondary analyses

In PP analyses, the intervention group was divided in two groups based on compliance rate to exercise programme; completing exercises less than 2 times/week (CE < 2), completing exercises more than 2 times/week (CE ≥ 2). Consequently, the effect of a high compliance to the exercise protocol could be analysed. The average bi-weekly substantial injury prevalence for the competitive season was 12% and 4%, whereas the number of substantial injuries across the competitive season was 12 and 4 per 1000 h of training exposure in the control and CE ≥ 2, respectively (Fig. 3). The GEE analyses showed a significant difference in substantial injured orienteerers (OR 0.25, 95% CI 0.06–0.97) with 65% reduced injury risk, and number of substantial injuries (OR 0.26, 95% CI 0.07–0.92) with 64% reduced injury risk, between control and CE ≥ 2, respectively. No significant differences occurred between control and CE < 2. In the intervention group, a significantly (p = 0.026) higher proportion of orienteerers completing the exercises less than two times per week were injured (n = 6, 55%) compared to orienteerers with a higher compliance (n = 3, 16%) (Table 5).

5. Discussion

This is the first study investigating the effect of a specific exercise programme on preventing lower extremity injury in elite orienteerers and the first RCT in orienteering. Our main finding was that completing the exercises at least 2 times/week reduce the prevalence of substantial injury by approximately 64%, in the PP analyses.

No study has previously tested an exercise programme in elite orienteerers. The exercise programme examined in this trial aims to prevent injuries by improving neuromuscular control of the lower extremity. These attributes are believed to be important qualities for an elite orienteerer (Creagh & Reilly, 1997), for instance to be able to run on uneven terrain. Previous studies have shown that balance exercises reduce ankle sprains by 38% (McGuine & Keene,

Table 1
Baseline characteristics for elite orienteerers.

	Intervention (n = 30)	Control (n = 32)	P-value
Age mean (SD)	24.1 (3.5)	24.2 (3.8)	0.925
BMI mean (SD)	20.8 (1.2)	21.5 (1.6)	0.077
Sex female/male (%)	15/15 (50.0/50.0)	15/17 (46.9/53.1)	0.806
Year as elite orienteerer	5.8 (3.3)	6.6 (3.6)	0.372
Average training volume in hours/week	7.3 (3.0)	7.4 (3.1)	0.635
Previous injury[a]	13 (43.3)	12 (37.5)	0.640
Previous ankle sprain[b]	13 (43.3)	12 (37.5)	0.640

[a] Sustained injury during last year, that have affected or completely hindered training for a continuous period of at least three weeks.
[b] Sustained ankle sprain during last year.

Table 2
Number of injuries and injury location presented for the complete period (week 1–14), preseason (week 1–4) and competitive season (week 5–14).

	All orienteerers (n = 62)	Intervention (n = 30)	Control (n = 32)
Number of injuries			
Complete period	64	28	36
Preseason	22 (34)	13 (46)	9 (25)
Competitive season (%)	42 (66)	15 (54)	27 (75)
Injury location (%)			
Foot	33 (52)	11 (39)	22 (61)
Lower leg	14 (22)	5 (18)	9 (25)
Knee	6 (9)	6 (21)	–
Thigh	5 (8)	5 (18)	–
Hip	6 (9)	1 (4)	5 (14)
Injury location, preseason (%)			
Foot	6 (27)	1 (8)	5 (56)
Lower leg	7 (32)	3 (23)	4 (44)
Knee	4 (18)	4 (31)	–
Thigh	4 (18)	4 (31)	–
Hip	1 (5)	1 (8)	–
Injury location, competitive season (%)			
Foot	27 (64)	10 (67)	17 (61)
Lower leg	7 (17)	2 (13)	5 (19)
Knee	2 (5)	2 (13)	–
Thigh	1 (2)	1 (7)	–
Hip	5 (12	–	5 (19)

Table 3
Injury data for elite orienteerers for the complete period (week 1–14) and the competitive season (week 5–14) by groups; control, intervention, completing exercises less than 2 times/week (CE < 2) and completing exercises more than 2 times/week (CE ≥ 2).

	Control (n = 32)	Intervention (n = 30)	CE ≥ 2 (n = 19)	CE < 2 (n = 11)
Substantial injured[a]				
Complete period	12.4 (5.1)	11.1 (5.2)	8.3 (7.9)	15.8 (8.4)
Competitive season	11.8 (5.1)	8.8 (3.7)	4.3 (4.4)	16.7 (9.6)
Substantial injury[b]				
Complete period	11.2 (3.9)	9.4 (3.6)	6.8 (5.1)	13.3 (6.9)
Competitive season	12.2 (4.0)	7.6 (2.9)	4.3 (4.5)	12.1 (8.2)
Ankle sprain[b]				
Complete period	2.8 (2.6)	3.4 (3.0)	2.8 (2.1)	4.1 (4.6)
Competitive season	3.6 (2.7)	5.1 (1.9)	4.3 (0.3)	6.1 (4.3)

[a] Average number of orienteerers reported lower extremity injury with standard deviation in parentheses.
[b] Number of substantial injuries in the lower extremity/ankle sprains per 1000 h of training exposure with standard deviation in parentheses.

Table 4
Generalised estimating equation (GEE) model with substantial injured and substantial injury as outcome across the competitive season.

	Mean difference in prevalence (%) Control vs. Intervention	OR	95% CI	P-value
Substantial injured[a]				
Intervention	−3.0	0.50	0.19–1.34	0.168
CE < 2	+4.9	1.11	0.38–3.24	0.851
CE ≥ 2	−8.5	0.25	0.06–0.97	0.045
Substantial injury[a]				
Intervention	−4.6	0.46	0.18–1.13	0.090
CE < 2	−0.1	0.88	0.35–2.25	0.792
CE ≥ 2	−7.9	0.26	0.07–0.92	0.037

CE < 2, completing exercises less than 2 times/week; CE ≥ 2, completing exercises more than 2 times/week.
[a] All analyses performed using control group as reference group.

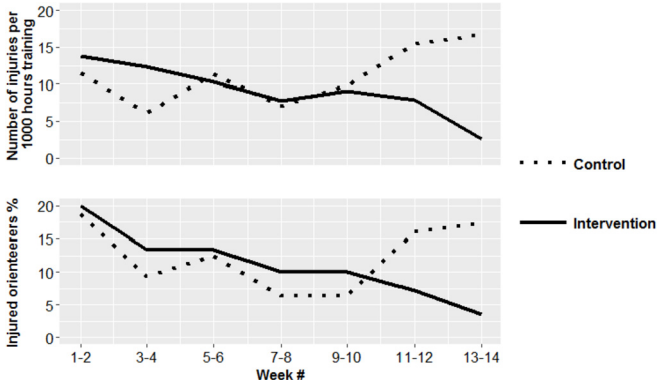

Fig. 2. Number of substantial injuries per 1000 h of training exposure and injured orienteerers in % across the complete study period and competitive season (week 5–14).

2006), and in youth athletes multifaceted neuromuscular training has been shown to reduce the risk of lower extremity injury (Herman, Barton, Malliaras, & Morrissey, 2012), exercises similar to the ones used in this trial. The reason ITT analyses revealed no significant differences between groups may be due to underpowering or a low compliance rate to training protocol. However, clear injury differences occurred during the last weeks of the trial when comparing the two groups and there were significant differences when considering the rate of compliance to the exercise programme.

Even if the elite orienteerers reported to be injured they did not stop training or competing. This suggests, in line with other studies (von Rosen et al., 2017; von Rosen et al., 2016), that the majority of injuries sustained by elite orienteerers are not related to time-loss. There was no difference in number of competition (control/intervention group, 1.4 competition/week) that was completed and

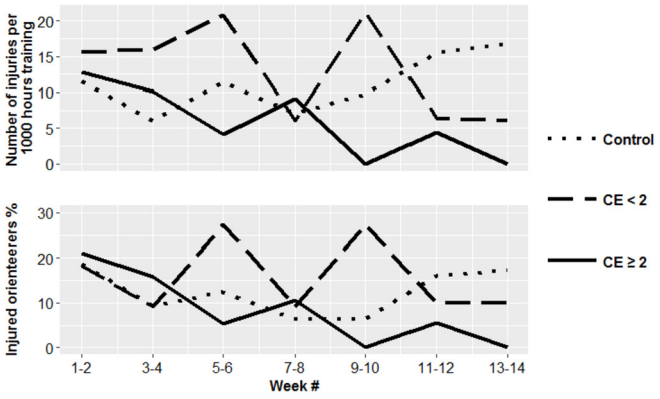

Fig. 3. Number of substantial injuries per 1000 h of training exposure and injured orienteerers in % across the complete study period and competitive season (week 5–14) by control group, orienteerers completing exercises less than 2 times/week (CE < 2) and orienteerers completing exercises more than 2 times/week (CE ≥ 2).

small difference in total training volume (control group 7.4 h/week; intervention 7.2 h/week) between the control and intervention group, suggesting that both groups were exposed to a similar amount of orienteering training and competition along the study course.

Our trial differs in one key factor compared to most sports injury prevention trials (Aaltonen, Karjalainen, Heinonen, Parkkari, & Kujala, 2007; Brushoj et al., 2008; Gagnier, Morgenstern, & Chess, 2013; Gilchrist et al., 2008), we included elite athletes. Although elite athletes have direct access to medical resources, they probably are more exposed to psychological and physical stress than recreational athletes (Rice et al., 2016). Adding a specific exercise programme into the tough schedule and daily life of an elite athlete may interfere with performed training and the competition calendar. Since, a high compliance rate to an exercise protocol is a cornerstone for the success of the programme (Silvers-Granelli, Bizzini, Arundale, Mandelbaum, & Snyder-Mackler, 2018; van Reijen, Vriend, van Mechelen, Finch, & Verhagen, 2016), this may often be an issue when implementing a new exercise programme in elite athletes. In our case, even though medical staff of the national orienteering team developed the exercise programme and the orienteerers were instructed to perform the exercises four times per week, only 13% of the orienteerers managed to complete the exercise programme more than three times a week and 37% less than two times a week. Still, the compliance rate is self-reported and we do not know the actual number of times. Even so, the time needed to perform the four exercises must be considered short. Interestingly, the CE ≥ 2 and CE < 2 differed in compliance rate to exercise programme at an early stage of the trial. For instance, after 4 weeks the average compliance rate was 2.3 and 3.2 times/week for CE < 2 and CE ≥ 2, respectively. However, we did not find any clear pattern suggesting that injury occurrence the first weeks explained the compliance rate to exercise programme, rather there seem to be unmeasured factors explaining which athletes that chose to perform the exercises.

Our results suggest that it take time for an exercise programme to have an injury prevention effect. Therefore, it is suggested that elite orienteerers start to perform the exercises six to eight weeks prior to the competitive season in order to have adequate time to become used to the exercise programme and receive enough time to achieve the benefits associated with completing it. Reducing the number of exercises may be beneficial for the compliance rate but may affect the effectiveness of the programme (Sugimoto, Myer, Foss, & Hewett, 2014). Monitoring the elite orienteerers on a regular basis, giving feedback on their performance, varying and making exercises more challenging over time, may improve compliance rate and thereby reduce the risk of injury.

The differences in the numbers of injuries were greater between control and intervention group at the end of the competitive season, compared to the first eight weeks of the study. Even if ankle sprains did not differ between groups, the intervention group reported fewer injuries in the foot, lower leg and hip compared to the control group. It is possible that misclassification of foot injuries may have occurred, since the total number of ankle sprains (n = 19) only constituted 58% of the total number of foot injuries. We believe it is likely that some of the reported foot injuries are recurrent ankle sprains. However, the design of this RCT makes it not possible to distinguish between new and recurrent injuries. Instead this trial was designed to monitor the prevalence of injuries, in line with other RCTs (Andersson et al., 2016; Haroy et al., 2019).

5.1. Methodological considerations

The strength of this study is the high response rate to the distributed questionnaires, monitoring a homogeneous group of elite athletes over a competitive season based on a valid questionnaire, resulting in a complete picture of injuries in the lower extremity, including time-loss injuries, being recorded. At baseline, no significant differences between the two groups were recorded. We also stratified by sex to ensure that groups were comparable. In addition, the exercise programme was developed by the medical staff of the Swedish national orienteering team and tested by elite orienteerer before it was implemented.

Despite this, there are some methodological limitations in this study. No detailed diagnostic information on each case was provided and different injury types such as medial shin pain or achilles peritendinitis were therefore likely recorded. The effect of the exercise programme on different injury types is likely not the same between these. The amount of time that the orienteerers were followed may be considered brief but was based on including the period with the greatest injury risk, i.e. the competitive season. When the trial ended, most elite orienteerers had finished the competitive season. A higher compliance rate to the exercise programme may have given a greater reduction in injury risk and a stronger result. In PP analyses, the group sizes must be considered small. In addition, the performance quality of the exercises was not monitored. Instead, the orienteerers were in charge of performing the exercises as perfectly as possible, to represent the practical setting of an elite orienteerer. Still, all orienteerers were given similar instructions on exercise performance quality. However, the compliance rate or injury risk reduction may have been improved if

Table 5
The proprotion elite orienteerers reported substantial injury and number of substantial injuries by compliance to exercise protocol across the competitive season.

	Compliance to exercise protocol		
	1-2 times/week (n = 11)	2-3 times/week (n = 15)	3-4 times/week (n = 4)
Substantial injured (%)	6 (55)	2 (13)	1 (25)
Substantial injury[a]	12.1	4.3	4.5

[a] Number of substantial injuries in the lower extremity per 1000 h of training exposure.

the orienteerer were monitored and provided feedback on performance. The control group was told not to add any additional balance, strength and jump exercises for the lower extremity, however, we do not know if this instruction was followed. Training exposure was self-reported which may be biased. However, elite athletes often wear GPS watches and keep training diaries, hopefully making these estimates accurate.

6. Conclusion

Orienteerers are at high risk of lower extremity injury that may be target by a specific exercise programme. Our results suggest that future studies should carefully monitoring the frequency of exercises performed and include balance and jump exercises when aiming at preventing injuries in elite orienteerers. The injury mechanisms are reasonably assumed to be similar between elite and non-elite orienteerers, which may suggest that the preventive effect observed in this trial can be generalised to non-elite orienteerers as well.

Conflicts of interest

Declarations of interest: none.

Ethical approval

Ethical approval has been received from the Regional Ethical Committee in Sweden (2018/135–32).

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