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# Universal prevention through a digital health platform reduces injury incidence in youth athletics (track and field): a cluster randomised controlled trial

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## ABSTRACT

**Objectives** To examine whether universal prevention via a digital health platform can reduce the injury incidence in athletics athletes aged 12–15 years and if club size had an influence on the effect of the intervention.

**Methods** This was a cluster randomised trial where young athletics athletes were randomised through their club following stratification by club size into intervention (11 clubs; 56 athletes) and control (10 clubs; 79 athletes) groups. The primary endpoint was time from baseline to the first self-reported injury. Intervention group parents and coaches were given access to a website with health information adapted to adolescent athletes and were encouraged to log in and explore its content during 16 weeks. The control group continued training as normal. Training exposure and injury data were self-reported by youths/parents every second week, that is, eight times. The primary endpoint data were analysed using the log-rank test. Cox proportional hazards regression was used to analyse the second study aim with intervention status and club size included in the explanatory models.

**Results** The proportion of completed training reports was 85% (n=382) in the intervention group and 86% (n=545) in the control group. The injury incidence was significantly lower (HR=0.62;  $\chi^2=3.865$ ; p=0.049) in the intervention group. The median time to first injury was 16 weeks in the intervention group and 8 weeks in the control group. An interaction effect between the intervention and stratification factor was observed with a difference in injury risk between athletes in the large clubs in the intervention group versus their peers in the control group (HR 0.491 (95% CI 0.242 to 0.998); p=0.049).

**Conclusions** A protective effect against injury through universal access to health information adapted for adolescent athletes was observed in youth athletics athletes. The efficacy of the intervention was stronger in large clubs.

**Trial registration number** NCT03459313.

## INTRODUCTION

Athletics (track and field) is a popular sport that encompasses a variety of events including jumping, throwing and running. In the past decades, epidemiological research in youth athletics have displayed an injury incidence ranging from 35% to 79%, and that overuse injuries (65%–95%) are a main concern.<sup>1–9</sup> Such relatively high injury numbers are a concern for the athlete's development and can possibly affect a future career in sport.<sup>10</sup> The

## WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Youth athletics athletes are at high risk of sustaining overuse injuries with complex causes.

## WHAT THIS STUDY ADDS

⇒ Universal prevention via provision of health information through a digital platform intended to increase self-management in athletes, parents and coaches, decreased the likelihood for sustaining injuries in youth athletics athletes during an outdoor season.  
⇒ The preventive effect was more pronounced in large athletics clubs than in small clubs.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Universal prevention strategies based on distribution of age-adjusted health information can be recommended for implementation in youth sports.  
⇒ Digital platforms provide novel opportunities to efficiently reach youth sports at grassroots levels with information that supports the development of safe sport practices.

cause of overuse injuries in youth sport is complex and involves multiple mechanisms, ranging from training load, training volume, equipment factors and track shoe wear to growth and sleep.<sup>6 8 10 11</sup>

The athlete's club environment has been highlighted as a key area for securing sustainable development in the sport.<sup>12</sup> Accordingly, socioecological models have been proposed for intervention planning in these settings in order to move the focus to the contexts that matter most for the safety of young athletes, for example, the decision-making among their coaches and parents.<sup>13–15</sup> A socioecological model is also meaningful in injury prevention among young athletes because such models bring to the fore the complexity of the associations between injury risk and environmental factors in the settings where daily training is planned and performed.<sup>12 16</sup>

Information technology provides an efficient means to communicate health information that facilitates self-management.<sup>17</sup> In youth athletics, a digital platform makes it possible to provide coaches, parents and athletes with updated evidence-based information on how to optimally structure daily training and recovery. Such a digital health platform for youth athletics athletes has been developed by

Swedish Athletics (SA) ([www.friskfriidrott.se](http://www.friskfriidrott.se)).<sup>18</sup> The objective of the digital health platform is to address the complex causes of injuries by increasing the self-efficacy of athlete-parent-coach triads with regard to injury and illness prevention.<sup>15 19–21</sup>

Universal prevention is an approach delivered to large groups without prior screening and involves reducing risk and fostering resilience among asymptomatic populations regardless of the individual risk level by, for example, providing necessary information to prevent the problem from occurring.<sup>22</sup> Preventive interventions in this category are often well tolerated because the measures are perceived as positive support delivered before problems arise, which facilitates adoption and supports programme sustainability.<sup>23</sup> For instance, before having reached high school age, child and youth athletes are advised by SA not to specialise but rather train and/or compete in all events.

Athletics in Sweden is structured according to the Scandinavian sport model and mainly run by volunteers.<sup>24 25</sup> The athletics clubs are of different sizes, where the larger clubs also have larger groups for young athletes. The primary aim of this study was to examine if universal prevention based on distribution of health information through a digital platform can reduce injury incidence in youth athletics athletes aged 12–15 years. A second aim was to examine if the club size had an influence on the effect of the intervention.

## METHODS

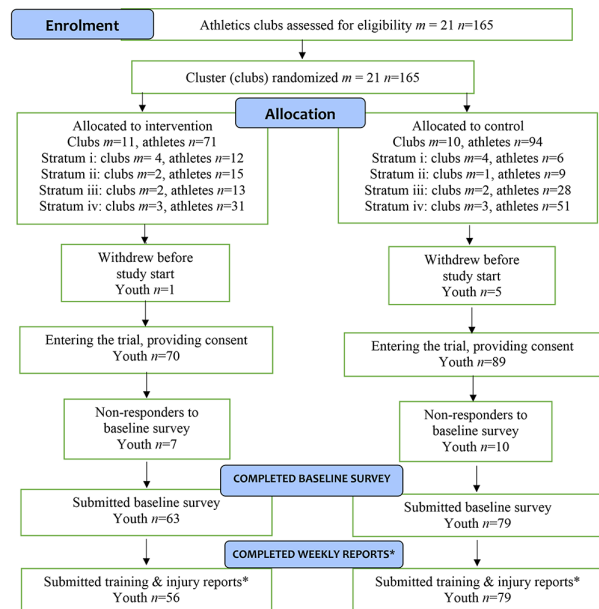
A parallel-group cluster randomised controlled trial (RCT) design was used for the study. The cluster randomisation was performed by athletics clubs and stratified with regard to club size. The study covered one youth athletics outdoor season and is part of the KLUB research programme.<sup>8 13 18</sup> The study is reported according to the Consolidation Standards of Reporting Trials statement.<sup>26</sup>

### Recruitment and participants

The youth athletes, age 12–15 years, with their parents/carers and coaches, were recruited in collaboration with the SA. To be eligible for the study, the youth athlete had to be in primary school and participate regularly (at least once a week) in organised athletics club training. Clubs that had previously participated in an observational study<sup>8</sup> were approached in the spring of 2017 via email and telephone by JJ, the primary investigator (PI), to provide information about the planned intervention study. In addition, during the autumn of 2017, the PI visited three coach education programmes with the aim of reaching additional clubs. A total of 21 clubs expressed interest in participating and provided email addresses for parents/carers and coaches. An invitation was sent to parents/carers, youth athletes and coaches in March 2018 via email with written information about the study. No information about the content of the intervention was given other than it included access to a digital health platform with accessible information that could guide how to best structure training and recovery for athletic youths. All correspondence in the study with the youth athletes was via the email address of the parents/carers. Those that accepted the invitation to participate were included in the study (figure 1).

### Randomisation

Before randomisation, the clubs were classified by the SA youth coordinator (DB, <https://www.friidrott.se>), who was blinded to the randomisation process and the study protocol, into small or large clubs (online supplemental appendix A). To minimise the risk of contamination bias between athletes within the same



**Figure 1** Flow chart of enrolment and randomisation of clusters (clubs) and youth athletes. \*At least once during the study period.

club, randomisation was performed as a cluster randomisation of clubs with a various number of athletes within each club. A statistician, not blinded at this stage, performed the computer-generated randomisation in blocks with a block size of 4 using nQuery V.7. The randomisation was revealed to study personnel and participants after recruitment to ensure concealment of allocation.

### Blinding

Due to the nature of the study, it was not possible to blind participants. The PI was blinded to the randomisation list until the clubs were consecutively enrolled and allocated to intervention or control groups. For analysis purposes, the randomisation list was merged with the analysis dataset by the statistician after the end of the trial.

### Intervention

The intervention programme, the digital health platform, was developed by practitioners and researchers, and focuses mainly on areas that have been identified as contributing to overuse injuries in youth athletes.<sup>18</sup> The aim with the platform is to support the self-efficacy of athlete-parent-coach triads regarding health protection and the various topics covered on the digital health platform are; training planning, growth and puberty, recovery, injury prevention, injuries and illnesses and mental illness (online supplemental appendix B). All training, health and medical information on the digital health platform is in line with the latest scientific evidence or best practice, and follows the recommendations provided from the SA, the Swedish Sports Confederation and the Swedish National Board of Health and Welfare. Before the invitation to the study, the SA youth coordinator and two coaches experienced working with youth and adult elite athletics athletes (OG and DM) were invited to assess the feasibility of the planned intervention; for example, regarding technical procedures like the log-in process and the content of the topics covered on the platform.<sup>27</sup>

Parents/carers (with corresponding youth) and coaches in the intervention group were given access to the digital health

platform via a password-protected interface. Over the 4-month period (16 weeks), participants were encouraged via email alerts to log on to the site on four occasions and explore its content. The first email was sent at the start of the study with a short description of the health platform and log-in details. Thereafter, email alerts with login information and suggestions on topics to explore were sent on a monthly basis. The participants were able to reach the PI if they experienced problems with the login. The participants allocated to the control group received an email explaining that they had been assigned to the control group and that they would get access to the digital health platform after the 4-month study period. The digital health platform was not accessible to the public during the preparation period or during the study period.

### Compliance

We did not control how the participants in the intervention group chose to act on the instructions provided in the email alerts or use the digital health platform during the 4-month study period. Retrospective usage data were collected after the study period via Google Analytics divided by each unique digital device accessing the platform. No user identification data were recorded.

### Collection of data

Data were collected using a web-survey system (Briteback AB, Linköping, Sweden). For youth athletes, three questionnaires were used (online supplemental appendix C): (1) baseline (2) training reports every 2 weeks and (3) new injury report.<sup>8 24</sup> Baseline data were collected in March 2018 before the participants received information about the group assignment. Youth athlete-specific questions included demographic data on sex, age, country of birth, number of sports they participated in, previous training, injury and illness data.

Data on training for youth athletes were collected every 2 weeks during the study period, with one reminder, directly from the athletes/parents (carers) (ie, eight times). The training reports included questions on (1) sessions and hours of training and competition in athletics and other sports, (2) if training had occurred according to plan (yes/no). If not, they were asked to provide the reason why not (eg, being ill, injured or on holiday) and (3) if having sustained a new injury during the preceding 2 weeks (yes/no). A new injury was reported in a questionnaire that included questions regarding the date of injury, in what context the injury had occurred (sport, leisure, etc), injury onset (gradual/sudden), symptoms, body area affected and type of injury. Reported injuries were classified by the PI according to the International Classification of Diseases, 10th Revision, Clinical Modification.<sup>8 28</sup>

For adults, one separate baseline questionnaire was used that included questions regarding demographic data on sex, age, country of birth, level of education, background in sport, current commitment as a coach and if they had any coaching education (online supplemental appendix C).

### Endpoint measures

The primary endpoint measure was the difference in time from baseline (randomisation) to the first self-reported injury between athletes in the intervention arm and athletes in the control arm of the study. A reportable injury was defined as any new physical complaint including pain and soreness resulting in reduced training volume, difficulties participating in normal training or competition, or reduced performance in athletics.<sup>8</sup>

### Sample size

The sample size calculation was based on differences in the proportion of athletes experiencing a first injury. A power calculation was performed in nQuery V7.0. using a two-sided  $\chi^2$  test assuming a 0.05 type 1 error rate and 90% power.<sup>29</sup> The sample size calculation was not performed on the primary end point time-to-first injury, because assumptions regarding number of events (injuries) and its intensity during a relatively short (4 months) follow-up were difficult to make based on the information available. Therefore, we used the overall difference between proportion aggregated over the 4 months period for the calculation, which was also approved by the ethical review board. The calculation revealed that at least 52 people per exposure group (exposed/unexposed) were needed to detect an 80%–50% reduction in injury rates.<sup>30</sup> Power calculations were also performed for cluster randomisation, assuming a coefficient of variation of true proportions between clusters within each group of 0.15 and at least 10 individuals in each cluster. The calculation revealed that at least 6.6 clusters were required. This study therefore aimed to recruit approximately 20 clubs (clusters) to also allow for stratification of clusters into 2 categories.

### Statistical methods

All data are presented using descriptive statistics in terms of frequency and percentage for categorical data, and number of individuals, mean and SD for continuous data. The exposure to injury risk was counted from the randomisation date to the end of the 4 months follow-up period. Athletes were censored at the latest time point for submitting training reports (lost to follow-up) or at withdrawal of consent. Athletes with ongoing injury at baseline were left censored until the youth was reported as being back in normal training.

The primary endpoint data were analysed by the log-rank test and Kaplan-Meier statistics for time to injury (univariate analysis) using observed cases. In addition, we present a measure of HR for descriptive purposes.

Cox proportional hazards regression was used for the analysis of the second study aim, including intervention and club size in the explanatory models. Two models were used for this analysis. The first model included variables for intervention (yes/no), club size (small/large) and the interaction between these factors as explanatory variables. The aim of the second model was to explain the interaction by combining the two factors into one variable representing four subgroups, where the subgroup large club randomised to the control was used as reference in the analysis.

To establish the robustness of the results regarding the primary study aim (effectiveness of the intervention), we used a Bayesian resampling approach based on the actual difference observed between the intervention and control groups.<sup>31</sup> The estimated regression coefficient and SE from the Cox proportional hazards regression were used as priors in the analysis. We assumed that the amount of independent variation was limited to the number of clubs used for cluster randomisation and not the entire sample of 135 participants. Simulations were performed using a t distribution with 19° of freedom and the resampling was repeated for 10 000 samples. The outcomes were compared with the threshold when there is no difference between exposed and controls (ie,  $t=0$ ). The results of these comparisons were then accumulated and used to calculate the probability of observing an outcome in favour of the control group or no difference at all (0), which constitutes the likelihood that the actual observed difference in favour of the intervention group was observed by

chance (ie, the *p* value). As an additional sensitivity analysis, we evaluated the primary endpoint with a worst-case and a best-case strategy using the intention-to-treat (ITT) approach, that is, including all randomised subjects.

The statistical analyses were performed in SPSS Statistics V.27. All tests were two sided and *p*<0.05 was regarded as statistically significant. In this study, there was only one primary endpoint of interest and one experimental factor used for the trial. Therefore, there were no adjustments for multiplicity. Data were analysed for observed cases.

## RESULTS

### Participants and response rate

In total, 159 youth athletes gave consent to participate (figure 1). Eighty-nine per cent of the athletes (92 females and 50 males) responded to the baseline survey (table 1). Among their supporting adults, 90% (n=107) of parents/carers and 91% (n=52) of the coaches gave consent and responded to the baseline survey (table 1). Of the coaches, 75% (n=39) were parents/carers for a youth participating in the study. During the study, 85% (n=135) of the athletes (together with parents/carers) provided training reports. The total proportion of completed weekly reports was 86% (n=927), 85% (n=382) in the intervention group and 86% (n=545) in the control group and the median follow-up time was 16 weeks (Q1 16 weeks, Q3 16 weeks) in both treatment arms. Twenty-four per cent in the intervention group and 19% in the control group were censored due to lost to follow-up.

### Compliance

The digital health platform was accessed from 113 digital devices in 233 sessions with a mean access time of 5 min per session (online supplemental appendix D).

### Athletic injury characteristics

Included in the analysis were 56 athletes in the intervention group and 79 athletes in the control group (figure 1). The proportion of athletes experiencing a first (new) injury during the study period was 25% (n=14) in the intervention group and 41% (n=32) in the control group (table 2). Of the first injuries recorded, 70% (n=32) had a gradual onset and 30% (n=14) had a sudden onset. The foot was the most common body location in the intervention group (29%, n=4) and the anterior knee in control group (22%, n=7). The most common diagnoses of first injury in the intervention group were ankle sprain (14%, n=2) and Osgood-Schlatter (14%, n=2) and in the control group, Osgood-Schlatter (16%, n=5) and ankle sprain (9%, n=3).

### Effect of the intervention on injury incidence

The univariate analysis of the primary endpoint data showed that the likelihood for injury was lower in the intervention group than in the control group (HR 0.62;  $\chi^2=3.865$ ; *p*=0.049) (figure 2). The median time to first injury was 16 weeks in the intervention group and 8 weeks in the control group.

The multivariate analyses of the influence of club size on intervention effect (the second study aim) revealed in the first model an interaction effect between club size and intervention (*p*=0.049). Analysis of the simple main effects in the second model (figure 3) showed that compared with the reference group (large clubs in the control category; HR 1.0), the injury risk among athletes in large clubs who received the intervention was significantly reduced (HR 0.491; 95% CI 0.242 to 0.998; *p*=0.049), whereas for athletes in small clubs who received the

**Table 1** Baseline description of the participants

|   | Intervention group | Control group |
|---|--------------------|---------------|
| Youth athletes (n=142)  | 63                 | 79            |
| Sex, n (%)  |                    |               |
| Female  | 46 (73)            | 46 (58)       |
| Club size, n (%)  |                    |               |
| Small   | 24 (38)            | 11 (14)       |
| Age (years), mean (SD)  | 12.4 (2.8)         | 13.2 (2.0)    |
| Height (cm), mean (SD)  | 164.0 (9.8)        | 164.5 (10.6)  |
| Weight (kg), mean (SD)  | 51.0 (10.8)        | 50.3 (12.1)   |
| Menarche (yes), n (%)   | 26 (57)            | 31 (67)       |
| Sleep per night (hours), mean (SD)                            | 8.5 (0.8)          | 8.4 (1.0)     |
| Participating in more than one sport (yes), n (%)             | 31 (49)            | 34 (43)       |
| Previous training volume, hours per week (SD)                 | 4 (2)              | 5 (3)         |
| Previous training sessions, times per week (SD)               | 3 (1)              | 3 (1)         |
| No of coaches, mean (SD)                                      | 3.0 (1.0)          | 3.0 (1.0)     |
| Previous 3 week injury, n (%)                                 | 17 (27)            | 21 (27)       |
| Previous 3 week illnesses, n (%)                              | 4 (6)              | 5 (6)         |
| Parents/carers (n=107)  | 40                 | 67            |
| Sex, n (%)  |                    |               |
| Female  | 27 (67)            | 40 (60)       |
| Age (years), mean (SD)  | 47.2 (4.6)         | 47.5 (3.9)    |
| Country of birth, n (%)                                       |                    |               |
| Nordic country  | 38 (95)            | 62 (93)       |
| Highest level of education, n (%)                             |                    |               |
| University  | 28 (70)            | 50 (75)       |
| Residence size, no of inhabitants, n (%)                      |                    |               |
| <20 000   | 7 (18)             | 13 (19)       |
| 20 000–100 000  | 12 (30)            | 18 (27)       |
| >100 000  | 20 (50)            | 36 (54)       |
| Former athlete, n (%)   |                    |               |
| Yes   | 7 (18)             | 21 (31)       |
| Coach today, n (%)  |                    |               |
| Yes   | 4 (10)             | 12 (18)       |
| Athletics as primary sport                                    | 0 (0)              | 0 (0)         |
| Any coach education, n (%)                                    |                    |               |
| Yes   | 37 (93)            | 56 (84)       |
| Coaches (n=52)  | 29                 | 23            |
| Sex, n (%)  |                    |               |
| Female  | 15 (52)            | 11 (48)       |
| Coach, and also parent for a youth participating in the study | 21 (72)            | 18 (78)       |
| Age (years), mean (SD)  | 47.5 (8.2)         | 43.1 (12.0)   |
| Country of birth, n (%)                                       |                    |               |
| Nordic country  | 31 (100)           | 19 (90)       |
| Highest level of education, n (%)                             |                    |               |
| University  | 20 (65)            | 14 (67)       |
| Residence size, no of inhabitants, n (%)                      |                    |               |
| <20 000   | 11 (35)            | 7 (33)        |
| 20 000–100 000  | 9 (29)             | 5 (24)        |
| >100 000  | 11 (35)            | 9 (43)        |
| Former athlete, n (%)   |                    |               |
| Yes   | 31 (100)           | 21 (100)      |
| Coach today, n (%)  |                    |               |
| Yes   | 31 (100)           | 21 (100)      |
| Athletics as primary sport                                    | 30 (97)            | 20 (95)       |

Continued

Table 1 Continued

|                            | Intervention group | Control group |
|----------------------------|--------------------|---------------|
| Any coach education, n (%) |                    |               |
| Yes                        | 26 (84)            | 18 (86)       |

intervention (HR 0.438; 95% CI 0.171 to 1.123,  $p=0.08$ ) and in small clubs in the control category (HR 0.18; 95% C, 0.025 to 1.336;  $p=0.09$ ), the difference was not statistically significant.

The sensitivity analysis of the results concerning the primary endpoint data using Bayesian resampling simulation with the parameters from the multivariate analysis as priors showed that there was a 2.9% likelihood that the difference between the intervention and control groups would occur by chance if the true difference in the entire population was as observed. The ITT analysis of the worst-case scenario (all athletes in the intervention group lost to follow-up were injured and no athlete was injured among controls) showed a tendency for intervention effect ((HR) 0.71;  $\chi^2=2.825$ ;  $p=0.091$ ), while the best-case scenario confirmed the observed effect ((HR) 0.56;  $\chi^2=5.168$ ;  $p=0.023$ ) (online supplemental appendix E).

## DISCUSSION

To our knowledge, this is the first RCT to examine the effects of implementing universal injury prevention in youth athletics. The results showed that youth athletes who received an intervention via a digital health platform, aimed at increasing self-health management, were less likely to be injured during an outdoor season compared with their peers in a control group. The preventive effect was more pronounced in large athletics clubs than in small clubs.

### Effect of the intervention on injury incidence

Although all reported injuries were of the overuse type, they were widely distributed over body locations. It is therefore not possible to determine the biomechanical mechanisms through which the intervention delivered its effect. Because our intervention design had not been implemented previously in organised youth sports, our results can only be compared, for example, with evaluations of interventions focused on specific injury types. Such interventions have shown injury reduction effects of between 35% and 65%.<sup>32-34</sup> For our intervention based on

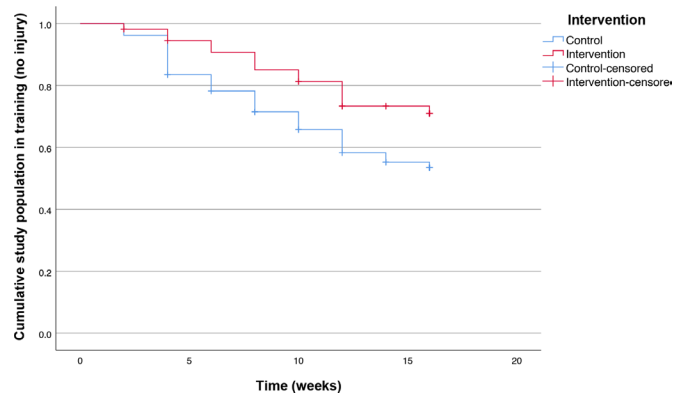


Figure 2 Kaplan-Meier curves for time to first injury: effect of the intervention on injury incidence.

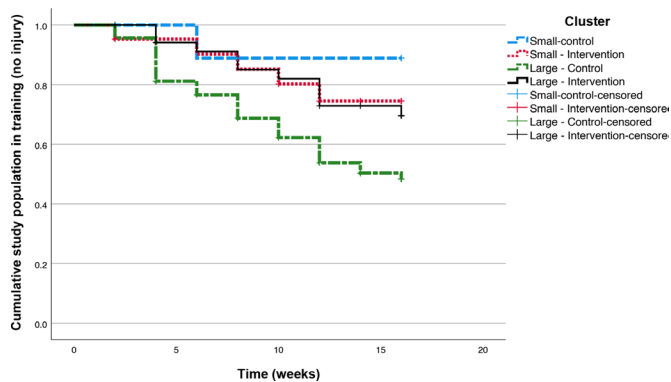
a universal prevention strategy, we observed a 50% reduction in time to the first injury in the intervention group compared with the control group, which indicates a medium-size effect. Given that an intervention delivered to a total population has the potential to prevent more injuries because it intervenes in a greater number of individuals and a real-world general population, a medium-sized preventive effect is in this context highly meaningful.<sup>35</sup>

### Parents as mediators of injury prevention in youth athletes

The socioecological framework illustrates how social and environmental mediating mechanisms and modifying conditions may contribute to the occurrence or avoidance of sports injury.<sup>36</sup> In Scandinavia, parents/carers have become increasingly involved in their children's participation in organised sports<sup>37</sup> and, in this study, three of four coaches were also parents for their child. Research indicates that parent/caregiver involvement has an advantage in producing positive health outcomes among their children and youth, in line with the results in our study.<sup>38</sup> The adherence with our intervention appears to have been good; we observed that the average time spent on the digital health platform was close to 5 min per session, which is in line with studies of similar design.<sup>39</sup> This observation can be explained by findings from studies in sports environments similar to ours that show parents' perceived need to have access to health-related

Table 2 Frequency of first (new) injury reported during the study period

| Body region                       | Intervention   |              |           | Control        |              |           |
|-----------------------------------|----------------|--------------|-----------|----------------|--------------|-----------|
|                                   | Overuse injury |              | Traumatic | Overuse injury |              | Traumatic |
|                                   | Gradual onset  | Sudden onset | Traumatic | Gradual onset  | Sudden onset | Traumatic |
| Vertebral column                  |                |              |           |                |              |           |
| Head, face                        | 0              | 0            | 0         | 0              | 0            | 0         |
| Cervical, thoracic                | 0              | 0            | 0         | 1              | 0            | 0         |
| Lumbar, pelvis, sacrum, abdomen   | 1              | 0            | 0         | 2              | 0            | 0         |
| Upper extremities                 |                |              |           |                |              |           |
| Shoulder                          | 0              | 0            | 0         | 0              | 0            | 0         |
| Upper arm, elbow                  | 0              | 0            | 0         | 0              | 0            | 0         |
| Forearm, wrist, hand              | 0              | 0            | 0         | 0              | 0            | 0         |
| Lower extremities                 |                |              |           |                |              |           |
| Hip, groin, thigh                 | 2              | 2            | 0         | 6              | 4            | 0         |
| Knee, lower leg                   | 3              | 1            | 0         | 10             | 2            | 0         |
| Achilles tendon, ankle, foot, toe | 3              | 2            | 0         | 4              | 3            | 0         |
| Total, n (%)                      | 9 (64)         | 5 (36)       | 0 (0)     | 23 (72)        | 9 (28)       | 0 (0)     |



**Figure 3** Kaplan-Meier curves for time to first injury: effect of the intervention on injury incidence according to the size of club.

information.<sup>40</sup> However, since we did not collect unique log-in data, we lack information about individual user patterns.

### Club size as injury risk moderator

Environmental factors, such as organisational culture and readiness, are suggested important for the development of the talented athlete as well as the adoption and implementation of proposed intervention programmes.<sup>12 41 42</sup> In our study, we observed that the efficacy of the intervention was more pronounced in large athletics clubs than in small clubs. These results suggest that an environmental impact on the individual athlete's risk of injury exists.<sup>43 44</sup> This finding requires further attention because it is not clear which factors in the environment had a negative impact on the athlete.<sup>12</sup> One explanation for this finding could be that small clubs are likely more focused on activities for youth, and perhaps with more mixed training groups, compared with large clubs that may have formally trained staff for youth training but at the same time are focused on performance in competition. A competitive climate has been linked to psychological stressors and behaviours that increase the risk of overuse injuries.<sup>45</sup>

### Study limitations

This study has limitations that need to be considered. A major limitation was the restricted number of Athletics clubs in the six Swedish regions. Every region has its specific preconditions for participation in Athletics (climate, urban/rural division, etc). Involving athletes from more regions would have required further stratification and added complexity to the study design. The restricted availability of clubs and athletes limited the possibility to adjust for clustering and stratification effects in the analysis and to detect, for example, potential measurement bias in ITT estimates, random confounding, and built-in selection bias in HR. Clustering of study participants may lead to correlation between observations which, if not accounted for, can lead to spurious conclusions of efficacy/effectiveness. Bayesian methodology offers a flexible framework to deal with such problems.<sup>31</sup> To ascertain the results, we, therefore, used Bayesian resampling simulation to estimate the uncertainty of the estimates customised for this RCT and a worst case/best case scenario analysis to evaluate drop-out effects. These analyses showed that the primary results were robust. Although the study population was relatively small, the amount of missing data was also small. Eleven per cent in the intervention group and 10% in the control group did not respond to the baseline survey, and 21% and 11%, respectively, never submitted training reports. The drop-out from submitting training reports could bias the injury estimates, but

we believe athletes are more likely to report injuries if they have had one rather than the opposite, that is, refrain/refuse to submit training reports. Consequently, the injury rates are likely to be slightly overestimated. Because there were slightly more athletes not responding to training reports in the intervention group, we believe that the missing data would not alter the results.

The accuracy of injury assessment and classification when using self-reported data is an additional limitation.<sup>46</sup> Also, the protective results observed may have been influenced by a selection effect, that is, that the participating athletes/parents/coaches were more interested, information seeking and responsive to the intervention than the non-participants. Because the governing body participated in the development of the athletic health platform, its content may have been perceived as particularly relevant and thus urgent to adopt and translate into practice.<sup>47 48</sup> Moreover, we did not evaluate the delivery of the intervention in detail, for example, the monthly email alerts and how the results might be related to the delivery process.<sup>49</sup> Access to the digital health platform in our study required a password. Therefore, participants may have chosen to not log on to the platform but instead search for suggested health information in other ways, for example, using other internet sources or by personal communication with other coaches or parents/carers. Furthermore, additional psychological factors could have influenced the participants' behaviour, for example, the Hawthorne effect (an observer-expectancy effect).<sup>50</sup> However, a corresponding observer effect may also have occurred in the control group. Finally, we have no information on whether any clubs, in the intervention or control group, had implemented any additional activities to prevent injuries that could have affected the results of our study

### Generalisability of the results

Interventions with a complex effect propagation mechanism are commonly context dependent and the observed effects might not be reproducible in other settings without careful considerations.<sup>51</sup> For example, possible heterogeneity in the environment requires special attention because it may affect both the implementation and the outcome of a study. To further understand the interaction with possible contextual factors, additional methods, besides examining injury incidence, for example, process evaluation, should be used to examine the protective mechanisms.<sup>48 52 53</sup>

### Implications for youth athletics

Applying one-size-fits-all strategies in prevention research has proved challenging.<sup>54</sup> In a mixed youth athletics training group, athletes are at risk can vary considerably over time. For example, some athletes enter puberty later than their peers, others experience stress due to school work, and some might focus on technique training before an upcoming competition. These dynamic systems consist of several components, including environmental, which interact and change in accordance with the current situation.<sup>55</sup> Our results provide insights into possibilities and challenges for injury prevention practitioners and researchers to consider. Digital platforms provide opportunities to reach groups with knowledge, but further research is needed to increase our understanding of dissemination, adoption and how the knowledge is used by the targeted groups. It should also be considered that universal prevention delivered through a digital platform may affect adherence selectively; for example, the intervention requires a high-speed internet connection and basic technical skills to obtain an effect.

## CONCLUSION

In this study, influenced by methodologies derived from social medicine,<sup>56</sup> we observed an injury protective effect for youth athletes whose parents and coaches were exposed to an intervention providing them with health information adapted for adolescent athletes. The efficacy of the intervention was more pronounced in large clubs, probably due to a higher baseline injury risk in these settings. The results provide insights that can be transferred to sports organisations and populations for implementation of broad universal prevention programmes in youth sports.<sup>57</sup> Further studies of universal prevention based on digital platforms in youth sports using suitable experimental designs are warranted.

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