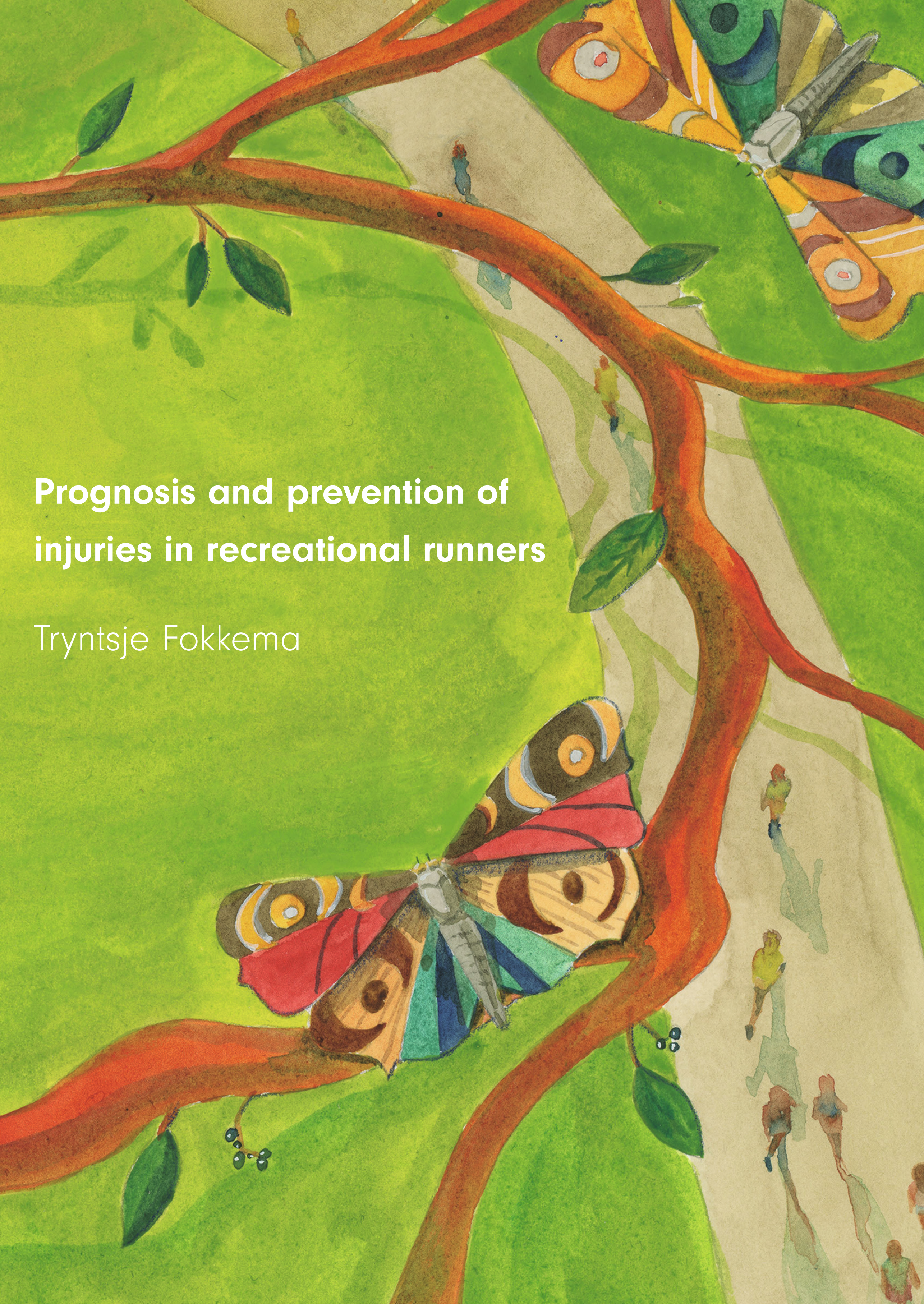

Prognosis and prevention of injuries in recreational runners

Tryntsje Fokkema

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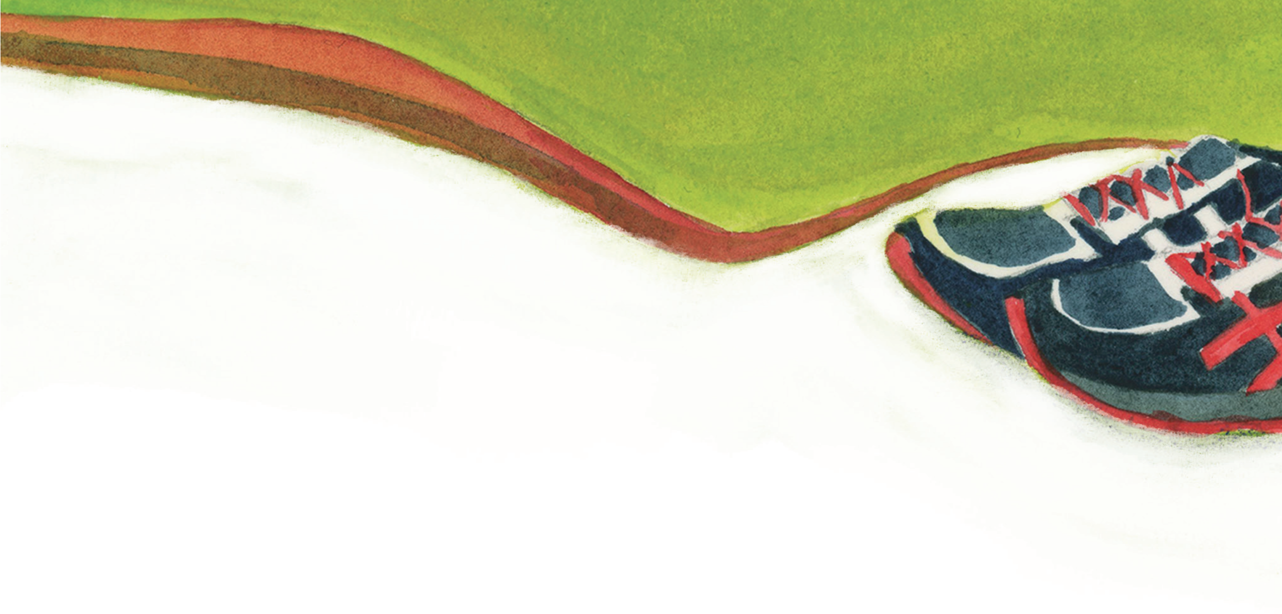
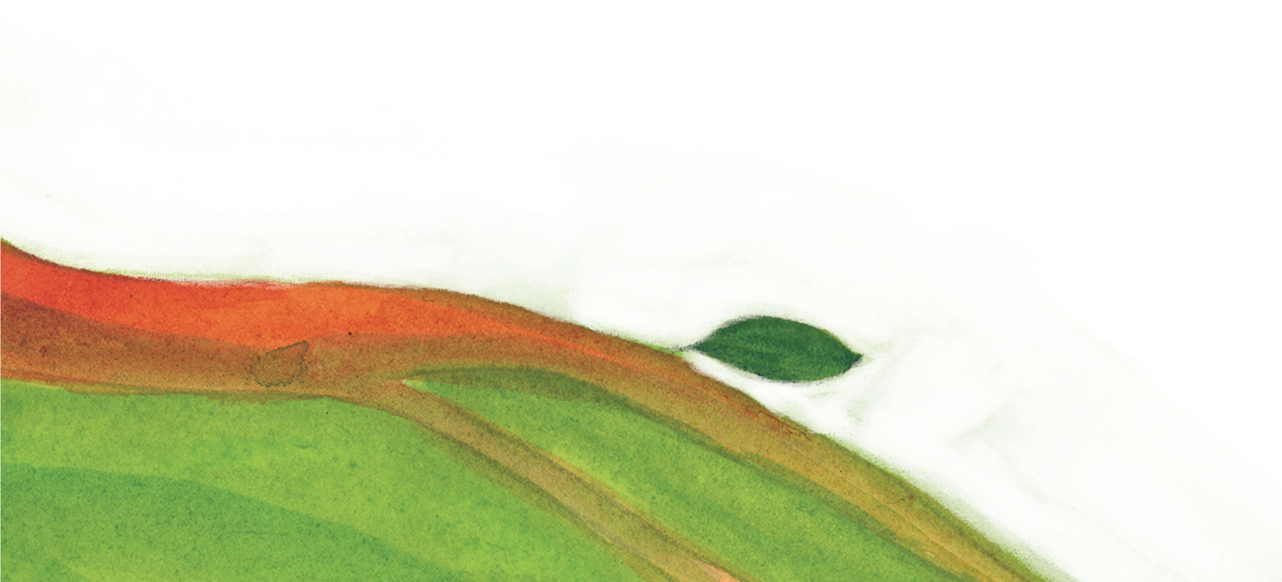


1

General introduction



Over the last decades, an increasing number of people in the western countries have sedentary jobs, resulting in less physical activity during the day[1]. The negative health effects of this sedentary lifestyle motivate many people to try to perform more physical activity during their leisure time[2]. A frequently chosen form of physical activity is running[3]. For example, in the Netherlands around 2 million people regularly ran in 2014, which is about 12.5% of the population[4]. This popularity is probably due to the low entry level of running: it is inexpensive and can be done when and where one likes[5,6]. Also, running is known to have several positive effects on both the physical and mental well-being[7]. Finally, many running events are organized that stimulate people to start or continue running[8]. However, a main drawback of running is the high number of running-related injuries (RRIs), which may force runners to stop running and hence they miss out on the positive effects of running. Furthermore, RRIs can cause absence from other forms of physical activity and work and can increase health care utilization[9]. This emphasizes the need for prevention of RRIs.

Injury prevention research

A frequently used framework in research on sports injury prevention is the ‘sequence of prevention’ framework of Van Mechelen et al.[10]. This framework describes four steps for research on sports injury prevention (Figure 1). The first step in injury prevention research is to identify and describe the extent of the sports injury problem. Next, risk factors for sports injuries must be identified. The third step is the development of interventions that modify the risk factors identified in step 2. Finally, the effectiveness of the preventive measures should be evaluated by repeating the first step. Over the last decades, several studies on RRIs have been performed using the ‘sequence of prevention’ framework.

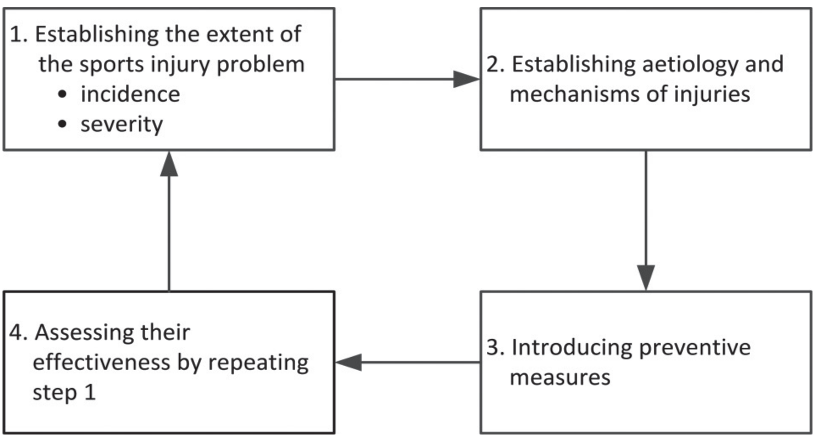


Figure 1. Sequence of prevention-framework (Van Mechelen et al., 1992 [10])

Incidence of RRIs

The incidence of RRIs is high. In 2014, 710.000 Dutch runners sustained an RRI, which makes running the sport with the second highest absolute number of injuries in the Netherlands[4]. This is partly explained by the high number of runners in the Netherlands. However, the injury risk of runners was also almost three times as high as the average injury risk of all sports, expressed in hours of sport participation (6.1 injuries for running versus 2.1 injuries in general per 1000 training hours)[4]. Also in scientific literature, high incidences of RRIs were found. A systematic review showed that injury proportions in runners ranged from 3.2% to 84.9% in studies with a follow-up time or recall period between 1 day and lifetime[11]. The highest proportion was found in novice runners. This finding was confirmed by the high injury risk of novice runners (17.8 RRIs per 1000 training hours in novice runners compared to 7.7 RRIs per 1000 training hours in experienced recreational runners)[12]. The most common injured site was the knee, followed by the lower leg and Achilles tendon[11,13,14]. Most frequently reported diagnoses of RRIs include medial-tibial stress syndrome, Achilles tendinopathy and patellofemoral pain[15,16]. So far, only little is known about the prognosis of RRIs. The median time-to-recovery in recreational runners was eight weeks and in novice runners 10 weeks, while 25.5% of injured marathon runners still reported persistent symptoms after three months follow-up[13,16,17]. However, these recovery times are based on a limited number of studies. Furthermore, nothing is known about the time-to-recovery from specific injury locations yet. This emphasizes the need for more insight in the impact and prognosis of RRIs.

Risk factors

To gain more insight in the aetiology of RRIs, several studies on the risk factors for RRIs have been performed. A variety of risk factors was identified, including overweight, a high weekly training distance, a low running cadence and running on outworn shoes[8,18-20]. Next to this variety, the reported risk factors are not consistent between the studies. A systematic review summarized the evidence and showed that in four studies a higher age was a risk factor for RRIs, while a higher age was a protective factor in two other studies[21]. Consistent evidence only exists for a previous RRI as a risk factor for RRIs[3,21,22]. The variety and inconsistency in risk factors can partly be explained by differences in study population, methodology, statistical analysis and RRI definition between the studies[22]. However, it also shows that RRIs are a complex problem, with a variety of factors and mechanisms that play a role in the occurrence.

Preventive measures

So far, the effectiveness of some RRI prevention interventions have been tested[23-29]. Most examined preventive interventions aimed at modifying a single risk factor for RRIs. For example, Bredeweg et al. targeted the risk factor 'no experience with sporting activities with axial loading' and offered novice runners a training program with walking and hopping exercises[23]. This training program had no effect on the number of RRIs in novice runners. Also with most other prevention measures, no reduction in the number of RRIs was effectuated. This may be related to the fact that most studies on RRI prevention aimed at one risk factor for RRIs, while many risk factors have been identified[3,21,22]. This suggests that a preventive intervention for RRIs should be multifactorial and aimed at modifying multiple risk factors for RRIs.

AIM AND OUTLINE OF THIS THESIS

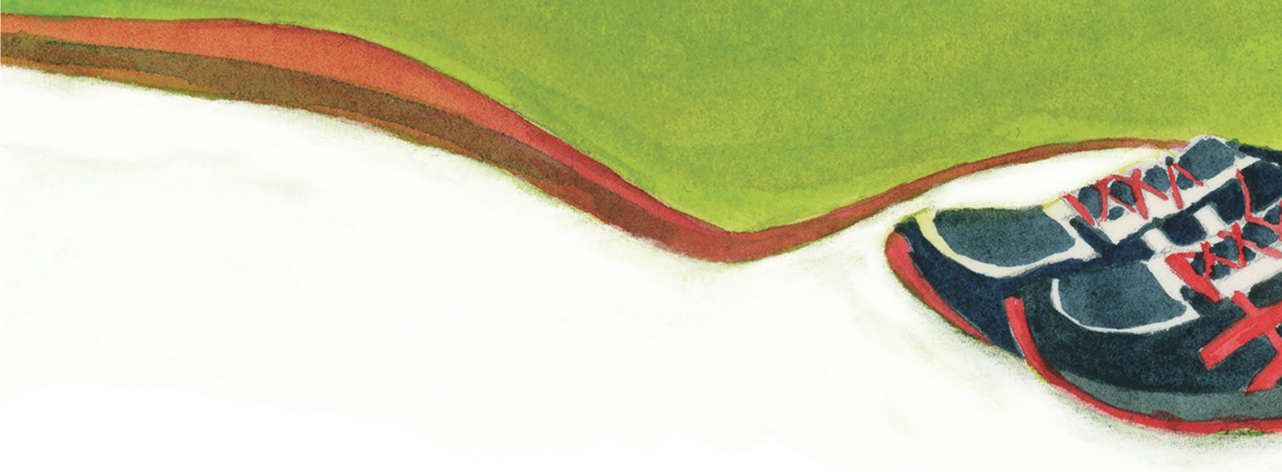
In the past decades, many studies on RRIs have been performed. However, there are still important gaps in literature, for example on time-to-recovery and prognostic factors of RRIs in specific subgroups of runners or specific injury locations. Also, no effective prevention measures have been identified yet. Therefore, the aim of this thesis is to gain more insight in the prognosis and prevention of RRIs in recreational runners.

Chapter 2 describes the reasons and predictors of discontinuation of running after a running program for novice runners. In **chapter 3**, we examined the prognosis and prognostic factors of RRIs in novice runners. **Chapter 4** describes the protocol of the INSPIRE-trial, a randomized-controlled trial on the effectiveness of an online, multifactorial injury prevention program for recreational runners, while in **chapter 5** the results of the INSPIRE-trial are presented. **Chapter 6** investigates the associations of training volume with performance indicators and RRIs in recreational half-marathon and marathon runners. In **chapter 7**, the impact and prognosis of running-related knee injuries among recreational runners are examined. **Chapter 8** investigates the opinions, barriers and facilitators of injury prevention in recreational runners. Finally, **chapter 9** discusses the main findings and limitations of this thesis. Furthermore, implications for future research and practice are given.

REFERENCES

1. Church TS, Thomas DM, Tudor-Locke C, et al. Trends over 5 decades in U.S. occupation-related physical activity and their associations with obesity. *PLoS One.* 2011; 6(5):e19657.
2. Allender S, Cowburn G, Foster C. Understanding participation in sport and physical activity among children and adults: a review of qualitative studies. *Health Educ Res.* 2006; 21(6):826-835.
3. van der Worp MP, ten Haaf DS, van Cingel R, et al. Injuries in runners; a systematic review on risk factors and sex differences. *PLoS One.* 2015; 10(2):e0114937.
4. VeiligheidNL. Hardloopblessures Blessurecijfers 2014. Amsterdam: VeiligheidNL; 2016
5. Buist I, Bredeweg SW, Lemmink KA, et al. Predictors of running-related injuries in novice runners enrolled in a systematic training program: a prospective cohort study. *Am J Sports Med.* 2010; 38(2):273-280.
6. Taunton JE, Ryan MB, Clement DB, et al. A retrospective case-control analysis of 2002 running injuries. *Br J Sports Med.* 2002; 36(2):95-101.
7. Lee DC, Brellenthin AG, Thompson PD, et al. Running as a Key Lifestyle Medicine for Longevity. *Prog Cardiovasc Dis.* 2017; 60(1):45-55.
8. Buist I, Bredeweg SW, Bessem B, et al. Incidence and risk factors of running-related injuries during preparation for a 4-mile recreational running event. *Br J Sports Med.* 2010; 44(8):598-604.
9. Smits DW, Huisstede B, Verhagen E, et al. Short-Term Absenteeism and Health Care Utilization Due to Lower Extremity Injuries Among Novice Runners: A Prospective Cohort Study. *Clin J Sport Med.* 2016.
10. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med.* 1992; 14(2):82-99.
11. Kluitenberg B, van Middelkoop M, Diercks R, van der Worp H. What are the Differences in Injury Proportions Between Different Populations of Runners? A Systematic Review and Meta-Analysis. *Sports Med.* 2015; 45(8):1143-1161.
12. Videbaek S, Bueno AM, Nielsen RO, Rasmussen S. Incidence of Running-Related Injuries Per 1000 h of running in Different Types of Runners: A Systematic Review and Meta-Analysis. *Sports Med.* 2015; 45(7):1017-1026.
13. Nielsen RO, Ronnow L, Rasmussen S, Lind M. A prospective study on time to recovery in 254 injured novice runners. *PLoS One.* 2014; 9(6):e99877.
14. van Poppel D, Scholten-Peeters GG, van Middelkoop M, Verhagen AP. Prevalence, incidence and course of lower extremity injuries in runners during a 12-month follow-up period. *Scand J Med Sci Sports.* 2014; 24(6):943-949.
15. Lopes AD, Hespanhol Junior LC, Yeung SS, Costa LO. What are the main running-related musculoskeletal injuries? A Systematic Review. *Sports Med.* 2012; 42(10):891-905.
16. Mulvad B, Nielsen RO, Lind M, Ramskov D. Diagnoses and time to recovery among injured recreational runners in the RUN CLEVER trial. *Plos One.* 2018; 13(10).
17. van Middelkoop M, Kolkman J, van Ochten J, et al. Course and predicting factors of lower-extremity injuries after running a marathon. *Clin J Sport Med.* 2007; 17(1):25-30.
18. Macera CA, Pate RR, Powell KE, et al. Predicting lower-extremity injuries among habitual runners. *Arch Intern Med.* 1989; 149(11):2565-2568.
19. Schubert AG, Kempf J, Heiderscheit BC. Influence of stride frequency and length on running mechanics: a systematic review. *Sports Health.* 2014; 6(3):210-217.
20. Taunton JE, Ryan MB, Clement DB, et al. A prospective study of running injuries: the Vancouver Sun Run "In Training" clinics. *Br J Sports Med.* 2003; 37(3):239-244.
21. van Gent RN, Siem D, van Middelkoop M, et al. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med.* 2007; 41(8):469-480; discussion 480.

22. Saragiotto BT, Yamato TP, Hespanhol Junior LC, et al. What are the main risk factors for running-related injuries? *Sports Med.* 2014; 44(8):1153-1163.
23. Bredeweg SW, Zijlstra S, Bessem B, Buist I. The effectiveness of a preconditioning programme on preventing running-related injuries in novice runners: a randomised controlled trial. *Br J Sports Med.* 2012; 46(12):865-870.
24. Buist I, Bredeweg SW, van Mechelen W, et al. No effect of a graded training program on the number of running-related injuries in novice runners. *Am J Sport Med.* 2008; 36(1):35-41.
25. Hespanhol Junior LC, van Mechelen W, Verhagen E. Effectiveness of online tailored advice to prevent running-related injuries and promote preventive behaviour in Dutch trail runners: a pragmatic randomised controlled trial. *Br J Sports Med.* 2018; 52(13):851-858.
26. Malisoux L, Chambon N, Delattre N, et al. Injury risk in runners using standard or motion control shoes: a randomised controlled trial with participant and assessor blinding. *Br J Sport Med.* 2016; 50(8):481-487.
27. Malisoux L, Chambon N, Urhausen A, Theisen D. Influence of the Heel-to-Toe Drop of Standard Cushioned Running Shoes on Injury Risk in Leisure-Time Runners: A Randomized Controlled Trial With 6-Month Follow-up. *Am J Sports Med.* 2016; 44(11):2933-2940.
28. Theisen D, Malisoux L, Genin J, et al. Influence of midsole hardness of standard cushioned shoes on running-related injury risk. *Brit J Sport Med.* 2014; 48(5).
29. Vanmechelen W, Hlobil H, Kemper HCG, et al. Prevention of Running Injuries by Warm-up, Cool-down, and Stretching Exercises. *Am J Sport Med.* 1993; 21(5):711-719.



2

Reasons and predictors of discontinuation of running after a running program for novice runners

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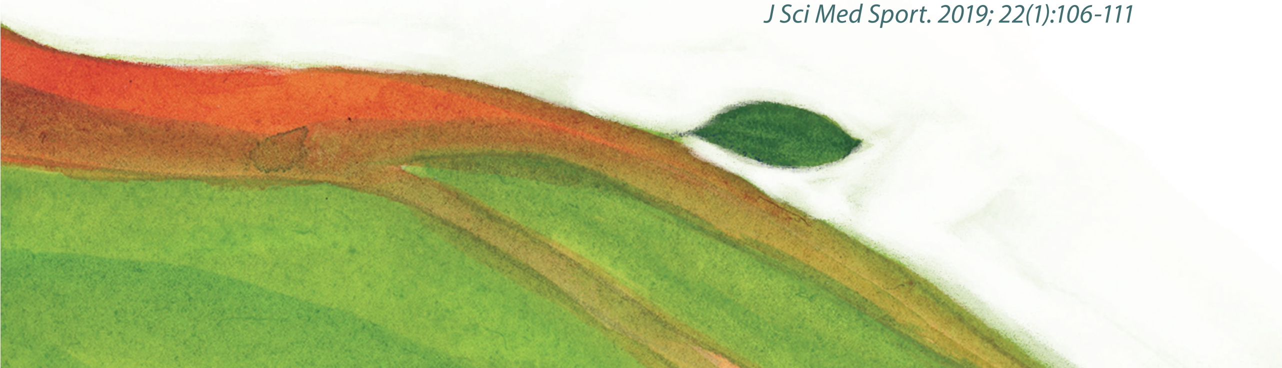


ABSTRACT

Objectives

To determine the proportion of participants of a running program for novice runners that discontinued running and investigate the main reasons to discontinue and characteristics associated with discontinuation.

Design

Prospective cohort study

Methods

The study included 774 participants of Start to Run, a 6-week running program for novice runners. Before the start of the program, participants filled-in a baseline questionnaire to collect information on demographics, physical activity and perceived health. The 26-weeks follow-up questionnaire was used to obtain information on the continuation of running (yes/no) and main reasons for discontinuation. To determine predictors for discontinuation of running, multivariable logistic regression was performed.

Results

Within 26 weeks after the start of the 6-week running program, 29.5% of the novice runners (n=225) had stopped running. The main reason for discontinuation was a running-related injury (n=108, 48%). Being female (OR 1.74, 95% CI 1.13;2.68), being unsure about the continuation of running after the program (OR 2.06, 95% CI 1.31;3.24) and (almost) no alcohol use (OR 1.62, 95% CI 1.11;2.37) were associated with a higher chance of discontinuation of running. Previous running experience less than one year previously (OR 0.46, 95% CI 0.26;0.83) and a higher score on the RAND-36 subscale physical functioning (OR 0.98, 95% CI 0.96;0.99) were associated with a lower chance of discontinuation.

Conclusions

In this group of novice runners, almost one-third stopped running within six months. A running-related injury was the main reason to stop running. Women with a low perceived physical functioning and without running experience were prone to discontinue running.

INTRODUCTION

Worldwide, the number of people with overweight and obesity has more than doubled between 1980 and 2013[1]. This is mainly due to changes in diet and a more sedentary lifestyle[2]. An increasing number of people have sedentary jobs, resulting in less physical activity during the day[3]. Moreover, in most European countries sports participation rates have remained the same since the 1990s and in some countries the rates have even decreased[4]. In response to this general sedentary behavior, many sport promotion programs have been started in European countries[5]. However, a common problem among novice sport participants is the high rate of discontinuation[6,7].

Running is an accessible type of sport, because it is inexpensive and can be done when and where one likes[8,9]. Moreover, many running events and running programs for novice runners are available that stimulate people to start running[10]. However, for a healthy and active lifestyle it is important that novice runners not only run during the preparation for a running event or during a running program, but that they also continue running after such an event or program. Among recreational runners participating in a running event, about 50% have stopped running by 10 years after the event[11]. In novice runners, 16% have stopped running after 180 days and 27% after 270 days[12]. However, little is known about the percentage of novice runners that continue running after participating in a running program. To prevent discontinuation of running in the future, more insight is required into the proportion and characteristics of novice runners that have stopped running.

In the Netherlands, a supervised running promotion program, 'Start to Run', is organized twice a year by the Dutch Athletics Federation at different locations throughout the Netherlands. During the Start to Run program, novice runners can participate in one group training and in one or two individual training sessions per week. In 2013, the ultimate goal of Start to Run was to be able to run for 20 minutes without breaks after six weeks training. An earlier study showed that 69% of the participants of this program were still running after six months[13]. However, this latter study had only 100 participants, and the main reasons for discontinuation and characteristics that make novice runners prone to stop are unknown. Therefore, the aims of the present study were to determine the proportion of participants of Start to Run that discontinued running and to determine the main reasons for stopping and the characteristics associated with discontinuation of running.

METHODS

Potential participants of this study were novice runners (aged 18 to 65 years) who signed up for the Start to Run program in March or September 2013. Runners willing to participate were asked to sign digital informed consent and complete the baseline questionnaire one week before the program started. A follow-up questionnaire was sent to the participants 26 weeks later (i.e. 20 weeks after Start to Run ended). The present study is part of the NLStart2Run-study[14] and was approved by the Medical Ethical committee (No. 2012/350) of the University Medical Center Groningen.

The first section of the baseline questionnaire collected data on demographics (sex, date of birth, height and weight). Body mass index (BMI) was calculated from weight and height. Regarding lifestyle, participants were asked if they smoked (yes/no/used to) and how often they drank alcohol. For the analyses, alcohol use was categorized into three categories: i.) less than once a month, ii.) between once a month and three times a week, and iii.) more than three times a week. The next section included questions on physical activity. Physical activity in daily life was assessed with the Short Questionnaire to Assess Health-enhancing physical activity (SQUASH)[15], where a higher score indicates more physical activity in daily life. Previous sport experience was established by asking about earlier running experience (yes/no; if yes, more or less than one year ago) and structural experience with other sports (yes/no). This section also asked about earlier running-related injuries (yes/no) defined as an injury to the feet, legs or lower back in the past that was caused by running, and other musculoskeletal complaints (yes/no). Finally, the participants were asked if they intended to continue running after the Start to Run program (yes/maybe/no). In the last section of the baseline questionnaire the participants' motivation to exercise was obtained with the Behavioral Regulation in Exercise Questionnaire-2 (BREQ-2)[16]. Using the scores on the five subscales, the relative autonomy index (RAI) was calculated with a higher RAI score indicating a higher level of intrinsic motivation. Perceived health was administered with the Dutch version of the RAND 36-item Health Survey (RAND-36), which was translated from the standardized SF-36 Health Survey[17]. Only the scores on the subscales physical fitness, mental health, vitality and general health (range 0-100, with a higher score indicating a better perceived health) were used in the present study.

The 26-week follow-up questionnaire obtained information on the continuation of running. Runners were asked if they were still structurally running (with no specific definition on running distance or frequency). Participants that were still running were asked for the main reason to continue running, their way of running (alone/

in a group) and how much time they currently spent on running during one week (minutes). The participants who discontinued running were asked what was their main reason to stop running (no time/running is not the preferred sport/health issues/running-related injury/other injury/other reasons) and if they intended to start running again in the future (yes/no).

Differences in baseline characteristics between the participants that did and did not fill in the follow-questionnaire were analyzed with the independent t-test, Mann-Whitney U test or chi-square test. For participants that filled-in the follow-up questionnaire and were therefore included in the analyses, descriptive statistics [frequencies and percentages for categorical data; mean and standard deviation (SD) for numeric data] were calculated for both the baseline and follow-up measures. Univariate logistic regression analysis was performed to test the univariate associations between the separate predictors and the outcome (i.e. discontinuation of running). To determine predictors for discontinuation, multivariable logistic regression analysis (enter method) was performed, with discontinuation of running as dependent variable and the baseline variables as independent variables. A p-value ≤ 0.05 was considered statistically significant. All analyses were performed with SPSS Statistics version 21.

RESULTS

Of the 7660 novice runners that signed up for Start to Run in March and September 2013, 1936 runners were included in the NLStart2Run-study (Figure 1). The 26-week follow-up questionnaire was filled in by 774 participants (43.7%). Three participants did not indicate whether they were still running and were excluded from the present analyses. Compared with the participants that did not fill in the follow-up questionnaire, participants that filled in the follow-up questionnaire were on average more frequently male (24.9% vs. 19.3%, p=0.005), older (44.6 (10.1) vs. 42.1 (9.9) years, p<0.001), had a lower BMI (25.3 (3.7) vs. 25.8 (4.3) $kg.m^{-2}$, p=0.034) and a higher score on the RAND-36 subscales mental health (74.7 (15.1) vs. 72.8 (16.1), p=0.012), vitality (62.3 (17.3) vs. 60.4 (18.1), p=0.024) and general health (72.2 (15.6) vs. 69.4 (17.3), p=0.001). Furthermore, the participants that filled in the follow-up questionnaire more often had earlier experience with running (43.2% vs. 36.8%, p=0.002) and other sports (46.9% vs. 39.9%, p=0.003) and reported that they had more frequently had a running-related injury in the past (20.3% vs. 15.1%, p=0.005).

At baseline, the average age of the participants included in the analyses was 44.6 (SD 10.1) years and the majority was female (75.0%) (Table 1). Most participants had no previous running experience (56.8%) and 53.1% had never participated in other sports. Furthermore, 79.6% of the participants reported no history of running-related injuries, while the majority reported no history of other musculoskeletal complaints (64.0%).

A total of 70.5% (n=546) of the participants that started the Start to Run program continued running at 26 weeks. They ran on average 98.9 (SD 89.7) minutes/week and the majority (55.7%) ran in a group. Becoming healthier and fitter was the most frequently mentioned reason to continue running (n=431, 78.9%). Other reasons were: to lose weight (n=50, 9.1%), achieve an athletic goal (n=47, 8.6%), social contact (n=14, 2.5%), fun (n=13, 2.4%) and mental health (n=9, 1.6%).

In total 225 participants (29.1%) stopped running within 26 weeks. A running-related injury was the most frequently reported (n=108; 48.0%) reason to stop running. Other reasons were an injury not related to running (n=26, 11.6%), no time (n=26, 11.6%), running is not the preferred sport (n=31, 13.8%), health issues (n=29, 12.9%) and other reasons (n=5, 2.2%). Of the runners that stopped running, 72% indicated that they intended to start running again in the future. This applied, in particular, to the runners who stopped running because of health issues (82.8%) or because they had no time (96.2%).

Univariable logistic regression analyses showed that being female (OR 1.72, 95% CI 1.17;2.53), being unsure about continuation of running after the Start to Run program (OR 2.11, 95% CI 1.40;3.20) and (almost) no alcohol use compared to alcohol use maximally three times per week (OR 1.76, 95% CI 1.23;2.51) were associated with a higher chance of discontinuation of running (Table 2). Previous running experience less than one year ago (OR 0.55, 95% CI 0.34;0.90), and a higher score on the RAND-36 subscales physical fitness (OR 0.97, 95% CI 0.96;0.99), mental health (OR 0.99, 95% CI 0.98;1.00), vitality (OR 0.98, 95% CI 0.97;0.99) and general health (OR 0.99, 95% CI 0.98;1.00) were associated with a lower chance of discontinuation. The multivariable logistic regression model showed that being female was associated with a higher chance of discontinuation than being male (OR 1.68, 95% CI 1.09;2.59) (Table 2). Previous running experience less than one year ago was associated with a lower chance of stopping compared to no previous running experience (OR 0.54, 95% CI 0.30;0.98). Furthermore, (almost) no alcohol use was associated with a higher chance of discontinuation than alcohol use maximally three times per week (OR 1.61, 95% CI 1.10;2.36). Also, being unsure about continuation of running after the Start to Run program was associated with a higher chance of discontinuation than wanting to continue running (OR 2.06, 95% CI 1.31;3.24). Finally, a higher score on the RAND-36 subscale physical functioning was associated with a lower chance of discontinuation (OR 0.98, 95% CI 0.96;1.00).

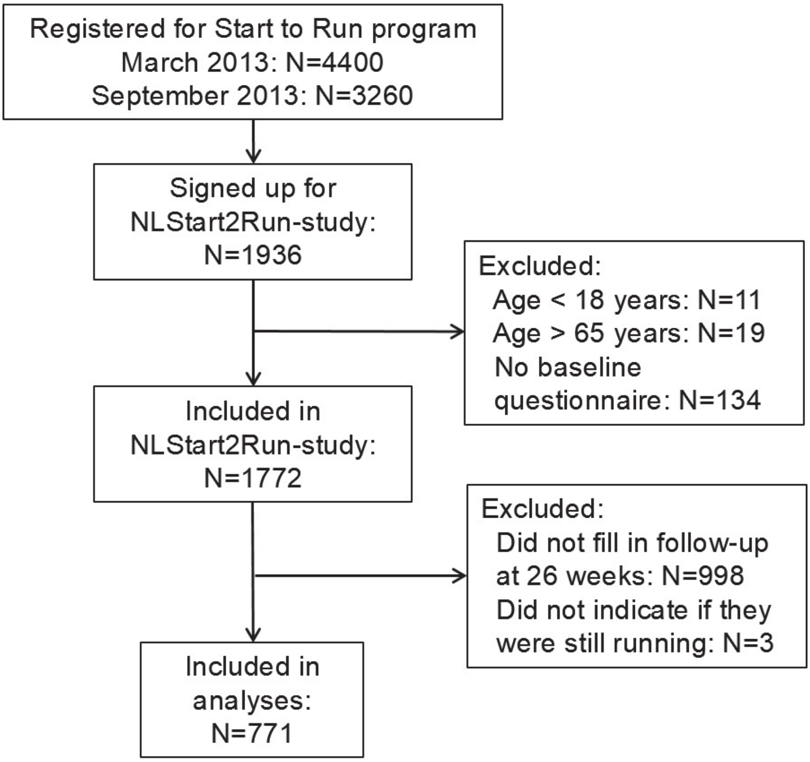


Figure 1. Flowchart of the participants

Table 1. Frequencies and percentages or means and standard deviations (SD) of the baseline characteristics

	All participants		**Continued running**		**Stopped running**	
	N	% / Mean (SD)	N	% / Mean (SD)	N	% / Mean (SD)
	771		546	70.5%	225	29.1%
Sex						
Male	192	24.9%	151	27.7%	41	18.2%
Age (years)		44.6 (10.1)		44.7 (10.1)		44.3 (10.0)
BMI (kg.m^{-2})[a]		25.3 (3.7)		25.1 (3.6)		25.6 (4.1)
Running experience						
No	437	56.7%	300	54.9%	137	60.9%
Yes, more than one year ago	215	27.9%	151	27.7%	64	28.4%
Yes, less than one year ago	119	15.4%	95	17.4%	24	10.7%
Earlier running injury						
Yes	157	20.4%	113	20.7%	44	19.6%
Participating in other sports						
Yes	360	46.7%	257	47.1%	103	45.8%
Earlier musculoskeletal complaints						
Yes	277	35.9%	188	34.4%	89	39.6%
Intended to continue running						
Yes	660	85.6%	483	88.5%	177	78.7%
Maybe	110	14.3%	62	11.4%	48	21.3%
No	1	0.1%	1	0.2%	0	0.0%
Smoking						
Yes	58	7.5%	42	7.7%	16	7.1%
No, but used to	298	38.7%	213	39.0%	85	37.8%
No, never did	415	53.8%	291	53.3%	124	55.1%
Alcohol use						
(Almost) none	203	26.3%	128	23.4%	75	33.3%
Maximally 3 times per week	448	58.1%	336	61.5%	112	49.8%
>3 times per week	120	15.6%	82	15.0%	38	16.9%
SQUASH questionnaire[b]						
Total score		6403 (3511)		6381 (3584)		6455 (3335)
RAND-36 questionnaire[c]						
Physical functioning		92.0 (10.4)		92.9 (9.1)		89.6 (12.6)
Mental health		74.7 (15.2)		75.8 (14.1)		72.1 (17.2)
Vitality		62.3 (17.3)		63.8 (16.0)		58.6 (19.7)
General health		72.2 (15.6)		73.2 (15.2)		69.5 (16.3)
BREQ-2 questionnaire						
RAI score[d]		11.4 (4.5)		11.5 (4.6)		11.3 (4.3)

[a] BMI was missing for one participant; [b] A higher score indicates more physical activity in daily life; [c] A higher score indicates a better perceived health, scores missing for six participants; [d] Relative Autonomy Index, a higher score indicates more self-determination, score missing for six participants

Table 2. Results of univariate and multivariable logistic regression analysis for discontinuation of running

	Univariate analysis		**Multivariable analysis**	
	OR	95% CI	OR	95% CI
Sex				
Female	1.72**	1.17;2.53	1.68*	1.09;2.59
Age (years)	1.00	0.98;1.01	1.00	0.99;1.02
BMI (kg.m^{-2})	1.04	0.99;1.08	1.04	0.99;1.09
Running experience				
No	Reference		Reference	
Yes, more than one year ago	0.93	0.65;1.32	0.96	0.62;1.51
Yes, less than one year ago	0.55*	0.34;0.90	0.54*	0.30;0.98
Earlier running injury				
Yes	0.93	0.63;1.38	1.20	0.71;2.02
Participating in other sports				
Yes	0.95	0.70;1.30	1.02	0.71;1.45
Earlier musculoskeletal complaints				
Yes	1.17	0.85;1.59	1.07	0.76;1.51
Intended to continue running				
Yes	Reference		Reference	
Maybe	2.11**	1.40;3.20	2.06**	1.31;3.24
No	0.00	0.00;0.00	0.00	0.00;0.00
Smoking				
No	Reference		Reference	
No, but used to	0.94	0.68;1.30	0.89	0.46;1.71
Yes	0.85	0.48;1.65	0.96	0.67;1.38
Alcohol use				
(Almost) none	1.76**	1.23;2.51	1.61*	1.10;2.36
Maximally 3 times a week	Reference		Reference	
>3 times a week	1.39	0.90;2.16	1.61	0.99;2.62
SQUASH questionnaire				
Total score	1.00	1.00;1.00	1.00	1.00;1.00
RAND-36 questionnaire				
Physical functioning	0.97**	0.96;0.99	0.98*	0.96;1.00
Mental health	0.99**	0.98;1.00	1.00	0.98;1.01
Vitality	0.98**	0.97;0.99	0.99	0.98;1.00
General health	0.99**	0.98;1.00	0.99	0.98;1.01
BREQ-2 questionnaire				
RAI score[a]	0.99	0.96;1.03	1.03	0.99;1.07

*P<0.05; ** P<0.01; [a] Relative Autonomy Index

DISCUSSION

This study aimed to determine the proportion of participants of the Start to Run-program that discontinued running and to investigate the main reasons to stop running and the characteristics associated with discontinuation. The results showed that 29.5% of the novice runners had stopped running 26 weeks after the start of a 6-week running course. The main reason to stop was a self-reported running-related injury. Being female, being unsure about continuation of running after the Start to Run program and (almost) no alcohol use were associated with a higher chance of discontinuation of running. Previous running experience less than one year ago and a higher score on the RAND-36 subscale physical functioning were associated with a lower chance of discontinuation.

The proportion of runners that stopped running (29.5%) six months after the Start to Run program started is comparable to the proportion reported by Ooms et al. (31%)[13]. However, both studies had a high loss to follow-up (56% and 43%, respectively), which possibly caused selection bias. In the present study the group of participants that filled in the follow-up questionnaire included significantly older runners and more males compared with the group of participants that did not fill in the follow-up questionnaire. Furthermore, the runners that filled in the follow-up questionnaire had more previous experience with running and other sports and perceived themselves to be physically fitter (higher RAND scores). Additionally, it is likely that participants who were still running were more inclined to fill in the follow-up questionnaire than participants that stopped running. Therefore, in the present study the high loss to follow-up may have led to an underestimation of the discontinuation of running. Consequently, it seems that at least one-third of the participants of a running course for novice runners stops running within 26 weeks. However, the goal of both the Start to Run program and of most participants was to continue running after the program. Therefore, these findings emphasize the need for measures to prevent discontinuation from running among novice runners.

A running-related injury incurred during the program or follow-up was the main reason to stop running. Since about half of the participants stopped running due to a running-related injury, injuries seem to be a considerable problem among novice runners. This is previously confirmed in other studies showing injury proportions in novice runners ranging from 7.8 to 84.9%[18,19]. Although it cannot be retrieved from the data of the current study, it seems unlikely that everyone who stopped running because of an injury still suffers from this injury. It therefore seems hard to restart running again after an injury. In order to decrease the discontinuation, it seems therefore important to pay more attention to injury prevention and the restart of running after an injury. Running courses offer a good setting to inform novice runners about these topics. For example, they could be informed about important risk factors for running injuries and how to start running again after an injury. However, more research on the prevention of injuries is necessary. Although several risk factors for running-related injuries have been identified[20,21] no effective prevention program has been identified so far. This may be because the cause of running injuries is multifactorial while previous prevention studies have mainly focused on single risk factors[22,23].

One aim of the present study was to investigate characteristics associated with the discontinuation of running. Since about half of the participants that stopped running did so because of a running-related injury, it might be expected that the factors associated with discontinuation of running are similar to those associated with sustaining a running-related injury. However, additional analyses showed that this is not the case. Multivariate logistic regression analysis with only the participants that stopped because of reasons other than a running-related injury yielded results similar to those including all participants.

In the present study (almost) no alcohol use was associated with a higher chance of discontinuation. However, the underlying mechanism behind this possible association is unclear. Alcohol use was included as a lifestyle factor of participants. Perhaps, alcohol use is a proxy variable for a non-measured variable in the present study, and not for lifestyle, since the opposite would have been expected.

It is interesting that no association was found between the answers on the BREQ-2 questionnaire and the discontinuation of running. The BREQ-2 was designed to measure motivation towards exercise[16] and we expected that this motivation would influence the continuation of running. The reason that no association was found may be due to the small variance in the scores on the BREQ-2 between the participants. However, being unsure about the continuation of running after the Start to Run program was associated with a higher chance of discontinuation than intending to continue running. Therefore, one single question about the intention of running seems a better indicator for the motivation towards running than the BREQ-2 questionnaire.

In response to the increasing rates of sedentary behavior and obesity, physical activity is being promoted worldwide[5]. Running is an accessible form of physical activity and is seen as one of the most efficient ways to improve the physical fitness[20]. In the present study, the main reason to continue running was 'to become healthier and fitter', indicating that participants were aware of the health benefits of increasing physical activity levels. However, continuation of physical activity in health promotion programs is a challenge. Discontinuation and drop-out are also high in lifestyle programs[24,25]. Studies on compliance and drop-out in lifestyle programs have identified many different predictors (e.g. BMI, age)[25-27]. However, there is no agreement between these studies regarding the predictors[28]. The discontinuation in lifestyle programs that included an exercise component was on average somewhat lower than that of the Start to Run program[29]. In these lifestyle programs the discontinuation ranged from 0 to 50%, with half of the programs having a discontinuation of less than 10%. The injury risk in the lifestyle programs is possibly lower than in the Start to Run program. Since the main reason for discontinuation after the Start to Run program was an injury, this may explain our higher discontinuation. Furthermore, the higher discontinuation may also be due to the duration of the Start to Run program (6 weeks) which is relatively short compared to that of lifestyle programs (4-72 months)[29]. Therefore, increasing the length of the Start to Run program might result in a lower discontinuation.

The present study showed that especially women with low perceived physical functioning and without running experience are prone to stop running. To prevent discontinuation, it is important that trainers are aware that these participants are prone to drop-out from running. With this knowledge, trainers might adapt their programs for novice runners by for example paying more attention to these specific groups or by separating these participants into specific training groups that pay extra attention on the continuation of running after the program. Offering an attractive post-program may contribute in a positive way. Furthermore, it seems important to pay extra attention to perceived physical functioning, since a higher perceived physical functioning was associated with a lower chance of discontinuation. Novice runners with a low perceived physical functioning might be encouraged to increase their physical functioning before they participate in a running course (e.g. by improving physical fitness by walking). This, in turn, may lower the chance of discontinuation of these runners.

Strengths of this study include the large study population and the relatively long follow-up. A limitation is the considerable loss to follow-up, which might have caused underestimation of the discontinuation. Furthermore, different reasons to stop running may act as competing risks, which might have underestimated the percentage of participants who reported at follow-up to have stopped due to a running injury. Participants who stopped for reasons other than an injury, might have stopped because of an injury if the other causes had been absent. To address these two limitations, a time-to-event analysis that takes competing risks into account would have been ideal[30]. However, since the time points when runners actually stopped running were not recorded, such an analysis is not possible. Furthermore, recall bias could have influenced characteristics such as running history, injury history and previous sports participation. Also the self-reported continuation of running and injuries might have been influenced by differences in interpretation between runners. In future research clear definitions of running continuation and injuries should be provided to participants. Moreover, this study only included participants in a program for novice runners. However, there are also many runners that start running by themselves. The results of the present study mainly apply to novice runners participating in the Start to Run program.

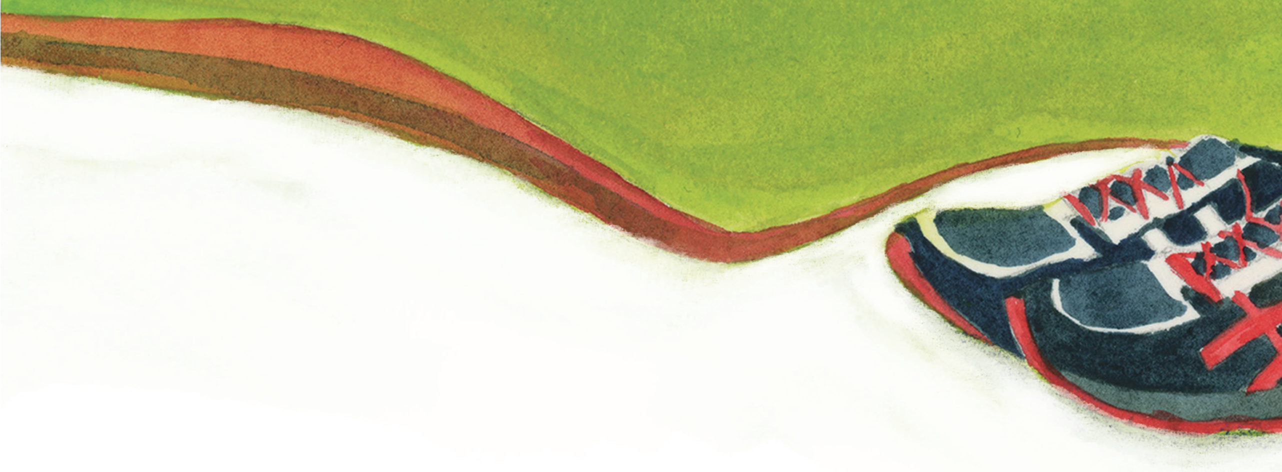
CONCLUSION

This study showed that about one-third of the novice runners participating in a running program stop running within six months. To decrease the discontinuation of running extra attention should be paid to injury prevention, both during running programs and in future studies evaluating the effects of preventive measures for runners. Furthermore, precautions should be taken to prevent discontinuation of running among women with low perceived physical functioning and without prior running experience.

REFERENCES

1. Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014; 384(9945):766-81.
2. Lau DC, Douketis JD, Morrison KM, et al. 2006 Canadian clinical practice guidelines on the management and prevention of obesity in adults and children [summary]. *CMAJ* 2007; 176(8):S1-13.
3. Church TS, Thomas DM, Tudor-Locke C, et al. Trends over 5 decades in U.S. occupation-related physical activity and their associations with obesity. *PLoS One* 2011; 6(5):e19657.
4. Downward P, Lera-Lopez F, Rasciute S. The correlates of sports participation in Europe. *Eur J Sport Sci* 2014; 14(6):592-602.
5. Christiansen NV, Kahlmeier S, Racioppi F. Sport promotion policies in the European Union: results of a contents analysis. *Scand J Med Sci Sports* 2014; 24(2):428-38.
6. Muller-Riemenschneider F, Reinhold T, Nocon M, et al. Long-term effectiveness of interventions promoting physical activity: a systematic review. *Prev Med* 2008; 47(4):354-68.
7. Robison JI, Rogers MA. Adherence to exercise programmes. Recommendations. *Sports Med* 1994; 17(1):39-52.
8. Buist I, Bredeweg SW, Lemmink KA, et al. Predictors of running-related injuries in novice runners enrolled in a systematic training program: a prospective cohort study. *Am J Sports Med* 2010; 38(2):273-80.
9. Taunton JE, Ryan MB, Clement DB, et al. A retrospective case-control analysis of 2002 running injuries. *Br J Sports Med* 2002; 36(2):95-101.
10. Buist I, Bredeweg SW, Bessem B, et al. Incidence and risk factors of running-related injuries during preparation for a 4-mile recreational running event. *Br J Sports Med* 2010; 44(8):598-604.
11. Koplan JP, Rothenberg RB, Jones EL. The natural history of exercise: a 10-yr follow-up of a cohort of runners. *Med Sci Sports Exerc* 1995; 27(8):1180-4.
12. Bertelsen ML, Rasmussen S, Nielsen RO. The impact of running injuries in relation to other reasons for discontinued running in novice runners. *Br J Sports Med* 2017; 51:296.
13. Ooms L, Veenhof C, de Bakker DH. Effectiveness of Start to Run, a 6-week training program for novice runners, on increasing health-enhancing physical activity: a controlled study. *BMC Public Health* 2013; 13:697.
14. Kluitenberg B, van Middelkoop M, Diercks RL, et al. The NLstart2run study: health effects of a running promotion program in novice runners, design of a prospective cohort study. *BMC Public Health* 2013; 13:685.
15. Wendel-Vos GC, Schuit AJ, Saris WH, et al. Reproducibility and relative validity of the short questionnaire to assess health-enhancing physical activity. *J Clin Epidemiol* 2003; 56(12):1163-9.
16. Markland D, Tobin V. A modification to the behavioral regulation in exercise questionnaire to include an assessment of a motivation. *J Sport Exerc Psychol* 2004; 26(2):191-96.
17. Hays RD, Sherbourne CD, Mazel RM. The RAND 36-Item Health Survey 1.0. *Health Econ* 1993; 2(3):217-27.
18. Kluitenberg B, van Middelkoop M, Diercks R, et al. What are the Differences in Injury Proportions Between Different Populations of Runners? A Systematic Review and Meta-Analysis. *Sports Med 2015*; 45(8):1143-61.
19. Van Ginckel A, Thijs Y, Hesar NG, et al. Intrinsic gait-related risk factors for Achilles tendinopathy in novice runners: a prospective study. *Gait Posture* 2009; 29(3):387-91.
20. van der Worp MP, ten Haaf DS, van Cingel R, et al. Injuries in runners; a systematic review on risk factors and sex differences. *PLoS One* 2015; 10(2):e0114937.

21. van Gent RN, Siem D, van Middelkoop M, et al. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med* 2007; 41(8):469-80; discussion 80.
22. Bredeweg SW, Zijlstra S, Bessem B, et al. The effectiveness of a preconditioning programme on preventing running-related injuries in novice runners: a randomised controlled trial. *Br J Sports Med* 2012; 46(12):865-70.
23. Buist I, Bredeweg SW, van Mechelen W, et al. No effect of a graded training program on the number of running-related injuries in novice runners. *Am J Sport Med* 2008; 36(1):35-41.
24. Jiandani D, Wharton S, Rotondi MA, et al. Predictors of early attrition and successful weight loss in patients attending an obesity management program. *BMC Obes* 2016; 3:14.
25. Batterham M, Tapsell LC, Charlton KE. Predicting dropout in dietary weight loss trials using demographic and early weight change characteristics: Implications for trial design. *Obes Res Clin Pract* 2016; 10(2):189-96.
26. Hadziabdic MO, Mucalo I, Hrabac P, et al. Factors predictive of drop-out and weight loss success in weight management of obese patients. *J Hum Nutr Diet* 2015; 28 Suppl 2:24-32.
27. Colombo O, Ferretti VV, Ferraris C, et al. Is drop-out from obesity treatment a predictable and preventable event? *Nutr J* 2014; 13:13.
28. Moroshko I, Brennan L, O'Brien P. Predictors of dropout in weight loss interventions: a systematic review of the literature. *Obes Rev* 2011; 12(11):912-34.
29. Schwingshackl L, Dias S, Hoffmann G. Impact of long-term lifestyle programmes on weight loss and cardiovascular risk factors in overweight/obese participants: a systematic review and network meta-analysis. *Syst Rev* 2014; 3:130.
30. Nielsen RO, Malisoux L, Moller M, et al. Shedding Light on the Etiology of Sports Injuries: A Look Behind the Scenes of Time-to-Event Analyses. *J Orthop Sports Phys Ther* 2016; 46(4):300-11.



3

Prognosis and prognostic factors of running-related injuries in novice runners: A prospective cohort study

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ABSTRACT

Objectives

To investigate the prognosis and possible prognostic factors of running-related injuries (RRIs) in novice runners.

Design

Prospective cohort study

Methods

Participants of Start to Run, a 6-weeks course for novice runners in The Netherlands, were asked to participate in this study. Before the start of the course a baseline questionnaire, on demographics, physical activity and perceived health, was sent to runners willing to participate. The 26- or 52-weeks follow-up questionnaires assessed information on RRIs and their duration. Only participants that sustained a RRI during follow-up were included in the analyses. An injury duration of 10 weeks or shorter was regarded as a relatively good prognosis, while an injury duration of more than 10 weeks was defined as a poor prognosis. To determine the associations between baseline characteristics and injury prognosis and between injury location and injury prognosis, multivariable logistic regression analyses were performed.

Results

347 participants (48.8%) sustained an RRI during follow-up. The RRIs had an overall median duration of eight weeks (range: 1;52 weeks). Participants with a previous RRI were more likely to have a poor prognosis (OR 2.31; 95% CI 1.12;4.79), while a calf injury showed a trend towards an association with a relatively good prognosis (OR 0.49; 95% CI 0.22;1.11).

Conclusions

The duration of RRIs in novice runners is relatively long, with only calf injuries being associated with a good prognosis. This emphasizes the need of injury prevention measures in novice runners and adequate support during and after an RRI, especially in runners with a previous injury.

INTRODUCTION

Running is one of the most popular forms of physical activity in Western countries[1]. For example, in the Netherlands the number of runners has increased over the last years to a running population of more than two million (about 12.5% of the Dutch population) in 2014[2]. Motives to start running include the health benefits (i.e. weight reduction), the low entry level and social elements[3]. It has been shown that running has a positive effect on both physical and mental well-being[4]. However, contradictory to the positive aspects of running, injury rates among runners are high, especially in novice runners[5,6]. These injuries can cause absence from sports, as well as from work, and can increase health care utilization[7]. Moreover, injuries can cause drop-out from running and other activities. Therefore, it is important to gain more insight in the impact of running related injuries (RRIs).

Van Middelkoop et al. performed a study on the course and 3-month prognosis of RRIs in male marathon runners and found that 25.5% of the injured runners still reported persistent complaints after three months follow-up[8]. Furthermore, runners that reported non-musculoskeletal comorbidities were more likely to have prolonged complaints of their injury, while runners who sustained a calf injury recovered relatively fast from this injury. Nielsen et al. described the time to recovery of RRIs in novice runners[9]. A median recovery time of 72 up to 87 days was found for the most common injuries (medial tibial stress syndrome, patellofemoral pain and meniscus injury). Though prognostic factors were not investigated in this study. More knowledge on the prognostic factors for RRIs in novice runners may assist in future guidance of clinicians in the treatment and education towards injured novice runners. Even if non-modifiable prognostic factors are identified, these may help to better inform runners on the prognosis of their RRI. Therefore, the aim of this study was to investigate the prognosis and possible prognostic factors of RRIs in novice runners.

METHODS

This study was part of the NLStart2Run study[10]. Novice runners who signed up for Start to Run, a 6-week running course for novice runners, in March or September 2013 were informed about the NLStart2Run study. Runners that were interested in participating in the study were asked to sign a digital informed consent form and complete the online baseline questionnaire one week before the start of the course. The follow-up questionnaire was sent 52 weeks later to the participants that started Start to Run in March and 26 weeks later to the participants starting in

September. The difference in follow-up duration was due to practical and financial reasons. Participants aged between 18 and 65 years, who sustained an RRI since the start of the NLStart2Run study were included in the analyses of the current study. The NLstart2run study was approved by the Medical Ethics Committee (number 2012/350) of the University Medical Center Groningen, The Netherlands and registered in the Netherlands Trial Registry (NTR3676).

Start to Run is a course for novice runners organized by the Dutch Athletics Federation. In 2013 the goal of the course was to be able to run for 20 consecutive minutes after a period of six weeks. Each training week consisted of one group training session, guided by a licensed athletics trainer, and one or two individual, non-supervised sessions. The duration and intensity of running gradually increased during the 6-weeks program.

In the baseline questionnaire information on demographics (sex, age, weight and height) was assessed. Weight and height were used to calculate the body mass index (BMI). Furthermore, participants were asked if they smoked (yes/no/in the past) and if they wore orthotics in their daily shoes (yes/no). Sport experience was administered with questions on previous running experience (yes/no and if yes, more or less than one year ago) and experience with other sports in the last 12 months. Moreover, participants with previous running experience were asked if they ever had an RRI (yes/no) and all participants were asked about previous musculoskeletal complaints (yes/no and if yes, if the complaints were attributed to sports). The RAND 36-item Health Survey (RAND-36), which is a Dutch translation of the SF-36 Health Survey, was used to administer the perceived health[11,12]. In this study only the scores on the subscales perceived health, mental health, vitality and general health (0-100, with higher scores indicating a better perceived health) were used. Motivation towards exercise was measured using the Behavioral Regulation in Exercise Questionnaire 2 (BREQ-2)[13]. With the score on the five subscales of the BREQ-2 the Relative Autonomy Index (RAI-score) was calculated, with higher RAI-scores indicating a higher level of intrinsic motivation. Finally, physical activity in daily life was assessed with the Short Questionnaire to Assess Health (SQUASH)[14]. A higher score on the SQUASH indicates a higher physical activity level in daily life.

In the follow-up questionnaire the participants were asked if they sustained an RRI since the start of the running program (yes/no). Participants who reported an RRI were asked to indicate the location of their RRI on a body chart. Participants that sustained more than one injury could select multiple locations. Furthermore, information on the duration of the RRI in weeks was asked. Finally, the injured participants were asked if they fully recovered from the RRI already (yes/no).

The primary outcome measure of this study was the duration of the RRIs. An RRI was defined as a self-reported complaint in the lower extremities or lower back caused by running that occurred since the start of the running course. The RRI must have been severe enough to cause a reduction in running for at least one week[10]. Therefore, only RRIs with a duration of at least one week were included in the analyses of this study. The duration of the RRIs was defined as the total duration of the complaints of the RRI in weeks as reported in the follow-up questionnaire. For participants that still suffered their RRI when filling in the follow-up questionnaire, RRI duration was defined as the duration of the complaints so far. Based on Nielsen et al., who found a median RRI duration of 10 weeks in novice runners, the duration of the RRIs was dichotomized into a good prognosis (duration shorter than or equal to 10 weeks) and poor prognosis (duration longer than 10 weeks)[9].

Participants that completed the follow-up questionnaire and participants that did not complete the follow-up questionnaire were compared using independent sample t-tests, Mann-Whitney U tests and chi-square tests. Descriptive statistics were used to describe baseline and injury characteristics. To visualize the course of recovery of the RRIs over the study period, two Kaplan-Meier survival curves (one for the 26 weeks and one for the 52 weeks follow-up) were made with the recovery of the RRI as the event. Differences in time-to-recovery between the two follow-up groups were tested with a log-rank test. Univariate logistic regression models were used to determine the associations between the baseline characteristics and a poor prognosis. Next, multivariable logistic regression analysis (enter-method) was performed using the same baseline characteristics as independent variables. To determine the associations between the injury location and RRI prognosis, both univariate and multivariable logistic regression analyses were performed with prognosis as dependent variable and the injury locations (lower back/hip/groin, anterior thigh, posterior thigh, knee, shin, calf, ankle, Achilles tendon, foot) as independent variables. All regression analyses were adjusted for the follow-up duration (26 or 52 weeks). In the multivariable logistic regression analysis for injury location, the presence of multiple injuries during follow up (yes/no) was included as an additional variable. Results of the logistic regression analyses are presented as odds ratios (OR) with 95% confidence intervals. P-values <0.05 were regarded as significant. All analyses were conducted with the SPSS software package (version 21; 2011, Inc., Chicago, IL).

RESULTS

In 2013, 7660 novice runners registered for Start to Run, of which 1772 participated in the Start2Run-study (Appendix A). The follow-up questionnaire was completed by 727 participants (41.0%). The group of participants that filled in the follow-up questionnaire were on average older (mean 44.7 (SD 10.1) vs. 42.1 (9.9) years, p<0.001), more often male (25.9 vs. 18.9%, p=0.001), had previous experience with running (43.2 vs. 37.0%, p=0.010) and other sports (48.4 vs. 39.1%, p<0.001) more often, had previous RRIs more often (20.4 vs. 15.3%, p=0.006) and scored on average higher on the RAND-36 questionnaire subscales mental health (mean 75.3 (SD 14.8) vs. 72.5 (16.3), p=0.001), general health perception (mean 72.5 (SD 15.6) vs. 69.3 (17.2), p<0.001) and vitality (mean 63.1 (SD 16.8) vs. 59.9 (18.4), p<0.001) than the groups of participants that did not complete the follow-up questionnaire. Of the participants that completed the follow-up questionnaire, 355 participants (48.8%) reported an RRI during follow-up. Eight of these injured participants did not report the duration of their RRI and therefore a total of 347 participants were included in the analyses.

The included participants were on average 45.0 (SD 9.4) years old, had an average BMI of 25.6 (SD 3.7) kg.m^{-2} and the majority was female (66.9%) (Table 1). About one-third of the participants (32.3%) had previous running experience more than a year ago and 13.3% less than a year ago, while 23.9% of the participants sustained an RRI before. Other previous musculoskeletal complaints were present in 38.6% of the participants.

During the follow-up period the 347 participants sustained 513 RRIs (Table 2). Multiple injury locations were reported by 35.7% of the participants. The knee (25.0%), lower back/hip/groin (15.4%) and the Achilles tendon (14.4%) were injured most frequently. The overall median duration of the RRIs was eight weeks. Injuries of the anterior thigh had the shortest median duration (5 weeks), while injuries of the Achilles tendon and posterior thigh had the longest median duration (9 weeks). The Kaplan-Meier curve showed that there was a significant difference in the distribution of the time-to-recovery of the RRIs between the two follow-up groups (26 and 52 weeks) (p=0.012) (Appendix B).

Results of the univariate and multivariable logistic regression analyses for prognostic factors are presented in Table 3. The univariate analyses showed that being female (OR 1.68, 95% CI 1.03;2.73) and a previous RRI (OR 1.87, 95% CI 1.13;3.11) were significantly associated with a poor prognosis of RRIs. In the multivariable logistic regression analysis, a previous RRI (OR 2.31, 95%CI 1.12;4.79) was related to a poor prognosis. In the univariate logistic regression analyses for injury location an RRI located in the calf (OR 0.42, 95% CI 0.21;0.82) was negatively associated with a poor prognosis (Table 2). Also in the multivariable analysis, a follow-up duration of 52 weeks (OR 1.73, 95% CI 1.08;2.77) was associated with a poor prognosis. A trend towards a negative association between an RRI located in the calf (OR 0.49, 95% CI 0.22;1.11) and a poor prognosis was seen.

Table 1. Baseline characteristics of injured runners and of runners with a good and poor prognosis.

Factor		RRI during follow-up[a]	Good prognosis (≤ 10 weeks)	Poor prognosis (>10 weeks)
N		347	220	127
Sex	*Female*	232 (66.9%)	138 (62.7%)	94 (74.0%)
Age (years)		45.0 (9.4)*	45.8 (9.4)*	43.8 (9.1)*
BMI (Kg/m^2)[b]		25.6 (3.7)*	25.5 (3.4)*	25.9 (4.1)*
Smoking	*Currently smoking*	26 (7.5%)	17 (7.7%)	9 (7.1%)
	Stopped smoking	140 (40.3%)	90 (40.9%)	50 (39.4%)
	Never smoked	181 (52.2%)	113 (51.4%)	68 (53.5%)
Running experience	*None*	189 (54.5%)	123 (55.9%)	66 (52.0%)
	Yes, more than a year ago	112 (32.3%)	71 (32.3%)	41 (32.3%)
	Yes, less than a year ago	46 (13.3%)	26 (11.8%)	20 (15.7%)
Previous RRI[a]	*Yes*	83 (23.9%)	43 (19.5%)	40 (31.5%)
Previous sport activity (last 12 months)	*Yes*	175 (50.4%)	108 (49.1%)	64 (50.4%)
Previous musculo-skeletal complaints	*None*	213 (61.4%)	137 (62.3%)	76 (59.8%)
	Yes, not attributed to sports	67 (19.3%)	41 (18.6%)	26 (20.5%)
	Yes, attributed to sports	67 (19.3%)	42 (19.1%)	25 (19.7%)
Orthotics in daily shoes	*Yes*	47 (13.5%)	27 (12.3%)	20 (15.7%)
BREQ-2[c]	*RAI-score[d]*	11.1 (4.9)*	11.0 (5.1)*	11.3 (4.7)*
SQUASH[e]	*Score*	6480.5 (3431.8)*	6431.4 (3618.2)*	6565.5 (3094.4)*
RAND36[f]	*Physical functioning*	91.5 (10.9)*	91.9 (10.3)*	90.6 (12.0)*
	Mental Health	75.2 (15.1)*	76.2 (13.9)*	73.4 (16.9)*
	Vitality	62.7 (16.6)*	64.0 (15.9)*	60.6 (17.5)*
	General health perception	70.5 (17.0)*	71.2 (16.1)*	69.4 (18.5)*

Categorical data are presented as N (%) and continuous data (*) as means (SD). [a] RRI = Running-related injury; [b] Body Mass Index; [c] Behavioral Regulation in Exercise Questionnaire 2; [d] Relative Autonomy Score; [e] Short Questionnaire to Assess Health; [f] RAND-36 Item Health Survey

Table 2. Anatomical distribution of running-related injuries with corresponding duration of complaints in weeks and the results of the univariate and multivariable logistic regression analyses of injury location associated with poor prognosis.

	Number (%)	**Duration of complaints (weeks)**	**Univariate analysis**		**Multivariable analysis**	
		[Median (range) *Mean (SD)*]	OR (95% CI)	P-value	OR (95% CI)	P-value
Lower back/hip/groin	79 (15.4)	8.0 (1;52) *12.8 (12.9)*	0.88 (0.52;1.50)	0.64	1.01 (0.50;2.02)	0.98
Anterior thigh	11 (2.1)	5.0 (2;24) *8.6 (7.1)*	0.32 (0.07;1.54)	0.16	0.38 (0.07;2.15)	0.28
Posterior thigh	19 (3.7)	9.0 (2;52) *12.1 (11.8)*	1.33 (0.52;3.43)	0.56	2.30 (0.75;7.10)	0.15
Knee	128 (25.0)	8.0 (2;52) *12.6 (12.0)*	1.11 (0.70;1.75)	0.66	1.19 (0.63;2.25)	0.59
Shin	60 (11.7)	8.0 (1;52) *11.7 (10.7)*	1.05 (0.59;1.87)	0.87	1.27 (0.60;2.69)	0.53
Calf	58 (11.3)	8.0 (1;50) *9.7 (9.6)*	0.42 (0.21;0.82)	0.01	0.49 (0.22;1.11)	0.09
Ankle	43 (8.4)	7.0 (2;52) *10.8 (11.1)*	0.77 (0.39;1.56)	0.47	0.94 (0.41;2.14)	0.88
Achilles tendon	74 (14.4)	9.0 (2;52) *13.8 (12.2)*	1.31 (0.77;2.23)	0.31	1.61 (0.81;3.20)	0.17
Foot	41 (8.0)	8.0 (2;52) *13.3 (12.4)*	0.86 (0.43;1.71)	0.66	1.06 (0.47;2.39)	0.88
Multiple injuries (yes)			0.65 (0.41;1.04)	0.65	0.59 (0.26;1.36)	0.21
Total	513 (100)	8.0 (1;52) *12.0 (11.2)*				

All logistic regression analyses are adjusted for follow-up duration

Table 3. Univariate and multivariable logistic regression analyses of prognostic factors associated with a poor prognosis.

Factor	**Qualifier**	**Univariate analysis**		**Multivariable analysis**	
		OR (95% CI)	P-value	OR (95% CI)	P-value
Follow-up duration	*52 weeks*	1.75 (1.11;2.76)	0.02	1.84 (1.12;3.02)	0.02
Sex	*Female*	1.68 (1.03;2.73)	0.04	1.58 (0.91;2.74)	0.11
Age (Years)		0.98 (0.96;1.00)	0.07	0.98 (0.95;1.01)	0.12
BMI (kg/m^2)[a]		1.04 (0.98;1.10)	1.04	1.05 (0.98;1.12)	0.15
Smoking	*Never smoked*	Reference		Reference	
	Currently smoking	1.09 (0.45;2.63)	0.86	0.97 (0.38;2.48)	0.95
	Stopped smoking	1.15 (0.48;2.74)	0.76	1.01 (0.61;1.67)	0.97
Running experience	*No*	Reference		Reference	
	Yes, >1 year ago	1.11 (0.68;1.82)	0.67	0.73 (0.38;1.40)	0.34
	Yes, <1 year ago	1.48 (0.76;2.87)	0.25	0.83 (0.35;1.96)	0.68
Previous RRI[b]	*Yes*	1.87 (1.13;3.11)	0.02	2.31 (1.11;4.79)	0.03
Previous sports activity	*Yes*	1.09 (0.70;1.69)	0.71	1.09 (0.66;1.80)	0.74
Previous musculo-skeletal complaints	*No*	Reference		Reference	
	Yes, not attributed to sports	1.19 (0.67;2.10)	0.56	1.14 (0.61;2.14)	0.68
	Yes, attributed to sports	1.13 (0.64;2.02)	0.67	0.99 (0.53;1.86)	0.97
Orthotics daily shoes	*Yes*	1.35 (0.72;2.54)	0.35	1.31 (0.65;2.64)	0.45
BREQ-2[c]	*RAI;score*[d]	1.01 (0.96;1.06)	0.71	1.02 (0.96;1.07)	0.60
SQUASH[e]		1.00 (1.00;1.00)	0.76	1.00 (1.00;1.00)	0.83
RAND-36[f]	*Physical functioning*	0.99 (0.97;1.01)	0.16	0.99 (0.97;1.02)	0.46
	Mental health	0.99 (0.97;1.00)	0.08	0.99 (0.97;1.01)	0.29
	Vitality	0.99 (0.98;1.00)	0.08	1.00 (0.98;1.02)	0.93
	General health perception	(0.98;1.01)	0.22	1.00 (0.98;1.02)	0.89

All analyses are adjusted for follow-up duration; [a] Body Mass Index; [b] Running related injury; [c] Behavioral Regulation in Exercise Questionnaire 2; [d] Relative autonomy score; [e] Short Questionnaire to Assess Health; [f] RAND-36 Item Health Survey

DISCUSSION

The aim of this study was to investigate the prognosis and possible prognostic factors for time to recovery of RRIs in novice runners. The median duration of the RRIs was eight weeks. Runners who suffered an RRI before had a higher chance of a poor prognosis (>10 weeks) of their new injury. Furthermore, an RRI in the calf seemed to be associated with a relatively good prognosis (≤10 weeks).

In the current study an RRI incidence rate of 48.8% was found, which is within the range (10.3-75.6%) of studies with a comparable follow-up period[15-17]. In addition, the injury locations were comparable to earlier studies, with the knee, Achilles tendon and shin as most frequently injured sites[1,18]. The median duration of the injuries (8 weeks) was a bit shorter than the median duration in the only other study on the prognosis of injuries in novice runners (10 weeks)[9]. The median duration of eight weeks is a substantial injury duration when compared to the prognosis of injured marathon runners. In a study on male marathon runners, 60% of the participants that suffered an RRI recovered within one month[8]. This shows that RRIs are not only common in novice runners[15], but that the duration of injuries is also relatively long in this group of runners. This emphasizes the need for suitable guidance of injured novice runners, especially in runners who suffered an RRI before.

This study showed that, next to the often identified risk factor for sustaining an RRI[1,19], a previous injury is also a risk factor for a poor prognosis of RRIs. Possible explanation might be that the runners did not completely recover from their previous RRI or that structural errors exist in the training or running pattern, what might have caused a more severe 'new' RRI[16,20,21]. Another explanation might be that runners who suffered an RRI before are more prone to RRIs and therefore also sustain more serious RRIs. Unfortunately this cannot be determined from the results of the current study. Therefore, more research on recurrent RRIs, the relationship between recurrences and specific risk factors for recurrent RRIs should be performed.

Despite that RRIs in the anterior thigh had the shortest median duration, calf injuries tended to have a relatively good prognosis. This finding is in accordance with a study performed in male marathon runners, in which calf injuries also had a relatively good prognosis[8]. In these male marathon runners the calf injuries were mostly self-diagnosed as cramps, strain and overload and it was suggested that these types of injuries recover relatively fast[8]. Furthermore it can be hypothesized that calf injuries are often muscle injuries, which recover faster than for example tendon injuries[22,23].

Since the present study collected no information on the type of injury, it remains unknown if the type of injury explains the relatively good prognosis of calf injuries.

A strength of this study is that it is the first study providing data on a broad spectrum of prognostic factors of RRIs in novice runners. Other strengths include the prospectively measured prognostic factors at baseline and relative large study population.

There are, however, some limitations that have to be taken into account when interpreting the results of this study. A limitation is that there were two follow-up durations (26 and 52 weeks), due to practical and financial reasons. There was a significant difference in the distribution of the RRI duration between the two follow-up groups. Therefore, we adjusted all regression analyses for the follow-up duration. Additional sensitivity analyses (data not presented) showed that the regression analyses without adjustment for follow-up duration showed similar results as the analyses with adjustment for follow-up duration. Additionally, analyses of prognostic factors in the two cohort groups (26 and 52 weeks follow up) separately showed similar results as analyzing the participants in one group, as presented in the current study. This confirms the robustness of the analyses by combining the data of the two groups with a different follow up duration.

However, the shorter follow-up of part of the study population may still have led to an underestimation of the RRI duration, since part of the study population was followed shorter and the maximal duration of complaints following their RRIs was therefore shorter. Additionally, 15% of the injured participants reported an RRI with, at the moment of filling in the questionnaire, a duration of 10 weeks or less with no full recovery yet. For these participants that still suffered their RRI when filling in the follow up questionnaire, the RRI duration was set at the duration of the complaints so far. Therefore, some of these RRIs may have been classified as having a good prognosis while they actually have lasted more than 10 weeks. This might have led to misclassifications of some of the injuries and an underestimation of RRI duration in this study.

This study had a follow-up of 26 or 52 weeks, so for some participants there may have been quite some time between their RRI and the follow-up questionnaire. This may have caused recall bias in the injury characteristics. Moreover, this may have led to an underestimation of RRIs with a relatively good prognosis, since less severe RRIs with a shorter time loss will be forgotten more easily than severe injuries with more time loss.

Another limitation is that participants were able to report multiple RRIs at different locations in the follow-up questionnaire. Though, injury duration could only be reported once. About 35% of the participants reported two or more injuries during the follow-up period. It is likely that these participants reported the duration of the injury with the longest duration. This may have led to an overestimation of the RRI duration per anatomical site and of all injuries taken together.

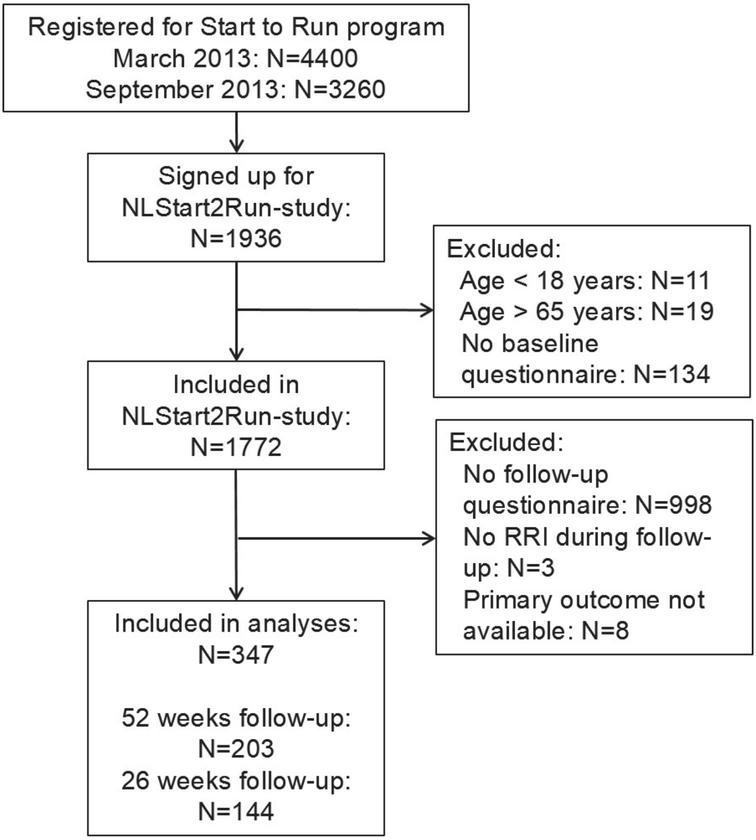
Finally, the percentage loss to follow-up (59.0%) was relatively high, which might have influenced the results. Since there were significant differences between the participants that did and did not complete the follow-up questionnaires, it seems that the relatively fit and older aged males were more likely to respond to the follow-up questionnaires. Therefore, the results may only apply to this selected population.

CONCLUSION

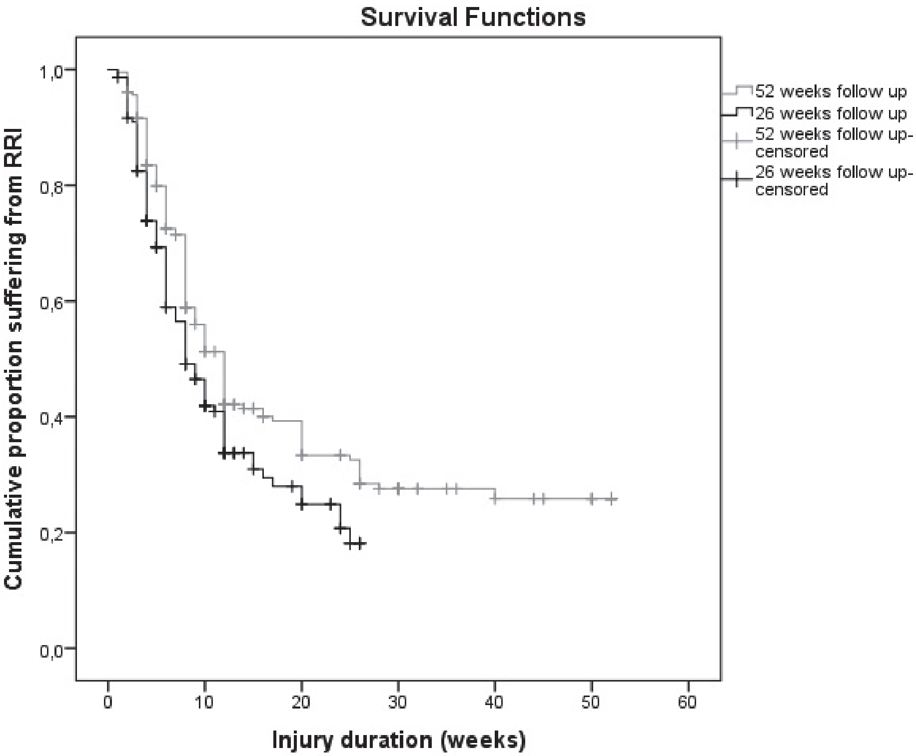
This study showed that the median duration of RRIs in novice runners was eight weeks (range 1-52 weeks). A previous RRI was associated with a higher chance of a poor prognosis of the current RRI, which emphasizes the need for well-founded rehabilitation programs and injury prevention measures in novice runners.

REFERENCES

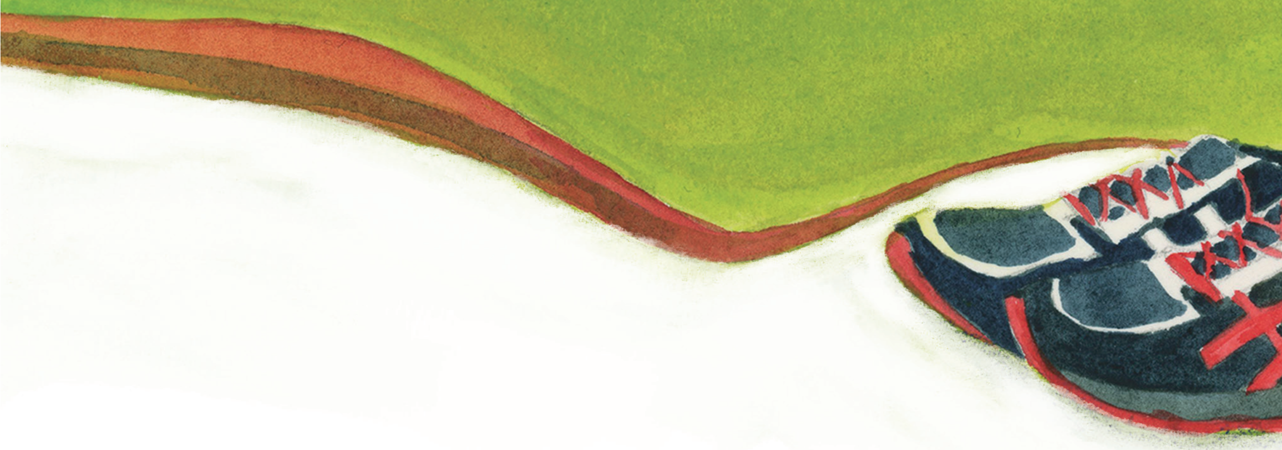
1. van der Worp MP, ten Haaf DS, R. van Cingel R, et al. Injuries in runners; a systematic review on risk factors and sex differences. *PLoS One* 2015; 10(2):e0114937.
2. VeiligheidNL. Hardloopblessures Blessurecijfers 2014. Amsterdam: VeiligheidNL; 2016
3. Verhagen E. Prevention of running-related injuries in novice runners: are we running on empty? *Br J Sports Med* 2012; 46(12):836-837.
4. Lee DC, Brellenthin AG, Thompson PD, et al. Running as a key lifestyle medicine for longevity. *Prog Cardiovasc Dis* 2017; 60(1):45-55.
5. van Gent RN, Siem D, van Middelkoop M, et al. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med* 2007; 41(8):469-480.
6. Videbaek S, Bueno AM, Nielsen RO, et al. Incidence of running-related injuries per 1000 h of running in different types of runners: a systematic review and meta-analysis. *Sports Med* 2015; 45(7):1017-1026.
7. Smits DW, Huisstede B, Verhagen E, et al. Short-term absenteeism and health care utilization Due to Lower Extremity Injuries Among Novice Runners: A Prospective Cohort Study. *Clin J Sport Med* 2016; 26(6):502-509.
8. van Middelkoop M, Kolkman J, van Ochten J, et al. Course and predicting factors of lower-extremity injuries after running a marathon. *Clin J Sport Med* 2007; 17(1):25-30.
9. Nielsen RO, Ronnow L, Rasmussen S, et al. A prospective study on time to recovery in 254 injured novice runners. *PLoS One* 2014; 9(6):e99877.
10. Kluitenberg B, van Middelkoop M, Diercks RL, et al. The NLstart2run study: health effects of a running promotion program in novice runners, design of a prospective cohort study. *BMC Public Health* 2013; 13:685.
11. van der Zee KI, Sanderman R. Het meten van de algemene gezondheidstoestand met de RAND-36. Groningen: Noordelijk Centrum voor Gezondheidsvraagstukken, Rijksuniversiteit Groningen; 1993.
12. Hays RD, Sherbourne CD, Mazel RM. The RAND 36-item health survey 1.0. *Health Econ* 1993; 2(3):217-227.
13. Markland D, Tobin V. A modification to the behavioral regulation in exercise questionnaire to include an assessment of a motivation. *J Sport Exerc Psychol* 2004; 26(2):191-196.
14. Wendel-Vos GC, Schuit AJ, Saris WH, et al. Reproducibility and relative validity of the short questionnaire to assess health-enhancing physical activity. *J Clin Epidemiol* 2003; 56(12):1163-1169.
15. Kluitenberg B, van Middelkoop M, Diercks R, et al. What are the differences in injury proportions between different populations of runners? A systematic review and meta-analysis. *Sports Med* 2015 45 (8), 1143-1161.
16. Rasmussen CH, Nielsen RO, Juul MS, et al. Weekly running volume and risk of running-related injuries among marathon runners. *Int J Sports Phys Ther* 2013 8 (2)111-120.
17. Jakobsen BW, Kroner K, Schmidt SA, et al. Prevention of injuries in long-distance runners. *Knee Surg Sports Traumatol Arthrosc* 1994; 2(4):245-249.
18. van Ginckel A, Thijs Y, Hesar NG, et al. Intrinsic gait-related risk factors for Achilles tendinopathy in novice runners: a prospective study. *Gait Posture* 2009; 29(3):387-391.
19. Saragiotto BT, Yamato TP, Hespanhol Junior LC, et al. What are the main risk factors for running-related injuries? *Sports Med* 2014; 44(8):1153-1163.
20. Mann R, Malisoux L, Nuhrenborger C, et al. Association of previous injury and speed with running style and stride-to-stride fluctuations. *Scand J Med Sci Sports* 2015; 25(6):e638-645.
21. Hespanhol LC, Costa LOP, Lopes AD. Previous injuries and some training characteristics predict running-related injuries in recreational runners: a prospective cohort study. *J Physiother* 2013; 59(4):263-269.
22. Askling C, Tengvar M, Saartok T, et al. Sports related hamstring strains-two cases with different etiologies and injury sites. *Scand J Med Sci Sports* 2000; 10(5):304-307.
23. Williams JG. Achilles tendon lesions in sport. *Sports Med* 1993; 16(3):216-220.



Appendix A. Flowchart of the participants



Appendix B. Kaplan-Meier survival curve for the proportion of recovery from RRI for the follow-up groups (26 and 52 weeks) during follow-up



4

Preventing running-related injuries using evidence-based online advice: the design of a randomised-controlled trial

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ABSTRACT

Introduction

Running-related injuries (RRIs) are frequent and can lead to cessation of health promoting activities. Several risk factors for RRIs have been identified. However, no successful injury prevention program has been developed so far. Therefore, the aim of the present study is to investigate the effect of an evidence-based online injury prevention programme on the number of RRIs.

Methods and analysis

The INSPIRE-trial is a randomised-controlled trial with a 3-month follow-up. Both novice and more experienced runners, aged 18 years and older, who register for a running event (distances 5 km up to 42.195 km) will be asked to participate in this study. After completing the baseline questionnaire, participants will be randomised into either the intervention group or control group. Participants in the intervention group will get access to the online injury prevention programme. This prevention programme consists of information on evidence-based risk factors and advices to reduce the injuries risk. The primary outcome measure is the number of self-reported RRIs in the time frame between registration for a running event and 1 month after the running event. Secondary outcome measures include the running days missed due to injuries, absence of work or school due to injuries and the injury location.

Ethics and dissemination

An exemption for a comprehensive application is obtained by the Medical Ethical Committee of the Erasmus University Medical Center Rotterdam, Netherlands. The results of the study will be published in peer-reviewed journals and presented on international congresses.

Trial registration

Dutch Trial Registration (NTR5998). Registered on August 22th 2016.

INTRODUCTION

Running is a frequently practiced sport that is still growing in popularity. In the Netherlands more than 2 million people performed regular running in 2014[1], which is around 12.5% of the Dutch population. While running provides many health benefits, the main drawback of running is the fact that runners are prone to musculoskeletal injuries. A systematic review showed that the injury proportions in running vary between 3.2 and 84.9%, where cross-country runners had lowest number of injuries and novice runners the highest number of injuries[2]. With the growing population of runners, the number of running-related injuries (RRIs) also increased. Since 2010 the number of RRIs doubled in the Netherlands to 710.000 injuries in 2014[1]. However, the number of RRIs is growing faster than the number of runners. In 2011, the number of RRIs in the Netherlands corresponded to 4.8 injuries per 1000 running hours, in 2014 this number increased to 6.1 injuries per 1000 running hours[1].

Several studies have been conducted in order to identify risk factors for RRIs, in which many different risk factors have been identified, for example overweight, a high weekly running distance, a low running cadence and running on outworn shoes[3-6]. However, the most frequently identified risk factor is a previous injury[7-9]. Therefore, prevention of this first injury is very important.

An extensive literature search showed that preventive interventions for runners have only been studied in a few randomised-controlled trials (Table 1). Most of these studies focused on one particular modifiable risk factor for RRIs. Only in a study on the use of motion control shoes a reduction in the number of RRIs was found[10]. However, these findings contrast with the results of another study on the effects of type of running shoe on pain during running[11]. The other prevention studies addressing one risk factor did not show a reduction in the number of RRIs[12-16]. Since the cause of running injuries is multifactorial, the focus on modifying one risk factor is probably not the best way to decrease the number of RRIs. A multifactorial approach, in which several risk factors are addressed at the same time, might therefore be more effective.

Therefore, the aim of the present study is to examine the effect of an evidence-based online injury prevention programme on the number of RRIs.

Table 1. Randomised controlled trials on the prevention of running related injuries (RRIs)

Study	Participants	Intervention	Outcome measure	Main results
Buist et al. (2008)[12]	532 novice runners, enrolled in a beginners' programme	Graded training programme with an increase in training volume of no more than 10% per week	Incidence of RRIs	No effect
Bredeweg et al. (2012)[14]	Healthy participants enrolled in beginners' 9-week training program	4-week preconditioning training programme with walking and hopping exercises	Incidence of RRIs	No effect
Malisoux et al. (2016a)[10]	372 recreational runners	Motion control vs. standard running shoes	Incidence of RRIs	Motion shoes reduced the number of injuries in runners with pronating foot type
Malisoux et al. (2016b)[16]	535 leisure-time runners	Standard cushioned running shoes with different levels of heel-to-toe drop	Incidence of RRIs	No effect
Theisen et al. (2014)[15]	247 leisure-time distance runners	Soft vs. hard midsoles in standard running shoes	Incidence of RRIs	No effect
Van Mechelen et al. (1993)[13]	421 male recreational runners	Standardised warm-up, cooldown and stretching exercises	Incidence of RRIs	No effect

Search in Pubmed with search terms: (running injury OR running injuries) AND (prevention OR preventing) AND randomised controlled trial. Search performed on 22 December 2016.

METHODS AND ANALYSIS

Study design

The INSPIRE trial (INtervention Study on Prevention of Injuries in Runners at Erasmus MC) is a randomised-controlled trial with a 3-month follow-up. Recruitment of participants for the INSPIRE trial takes place from October 2016 onwards and data analysis starts in September 2017. A flow chart of the design and follow-up is shown in Figure 1.

This study is funded by the Netherlands Organisation for Health Research and Development (ZonMW) and is performed in collaboration with Golazo, an organisation of large running events in the Netherlands. An exemption for a comprehensive application is obtained by the Medical Ethical Committee of the Erasmus University Medical Center Rotterdam, The Netherlands (MEC-2016-292) and the study is registered in the Dutch Trial Register (NTR5998). All participants will provide electronic informed consent.

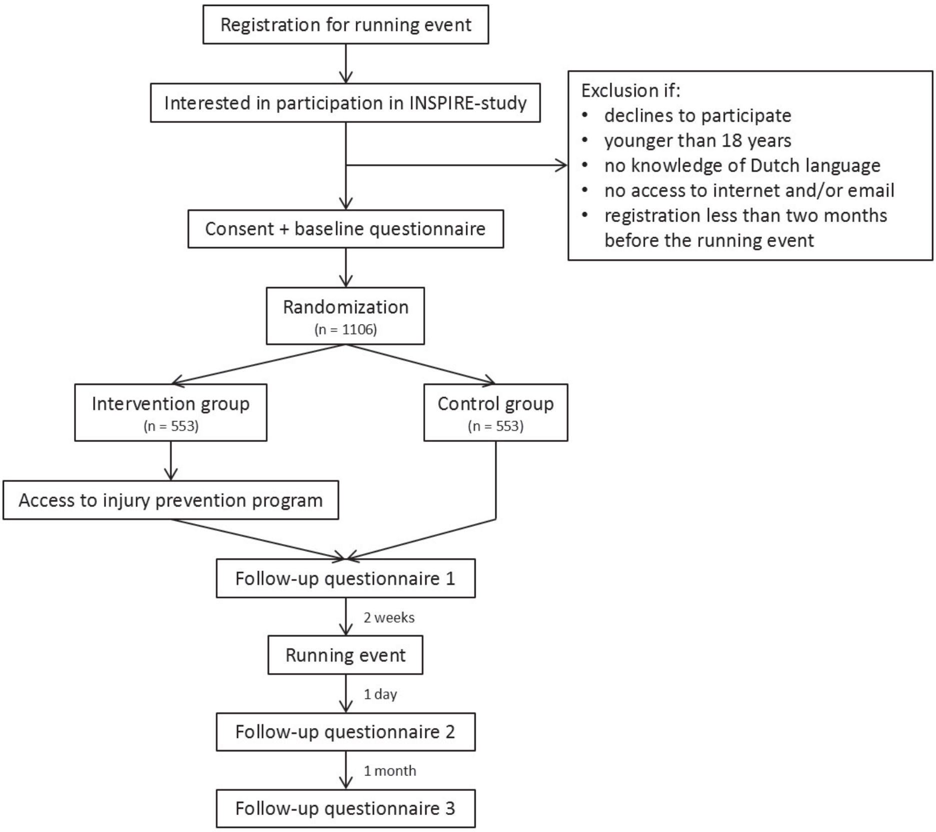


Figure 1. Flowchart of the INSPIRE trial.

Study population

All runners who register for one of three large running events are potential participants of the study. The running events include the NN City Pier City Run The Hague (5, 10 and 21.1 km), NN Marathon Rotterdam (10.55 and 42.195 km) and the Ladies Run Rotterdam (5, 7.5 and 10 km). Runners can register online for these events. For the current study purpose, the runners are asked if they are interested in participating in a study of the Erasmus MC on the prevention of running related injuries on the registration form. Contact information of interested runners is sent to the research team. Subsequently, all interested runners will be sent additional online information about the study and, if still interested, will be asked to provide informed consent for the study and fill in the baseline questionnaire.

Both novice and more experienced runners, aged 18 years and older, can participate in this study. Exclusion criteria are no knowledge of the Dutch language and no access to internet and/or email. Additionally, runners that register less than 2 months before the running event will be excluded because the minimum follow-up of all runners is 3 months.

Sample size

Based on a recent systematic review on incidence of RRIs among a mixed population of long-distance runners, an injury incidence of 16% is expected in the control group[2]. Given the 10.9% injury incidence found in novice runners[17], it is estimated that 14% of the runners in our population will occur an injury during follow-up. With a risk difference of 5% (this means a reduction of 90.000 injuries in the Netherlands), 0.05 significance level (one-sided testing) and a power of 80%, a total of 1006 runners should be included in the analyses to detect a relevant difference in RRIs. Taking a loss to follow-up of 10% into account, at least 1106 runners (553 in each group) will be included in the trial.

Randomisation

After completing the baseline questionnaire, the participants will be randomised into either the intervention group or the control group using a computer generated randomisation list with block size of 10. The randomisation list is developed by an individual, who is not part of the research team.

Control group

All participants randomly assigned to the control group will follow their regular preparation for the running event. These participants will not receive additional advices for injury prevention.

Injury prevention programme

After randomisation, all participants randomly assigned to the intervention group will receive an email with a username and password in order to get access to the online injury prevention programme. This prevention programme can only be accessed with the username and password. The prevention programme is developed by the researchers by means of an extensive literature search and aims to modify evidence-based risk factors for RRIs. The intervention programme is focused on four main topics: personal factors, training factors, equipment and biomechanics. An overview of the topics and advices in the prevention programme is presented in Table 2.

The structure of the information about every risk factor is the same and is provided in layman's language. After a short introduction, an overview on the scientific literature is given for the presented risk factor. This is, for example, information on how much higher the chances of sustaining an RRI gets due to the risk factor. When there are contradictory findings in literature, it is also mentioned in this section. Information on, for example, the impact of the risk factor is given, and on uncertainties from literature. Next, the findings from literature are explained, for example, the mechanism on how the risk factor can lead to more RRIs. If necessary, critical notes about studies are also discussed in this section. Finally, the results from literature are translated into practical advices for the runners. These advices are based on interventions that can potentially reduce the risk factor, based on the best available evidence. All advices and information are supported by images, graphics and movies in order to improve the information transfer. All evidence is supported by references and links to other websites, online applications and scientific literature.

The information in the injury prevention program is different for novice and for experienced runners. A few guidelines will be given to decide whether a runner is considered novice or experienced. In these guidelines novice runners are considered as runners that just started running or have not been running for a long time due to an injury or illness. Experienced runners are considered as runners that have quite some running experience and are able to run shorter distances (e.g. 5 kilometer) without problems. However, the participants will choose for themselves which category they belong to and will have the possibility to switch between the categories.

Personal factors

Personal factors are the characteristics of an individual (e.g. length, sex and weight). Personal factors that are associated with RRIs include a higher age, over- and underweight, previous injuries and absence of previous experience with running or other sports[3,4,6,18,19]. The associations for weight and absence of previous experience with running or other sports is only studied in novice runners[3,4,20].

Training

Training errors are frequently suggested as the most important cause of injuries[48]. Several training factors that increase the risk of RRIs have previously been identified. These factors are discussed in the injury prevention programme. The first risk factor that is discussed is the running distance. In several studies it is shown that running more than 64 kilometers per week increases the risk of RRIs[4,22]. Running too many times per week[23,24] and running only one time a week increases the risk of RRIs[6,25]. These data suggest that there might be an optimum running frequency for the majority of runners. Also runners that intensively train all year around have a higher chance of sustaining an RRI[21,22]. Therefore, the injury prevention programme contains a section about periodisation. For the novice runners a general advice is provided to plan periods of rest. For the experienced runners a more elaborated explanation of periodisation and its application is given. Also the running surface has influence on the risk of RRIs. It has been shown that running on a hard surface increases the risk of injuries and it is therefore advised to perform the majority of the training sessions on a soft surface[4]. The last training factor that is discussed in the injury prevention programme is stretching. There still is debate about the use of stretching for injury prevention[49,50]. However, one thing is clear: occasional stretching increases the risk of RRIs[4]. Therefore, the participants are advised to stretch at every training session or not at all.

Biomechanics

In the biomechanics section cadence and foot strike are discussed. There are indications that a higher cadence decreases the risk of injuries, because running with a higher cadence, and consequently with a smaller step length, reduces the forces in the knee and hip joints[5,27-29]. Additionally, the different types of foot strike (rearfoot, midfoot and forefoot strike) are discussed. There is some evidence that running with a forefoot strike pattern may reduce injuries[51-53] due to the reduction in impact forces seen in this footstrike pattern. However, changing to a forefoot strike takes adequate preparation and can result in calf muscle injuries and Achilles tendon overuse injuries if transitioning too quickly. Therefore, if runners would like to transition to a forefoot strike pattern, a training programme developed by Spaulding National Running Center (Harvard Medical School, Cambridge, Massachusetts, USA) is provided. This training programme contains strengthening exercises for the foot and ankle muscles and a schedule to gradually build up mileage[54].

Table 2. Topics and advices in the online injury prevention program

	Risk factors		**Short summary of the advice**	**References**
	Novice runners	*Experienced runners*		
Personal factors	Higher age	Higher age	Be aware of the higher risk and do not run when you have any pain	6,17
	Over- or underweight	-	Adapt a preconditioning phase of partial weight-bearing sports	3,9,19,20
	Previous injuries	Previous injuries	Start building up at a very low level after an injury, for example, with a training programme for starting runners	3,7-9,21
	No experience with running or other sports	-	Adapt a preconditioning phase of walking	3,4,7,14,17,19
Training	Distance	Distance	Run no more than 64 km per week	4,21-23
	Frequency	Frequency	Train at least two times a week, but not too much. Search for the optimal frequency	6,22-26
	Overtraining	Overtraining	Consciously apply rest periods using periodisation	21,22
	Surface	Surface	Perform the majority of the training session on a soft surface	4
	Stretching	Stretching	Implement stretching at every training session or not at all	4
Biomechanics	Cadence	Cadence	Increase cadence with use of apps	5,27-35
	Foot landing	Foot landing	Forefoot strike reduces the risk of RRIs. However, switching to a forefoot strike increases the risk of RRIs. Therefore, perform foot muscle exercises when you want to change to a forefoot strike	36-39
Equipment	Barefoot running and minimalistic footwear	Barefoot running and minimalistic footwear	Minimalistic shoes might reduce the risk of RRIs. However, switching to minimalistic shoes increases the risk of RRIs. Therefore, adapt a habituation period and use a training schedule when you want to switch to minimalistic shoes	36,40-42
	Neutral, stabilising and motion-control shoes	Neutral, stabilising and motion-control shoes	Not clear if a certain type of shoe belongs to a certain type of foot. Do not change the type of shoes when you have no RRIs	10,11,43
	Orthotics/inlays	Orthotics/inlays	Do not wear orthotics to prevent injuries. Only consider to wear them when you often have RRIs	44-46
	Use of running shoes	Use of running shoes	Be aware of the wear pattern of your shoes, especially when they are older than 6 months. Use multiple pairs of shoes	6,47

Equipment

This section of the injury prevention programme contains information about running equipment, including shoes and insoles. There are indications that minimalistic shoes reduce the incidence of RRIs[41]. They have also been shown to increase foot muscle size indicating stronger feet[55]. However, changing to minimalistic shoes increases the demand on the foot due to the reduced support. They also tend to facilitate a more anterior strike pattern increasing the demand on the calf. If transitioning to a minimal shoe too quickly, foot and ankle injuries can occur[56-58]. Therefore, the same training programme as for the forefoot strike transition is provided to runners who want to transition to minimal shoes. In this section the correcting types of shoes are also discussed (neutral, cushioning, stabilizing and motion control shoes). Because there is debate about the effect of correcting shoes on the number of RRIs[11,43], runners are advised not to change the type of shoes when they never have injuries. When a runner is injured often, it could be wise to change the type of shoes. Furthermore, there is no conclusive evidence that wearing inlays has effect on injury prevention[44-46]. Finally, wearing outworn shoes increases the risk of injuries[6], while using multiple pairs of running shoes decreases the risk of RRIs[47].

Reminders

All participants in the intervention group will receive monthly reminders about the injury prevention programme by email. Depending on the moment of registration for the study, the participants will receive a maximum of four reminders. These reminders include an update on or repetition of one of the topics in the injury prevention programme.

Measurements

All participants are asked to complete four questionnaires during the study period: at baseline, 2 weeks before the running event for which the runners registered, 1 day after the running event and 1 month after the running event. For all questionnaires the participants will receive an email that contains a secured hyperlink to the questionnaire, using the survey application LimeSurvey. Reminder emails will be used to minimise loss to follow-up and missing data.

Baseline questionnaire

The baseline questionnaire consists of questions divided in six different sections. General characteristics of the participants include sex, date of birth, length and weight[21]. The running characteristics section includes questions on running history ("How long are you running already?"), training characteristics during the past week, month, 3 months and year (average running frequency per week, minutes running per week, kilometres per week and average running speed in minutes per km), membership of an athletics association (yes/no), use of training schedules, training surface (paved/unpaved and flat/non-flat), types of training (endurance/interval/exercises), number of, type (neutral/pronating/ minimalistic) and advices on running shoes, use of bandages, braces, tape, sport compression socks and inlays, step frequency and landing type (forefoot/midfoot or heel/unknown)[21,59]. The third section consists of questions on previous participation in running events (first participation, average number of participations per year, last participation, distances covered during running events and running shoes used during running events)[21]. Next there is a section on lifestyle, including current smoking (yes/no), alcohol consumption (number of glasses per week) and the Short Questionnaire to Assess Health-enhancing Physical Activity (SQUASH)[59, 60]. The SQUASH-questionnaire is a validated questionnaire that can be used to evaluate the health-enhancing physical activity in large populations[60,61]. The fifth section includes RRIs. The participants will be asked about RRIs in the past year ("Did you suffer an RRI during the past 12 months?"), the injured structures, the onset of the injury (sudden/gradually), diagnosis and if they still suffer this injury[21, 59]. The last section includes other health complaints. The participants will be asked if they have health complaints that are not related to running (yes/no) and if yes, which health complaints[21].

Follow-up questionnaires

All follow-up questionnaires contain a section on RRIs. First, participants will be asked about RRIs they already had when they filled in the previous questionnaires (injured structures and the diagnosis). The next questions include new RRIs, that developed after filling in the previous questionnaire. The questions are on the injured structure, the onset of the injury (sudden/gradually), if it is a recurrent injury (yes/no), type of injury (bruise/muscle- or tendon injury/sprain/distortion/ligament injury/bone fracture/joint dislocation/cartilage or meniscus injury/nerve entrapment/unknown) and the diagnosis, and on the treatment (including medication) and the cause of the injury[59]. Next there are questions on pain due to the RRI (0-10 visual analog scale) during running and rest in the past week, ability to perform activities of daily living in the first week after the injury and in the past week, absence from work or school due to the injury, and the duration of and recovery from the injury[59, 62]. Also the influence of the injury on running will be asked: limitations in running distance, speed, duration or frequency due to the injury, if they resumed running already and if they plan to/did run the event they registered for[62].

Additionally, the first follow-up questionnaire contains questions about the preparation for the running event. Participants in the intervention group will also receive questions on the actual use of the injury prevention programme in all follow-up questionnaires. These questions focus on which topics of the intervention programme (personal factors, training factors, biomechanics and equipment) the participants read, which advices they used and for how many weeks they used these advices. In the last follow-up questionnaire the participants in the control group will be asked if they used any injury prevention measures.

Outcome measures

The primary outcome measure is the number of RRIs in both the intervention and control group in the period between the moment of registration for the INSPIRE trial and 1 month after the running event they registered for. In this study an RRI is established if one or more of the following criteria are met[17,59]:

1. An injury of the muscles, joints, tendons and/or bones in the lower back or lower extremities (hip, groin, thigh, knee, leg, ankle, foot and toes) that is caused by running.
2. The injury is severe enough to cause a reduction in running distance, speed, duration or frequency for at least 1 week.
3. The injury leads to a visit to a doctor and/or physiotherapist.
4. Medication is necessary to reduce symptoms as a result of the injury.
5. Secondary outcome measures include the running days missed due to injuries, absence of work or school due to injuries, and the location of the injury.

Statistical analyses

Descriptive statistics and their corresponding SD and frequency distributions will be calculated for all variables. Consistent with the CONSORT statement, an intention-to-treat analysis will be performed. Missing data (if more than 5%) will be completed using a multiple imputation procedure. Injury incidence rates (IIR) will be calculated for all runners and for the intervention and control group separately. Also the IIRs for male/female and novice/experienced runners will be calculated separately. For each IIR, a 95% confidence interval will be calculated assuming Poisson errors. The IIRs of the intervention and control group will be compared by calculating the difference with the 95% confidence interval. Since no difference in distribution between the intervention and control group is expected, ORs will be calculated using univariate logistic regression. Significance of the ORs will be tested with a Mantel-Haenszel test, with a significance level of 5%. Additionally, effect modification per important subgroup (e.g. male/female, novice/experienced and per running distance) will be performed. Also adjusted analysis for main risk factors (e.g. age, body mass index and earlier injuries) will be done. The same analyses will be performed for the five most frequent specific injuries separately.

DISCUSSION

Although RRIs are a major problem among runners[2], no effective injury prevention programme has been developed yet. In the present study, the effectiveness of an evidence-based online injury prevention programme will be examined. The prevention programme will be tested in a large and mixed population of runners, which makes it possible to extensively examine the efficacy of the prevention programme. It might also be possible to compare the efficacy in different subgroups of runners (e.g. novice/experienced, male/female and different running distances). If the injury prevention programme proofs to be successful, it can be implemented in a large group of runners, for example, as a standard procedure at the registration for running events. This can easily be done, because the prevention programme is on a website and can therefore be easily spread amongst runners. Furthermore, the programme is aimed at different types of runners and is therefore suitable for all participants of running events.

A limitation of the current study is that there is no control over and insight in the use of the injury prevention programme. This is partly solved by the questions about the use of the prevention programme in the follow-up questionnaires for the intervention group. These questions give some insight in who read the prevention programme and used which part of the programme. Furthermore, in case of a future implementation of the prevention programme there will be no control over the use of the prevention programme as well and therefore will the current study give a realistic view of possible future use of the injury prevention programme. Another limitation of this study is that self-reported injuries are used. With self-reported injuries there is no uniformity in when pain considered as an injury or not. This is partly solved by providing the participants with a clear definition of RRI. Another disadvantage of self-reported injuries is that there often is no diagnosis of the injury or that the runner diagnosed himself or herself.

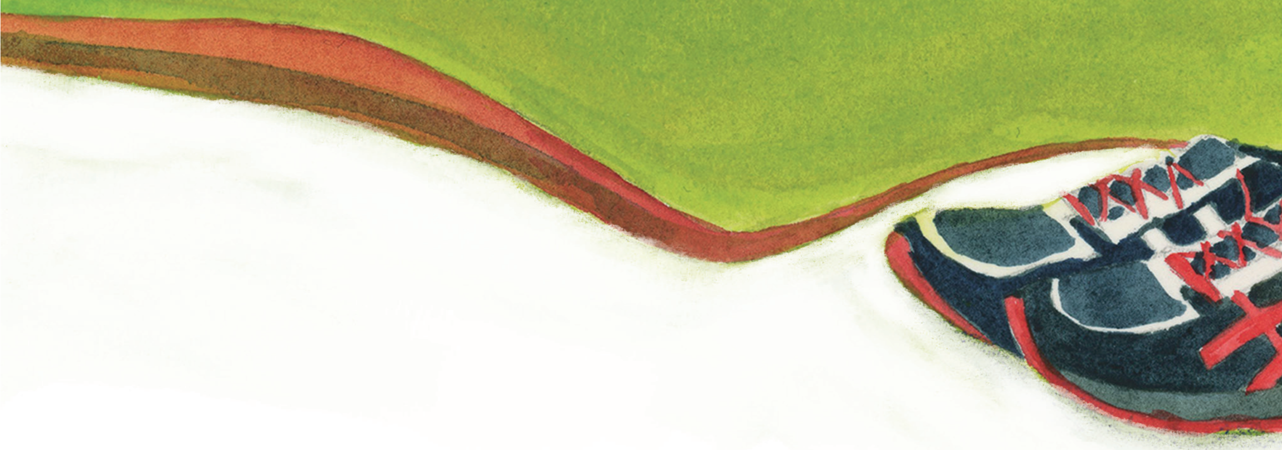
In conclusion, the INSPIRE trial is the first randomised controlled prevention trial that examines the effectiveness of an evidence-based online advice on reduction of RRIs.

REFERENCES

1. VeiligheidNL. Hardloopblessures Blessurecijfers 2014. Amsterdam: VeiligheidNL; 2016
2. Kluitenberg B, van Middelkoop M, Diercks R, van der Worp H. What are the Differences in Injury Proportions Between Different Populations of Runners? A Systematic Review and Meta-Analysis. *Sports Med.* 2015; 45(8):1143-1161.
3. Buist I, Bredeweg SW, Bessem B, et al. Incidence and risk factors of running-related injuries during preparation for a 4-mile recreational running event. *Br J Sports Med.* 2010; 44(8):598-604.
4. Macera CA, Pate RR, Powell KE, et al. Predicting lower-extremity injuries among habitual runners. *Arch Intern Med.* 1989; 149(11):2565-2568.
5. Schubert AG, Kempf J, Heiderscheit BC. Influence of stride frequency and length on running mechanics: a systematic review. *Sports Health.* 2014; 6(3):210-217.
6. Taunton JE, Ryan MB, Clement DB, et al. A prospective study of running injuries: the Vancouver Sun Run "In Training" clinics. *Br J Sports Med.* 2003; 37(3):239-244.
7. van der Worp MP, ten Haaf DS, van Cingel R, et al. Injuries in runners; a systematic review on risk factors and sex differences. *PLoS One.* 2015; 10(2):e0114937.
8. Saragiotto BT, Yamato TP, Hespanhol Junior LC, et al. What are the main risk factors for running-related injuries? *Sports Med.* 2014; 44(8):1153-1163.
9. van Gent RN, Siem D, van Middelkoop M, et al. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med.* 2007; 41(8):469-480; discussion 480.
10. Malisoux L, Chambon N, Delattre N, et al. Injury risk in runners using standard or motion control shoes: a randomised controlled trial with participant and assessor blinding. *Br J Sport Med.* 2016; 50(8):481-487.
11. Ryan MB, Valiant GA, McDonald K, Taunton JE. The effect of three different levels of footwear stability on pain outcomes in women runners: a randomised control trial. *Br J Sports Med.* 2011; 45(9):715-721.
12. Buist I, Bredeweg SW, van Mechelen W, et al. No effect of a graded training program on the number of running-related injuries in novice runners. *Am J Sport Med.* 2008; 36(1):35-41.
13. Vanmechelen W, Hlobil H, Kemper HCG, et al. Prevention of Running Injuries by Warm-up, Cool-down, and Stretching Exercises. *Am J Sport Med.* 1993; 21(5):711-719.
14. Bredeweg SW, Zijlstra S, Bessem B, Buist I. The effectiveness of a preconditioning programme on preventing running-related injuries in novice runners: a randomised controlled trial. *Br J Sports Med.* 2012; 46(12):865-870.
15. Theisen D, Malisoux L, Genin J, et al. Influence of midsole hardness of standard cushioned shoes on running-related injury risk. *Br J Sport Med.* 2014; 48(5).
16. Malisoux L, Chambon N, Urhausen A, Theisen D. Influence of the Heel-to-Toe Drop of Standard Cushioned Running Shoes on Injury Risk in Leisure-Time Runners: A Randomized Controlled Trial With 6-Month Follow-up. *Am J Sports Med.* 2016; 44(11):2933-2940.
17. Kluitenberg B, van Middelkoop M, Smits DW, et al. The NLstart2run study: Incidence and risk factors of running-related injuries in novice runners. *Scand J Med Sci Sports.* 2015; 25(5):e515-523.
18. van der Worp H, Vrielink JW, Bredeweg SW. Do runners who suffer injuries have higher vertical ground reaction forces than those who remain injury-free? A systematic review and meta-analysis. *Br J Sports Med.* 2016; 50(8):450-457.
19. Taunton JE, Ryan MB, Clement DB, et al. A retrospective case-control analysis of 2002 running injuries. *Br J Sports Med.* 2002; 36(2):95-101.
20. Buist I, Bredeweg SW, Lemmink KA, et al. Predictors of running-related injuries in novice runners enrolled in a systematic training program: a prospective cohort study. *Am J Sports Med.* 2010; 38(2):273-280.

21. Van Middelkoop M, Kolkman J, Van Ochten J, et al. Risk factors for lower extremity injuries among male marathon runners. *Scand J Med Sci Sports.* 2008; 18(6):691-697.
22. Walter SD, Hart LE, McIntosh JM, Sutton JR. The Ontario cohort study of running-related injuries. *Arch Intern Med.* 1989; 149(11):2561-2564.
23. Jacobs SJ, Berson BL. Injuries to runners: a study of entrants to a 10,000 meter race. *Am J Sports Med.* 1986; 14(2):151-155.
24. McKean KA, Manson NA, Stanish WD. Musculoskeletal injury in the masters runners. *Clin J Sport Med.* 2006; 16(2):149-154.
25. Malisoux L, Nielsen RO, Urhausen A, Theisen D. A step towards understanding the mechanisms of running-related injuries. *J Sci Med Sport.* 2015; 18(5):523-528.
26. Kluitenberg B, van der Worp H, Huisstede BM, et al. The NLstart2run study: Training-related factors associated with running-related injuries in novice runners. *J Sci Med Sport.* 2015.
27. Hobara H, Sato T, Sakaguchi M, et al. Step frequency and lower extremity loading during running. *Int J Sports Med.* 2012; 33(4):310-313.
28. Lieberman DE, Warrener AG, Wang J, Castillo ER. Effects of stride frequency and foot position at landing on braking force, hip torque, impact peak force and the metabolic cost of running in humans. *J Exp Biol.* 2015; 218(Pt 21):3406-3414.
29. Hafer JF, Brown AM, deMille P, et al. The effect of a cadence retraining protocol on running biomechanics and efficiency: a pilot study. *J Sports Sci.* 2015; 33(7):724-731.
30. Clarke TE, Cooper LB, Hamill CL, Clark DE. The effect of varied stride rate upon shank deceleration in running. *J Sports Sci.* 1985; 3(1):41-49.
31. Derrick TR, Hamill J, Caldwell GE. Energy absorption of impacts during running at various stride lengths. *Med Sci Sports Exerc.* 1998; 30(1):128-135.
32. Heiderscheit BC, Chumanov ES, Michalski MP, et al. Effects of step rate manipulation on joint mechanics during running. *Med Sci Sports Exerc.* 2011; 43(2):296-302.
33. Mercer JA, Devita P, Derrick TR, Bates BT. Individual effects of stride length and frequency on shock attenuation during running. *Med Sci Sports Exerc.* 2003; 35(2):307-313.
34. Seay J, Selbie WS, Hamill J. In vivo lumbo-sacral forces and moments during constant speed running at different stride lengths. *J Sports Sci.* 2008; 26(14):1519-1529.
35. Morin JB, Samozino P, Zameziati K, Belli A. Effects of altered stride frequency and contact time on leg-spring behavior in human running. *J Biomech.* 2007; 40(15):3341-3348.
36. Lieberman DE, Venkadesan M, Werbel WA, et al. Foot strike patterns and collision forces in habitually barefoot versus shod runners. *Nature.* 2010; 463(7280):531-535.
37. Giandolini M, Horvais N, Rossi J, et al. Foot strike pattern differently affects the axial and transverse components of shock acceleration and attenuation in downhill trail running. *J Biomech.* 2016; 49(9):1765-1771.
38. Davis IS, Bowser BJ, Mullineaux DR. Greater vertical impact loading in female runners with medically diagnosed injuries: a prospective investigation. *Br J Sports Med.* 2016; 50(14):887-892.
39. Zadpoor AA, Nikooyan AA. The relationship between lower-extremity stress fractures and the ground reaction force: a systematic review. *Clin Biomech (Bristol, Avon).* 2011; 26(1):23-28.
40. Ryan M, Elashi M, Newsham-West R, Taunton J. Examining injury risk and pain perception in runners using minimalist footwear. *Br J Sports Med.* 2014; 48(16):1257-1262.
41. Tam N, Astephen Wilson JL, Noakes TD, Tucker R. Barefoot running: an evaluation of current hypothesis, future research and clinical applications. *Br J Sports Med.* 2014; 48(5):349-355.
42. Bonacci J, Saunders PU, Hicks A, et al. Running in a minimalist and lightweight shoe is not the same as running barefoot: a biomechanical study. *Br J Sports Med.* 2013; 47(6):387-392.
43. Nielsen RO, Buist I, Parner ET, et al. Foot pronation is not associated with increased injury risk in novice runners wearing a neutral shoe: a 1-year prospective cohort study. *Br J Sports Med.* 2014; 48(6):440-447.

44. Mattila VM, Sillanpaa PJ, Salo T, et al. Can orthotic insoles prevent lower limb overuse injuries? A randomized-controlled trial of 228 subjects. *Scand J Med Sci Spor.* 2011; 21(6):804-808.
45. Franklyn-Miller A, Wilson C, Bilzon J, McCrory P. Foot orthoses in the prevention of injury in initial military training: a randomized controlled trial. *Am J Sports Med.* 2011; 39(1):30-37.
46. Leppanen M, Aaltonen S, Parkkari J, et al. Interventions to prevent sports related injuries: a systematic review and meta-analysis of randomised controlled trials. *Sports Med.* 2014; 44(4):473-486.
47. Malisoux L, Ramesh J, Mann R, et al. Can parallel use of different running shoes decrease running-related injury risk? *Scand J Med Sci Sports.* 2015; 25(1):110-115.
48. Nielsen RO, Buist I, Sorensen H, et al. Training errors and running related injuries: a systematic review. *Int J Sports Phys Ther.* 2012; 7(1):58-75.
49. Hartig DE, Henderson JM. Increasing hamstring flexibility decreases lower extremity overuse injuries in military basic trainees. *Am J Sports Med.* 1999; 27(2):173-176.
50. Pope R, Herbert R, Kirwan J. Effects of ankle dorsiflexion range and pre-exercise calf muscle stretching on injury risk in Army recruits. *Aust J Physiother.* 1998; 44(3):165-172.
51. Cheung RT, Davis IS. Landing pattern modification to improve patellofemoral pain in runners: a case series. *J Orthop Sports Phys Ther.* 2011; 41(12):914-919.
52. Daoud AI, Geissler GJ, Wang F, et al. Foot strike and injury rates in endurance runners: a retrospective study. *Med Sci Sports Exerc.* 2012; 44(7):1325-1334.
53. Diebal AR, Gregory R, Alitz C, Gerber JP. Forefoot running improves pain and disability associated with chronic exertional compartment syndrome. *Am J Sports Med.* 2012; 40(5):1060-1067.
54. Davis IS. The Re-emergence of the Minimal Running Shoe. *J Orthop Sport Phys Ther.* 2014; 44(10):775-784.
55. Chen TL, Sze LK, Davis IS, Cheung RT. Effects of training in minimalist shoes on the intrinsic and extrinsic foot muscle volume. *Clin Biomech (Bristol, Avon).* 2016; 36:8-13.
56. Giuliani J, Masini B, Alitz C, Owens BD. Barefoot-simulating footwear associated with metatarsal stress injury in 2 runners. *Orthopedics.* 2011; 34(7):e320-323.
57. Ridge ST, Johnson AW, Mitchell UH, et al. Foot bone marrow edema after a 10-wk transition to minimalist running shoes. *Med Sci Sports Exerc.* 2013; 45(7):1363-1368.
58. Salzler MJ, Bluman EM, Noonan S, et al. Injuries observed in minimalist runners. *Foot Ankle Int.* 2012; 33(4):262-266.
59. Kluitenberg B, van Middelkoop M, Diercks RL, et al. The NLstart2run study: health effects of a running promotion program in novice runners, design of a prospective cohort study. *BMC Public Health.* 2013; 13.
60. Wendel-Vos GCW, Schuit AJ, Saris WHM, Kromhout D. Reproducibility and relative validity of the Short Questionnaire to Assess Health-enhancing physical activity. *J Clin Epidemiol.* 2003; 56(12):1163-1169.
61. de Hollander EL, Zwart L, de Vries SI, Wendel-Vos W. The SQUASH was a more valid tool than the OBiN for categorizing adults according to the Dutch physical activity and the combined guideline. *J Clin Epidemiol.* 2012; 65(1):73-81.
62. van Middelkoop M, Kolkman J, van Ochten J, et al. Prevalence and incidence of lower extremity injuries in male marathon runners. *Scand J Med Sci Spor.* 2008; 18(2):140-144.



5

Online multifactorial prevention programme has no effect on the number of running-related injuries: a randomised-controlled trial

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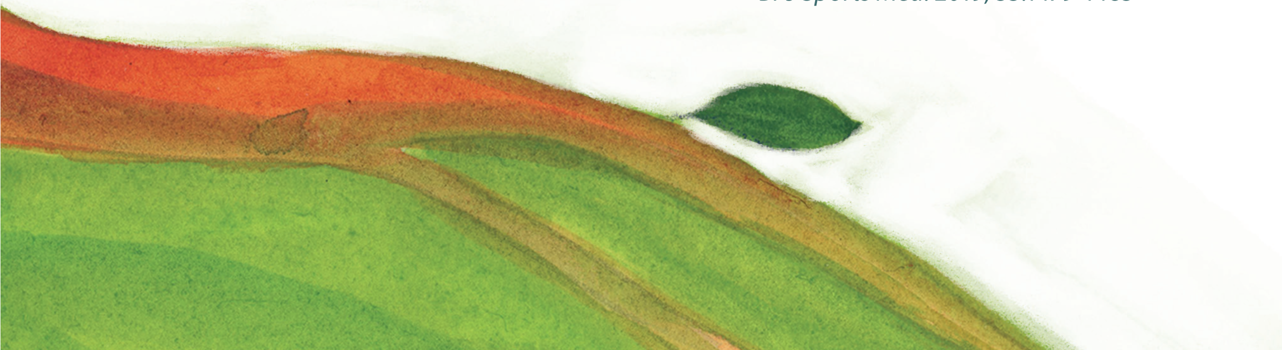

ABSTRACT

Objective

To examine the effect of a multifactorial, online injury prevention programme on the number of running-related injuries (RRIs) in recreational runners.

Methods

Adult recreational runners who registered for a running event (distances 5 km up to 42.195 km) were randomised into the intervention group or control group. Participants in the intervention group were given access to the online injury prevention programme, which consisted of information on evidence-based risk factors and advices to reduce the injury risk. Participants in the control group followed their regular preparation for the running event. The primary outcome measure was the number of self-reported RRIs in the time frame between registration for a running event and one month after the running event.

Results

This trial included 2378 recreational runners (1252 males; mean [SD] age 41.2 [11.9] years), of which 1196 were allocated to the intervention group and 1182 to the control group. Of the participants in the intervention group 37.5% (95% CI 34.8;40.4) sustained a new RRI during follow-up, compared to 36.7% (95% CI 34.0;39.6) in the control group. Univariate logistic regression analysis showed no significant difference between the intervention and control group (OR 1.08, 95% CI 0.90;1.30). Furthermore, the prevention program seemed to have negative impact on the occurrence of new RRIs in the subgroup of runners with no injuries in the 12 months preceding the trial (OR 1.30, 95% CI 0.99;1.70).

Conclusion

A multifactorial, online injury prevention programme did not decrease the total number of RRIs in recreational runners.

INTRODUCTION

Running is a sport that is frequently practiced and is still growing in popularity[1]. In the Netherlands, about 2 million people performed running regularly in 2014, which is about 12.5% of the Dutch population[2]. Regular running has many positive effects on both physical and mental health and is an efficient way to improve physical fitness[3]. A main drawback, however, is the high number of musculoskeletal injuries among runners.

The injury proportions in runners vary between 3.2 and 84.9%, with novice runners having the highest injury proportion and cross-country runners having the lowest proportion[4]. Survey data suggest that the incidence of running-related injuries (RRIs) has increased over the last years from 4.8 RRIs per 1000 running hours in 2011 up to 6.1 RRIs per 1000 running hours in 2014 in the Netherlands[2]. In order to prevent future injuries, several studies have aimed to identify risk factors for RRIs. These studies have identified a variety of risk factors, including overweight, a high weekly running distance, a low running cadence and running on outworn shoes[5-8]. However, the risk factors for RRIs are not uniform between studies[9-11]. A systematic review showed, for example, that a higher age was identified as a risk factor for RRIs in four studies, while it was a protective factor for RRIs in two other studies[9]. Only a previous injury is a consistent and frequently identified risk factor for RRIs[9-11], which emphasizes the need for primary injury prevention measures in runners.

So far only a few randomized controlled trials (RCTs) have investigated the effects of injury prevention measures in runners[12-17]. Most of these RCTs targeted one specific risk factor for RRIs. For example, Bredeweg et al. performed an RCT aiming to modify the risk factor 'absence of experience with sporting activities with axial loading'[13]. They offered novice runners a preconditioning training programme with walking and hopping exercises, but this training programme had no effect on the number of RRIs. Also in other RCTs on RRI prevention, no effect on the number of RRIs was found[12,16,18]. This may be related to the fact that these RCTs targeted only one risk factor for RRIs, while the cause of RRIs seems to be multifactorial[10,12]. Therefore, the aim of this study was to examine the effect of a multifactorial, online injury prevention programme on the number of RRIs in recreational runners.

METHODS

Trial design

The INSPIRE trial (INtervention Study on Prevention of Injuries in Runners at Erasmus MC) is a randomized-controlled trial with a minimum follow-up of 3 months. A detailed study protocol has been published elsewhere (https://bmjopensem.bmj.com/content/3/1/e000265)[18]. The INSPIRE trial was funded by the Netherlands Organization for Health Research and Development (ZonMW, 536001001) and was performed in collaboration with Golazo Sports, an organisation of large running events in the Netherlands.

Participants

Potential participants of the INSPIRE trial were runners who registered for one of three large running events in the Netherlands in 2017. These running events included the NN City Pier City The Hague (5, 10 and 21.1 km), NN Marathon Rotterdam (10.55 and 42.195 km) and the LadiesRun Rotterdam (5, 7.5 and 10 km). During the online registration for the running events, the runners were asked if they were willing to participate in the INSPIRE trial. Contact information of the interested runners was sent to the researchers. Runners who met the inclusion criteria (18 years or older, registration at least two months before the running event, knowledge of the Dutch language and access to the internet and e-mail) received more information about the INSPIRE trial through email. If they were still interested in participation, they could immediately provide digital informed consent and complete the baseline questionnaire.

Randomization and follow-up

After completing the baseline questionnaire, participants were randomised into either the intervention or control group, using a computer-generated randomisation list with blocks of 10. The randomisation list was developed by an individual who is not part of the research team. The participants were enrolled and assigned to the interventions by a member of the research group.

Participants allocated to the intervention group were given access to an online injury prevention programme. Participants in the control group were informed about their allocation into the control group and consequently followed their regular preparation for the running event. All participants received three follow-up questionnaires during the study period; 2 weeks before the running event they registered for, 1 day after the running event and 1 month after the running event.

The participants received additional monthly reminders about the study per email. For the participants in the intervention group these reminders included a repetition of one of the topics in the injury prevention programme. To improve adherence to the intervention, these reminders also included a link to the intervention website. For the control group the reminders contained an update of the progress of the INSPIRE trial (eg, information on the number of participants that had been included) or general information on epidemiology of RRIs. Depending on the moment of registration, the participants received maximal five reminders.

Interventions

The injury prevention programme was developed by means of an extensive literature search and aimed to modify evidence-based risk factors for RRIs. The prevention program was presented on a website that could only be accessed with a username and password, which were provided to the participants in the intervention group through email. We instructed the participants to keep these data strictly personal. The website contained information on four main topics: personal factors (age, weight, previous injuries and running experience), training (running distance, frequency, surface, overtraining and stretching), biomechanics (cadence and foot landing) and equipment (footwear, orthotics and the use of running shoes). Different versions of the prevention program for novice and experienced runners were available. Details of the injury prevention program can be found elsewhere[18]. Participants in the intervention group had unlimited access to the website. The runners were expected to work autonomously with the website. They were encouraged to read the information they thought was relevant to them and apply this in their training. It was not logged how many times individual runners accessed the site.

Measurements

The baseline questionnaire consisted of five sections (demographics, training, running events, lifestyle and previous RRIs). The items of these sections are shown in Table 1. The follow-up questionnaires informed on RRIs during follow-up and the use of the prevention program. The items of the follow-up questionnaires are shown in Table 1.

Outcomes

The primary outcome measure of this study was a self-reported RRI between the moment of registration and one month after the running event. To avoid confusion, a definition of an RRI was provided to the participants. An RRI was defined as an injury of the muscles, joints, tendons and/or bones in the lower back or lower extremities (hip, groin, thigh, knee, leg, ankle, foot and toes) that was caused by running. Furthermore, one of the following criteria had to be met:

1. The injury was severe enough to cause a reduction in running distance, speed, duration or frequency for at least 1 week.
2. The injury led to a visit of a doctor and/or physiotherapist.
3. Medication was necessary to reduce symptoms as a result of the injury.
4. The location of the injury was a secondary outcome measure.

Sample size

Based on a recent systematic review among a mixed population of long-distance runners, an injury incidence of 16% was expected in the control group[4]. A 10.9% injury incidence has been reported in a study on novice runners with a comparable follow-up time[19]. Based upon these studies, we estimated that 14% of the participants would sustain an injury during follow-up. With a risk difference of 5% (this means a reduction of 90 000 injuries in the Netherlands), 0.05 significance level (one-sided testing) and a power of 80%, a total of 1006 runners had to be included in the analyses to detect a relevant difference in RRIs. Taking a loss to follow-up of 10% into account, at least 1106 participants had to be included in this trial.

Statistical analyses

Descriptive statistics were calculated for all variables. Consistent with the CONSORT statement, an intention-to-treat analysis was performed. Injury proportions with corresponding 95% confidence intervals (CIs) were calculated for the whole group and for the intervention and control group separately. We determined the injury proportions by calculating the percentages of participants who indicated a new RRI in one or more of the follow-up questionnaires. To correct for errors, we checked whether participants who indicated they still suffered an existing RRI indeed filled in an RRI on the same location in the previous questionnaire. If not, the RRI was interpreted as a new RRI. Also for RRIs of which participants indicated to be new, we checked whether the participants did not fill in this RRI in the previous questionnaire. If they did, this RRI was not regarded as a new RRI. The injury proportions of the intervention and control group were compared by calculating the difference in percentages with 95% CI between the injury proportions. Additionally, odds ratios (OR) with 95% CI were calculated using univariate logistic regression analysis. Also, the risk ratios with 95% CI were calculated. Finally, adjusted analysis including potential confounders (age, body mass index [BMI] and earlier injury) was performed with multivariate logistic regression analysis.

Table 1. Items of the questionnaires of the INSPIRE trial.

Questionnaire	Section	Items
Baseline questionnaire	Demographics	Sex
		Date of birth
		Height (cm)
		Weight (kg)
	Training	Running experience (years)
		Average running frequency over last month (times per week)
		Average running time over last month (min/week)
		Average running distance over last month (km/week)
		Average training speed over last month (min/km)
		Types of training
		- Endurance training (%)
		- Interval training (%)
		- Exercises (%)
		Membership of athletic association (yes/no)
	Running events	Previous participation in running events (yes/no)
		Average participations in running events per year
	Lifestyle	Current smoking (yes/no)
		Average alcohol consumption (glasses per week)
	Previous running-related injuries[a]	Running-related injury in previous 12 months (yes/no)
		Location of running injury (lower back/buttock/hip/groin/ventral thigh/dorsal thigh/knee/shin/calf/Achilles tendon/ankle/foot/toe)
		Still suffering running injury (yes/no)
Follow-up questionnaires	Existing running-related injuries[a]	Still suffering running-related injury that was already indicated in previous questionnaire (yes/no)
		Location of existing running injury (lower back/buttock/hip/groin/ventral thigh/dorsal thigh/knee/shin/calf/Achilles tendon/ankle/foot/toe)
	New running-related injuries[a]	New running-related injury since filling in previous questionnaire (yes/no)
		Location of new running injury (lower back/buttock/hip/groin/ventral thigh/dorsal thigh/knee/shin/calf/Achilles tendon/ankle/foot/toe)
	Injury prevention programme[b]	Read injury prevention programme (yes/no)
		If yes, which topic(s) (personal factors/training/biomechanics/equipment)
		Used injury prevention program (yes/no)
		If yes, which topic(s) (personal factors/training/biomechanics/equipment)

[a] Participants could list multiple injuries; [b] This section was only in the follow-up questionnaires for the intervention group.

The number of injured runners per location and the percentages of the total number of participants were determined for the intervention and control group separately. For further analyses, the injury locations were divided into five groups: lower back, buttock/hip/groin, upper leg/knee, lower leg (shin/calf/Achilles tendon/ankle) and foot/toe.

Predefined subgroup analyses were performed for sex, running experience (≤1 year/ >1 year running experience), distance of running event, earlier RRI in previous 12 months and for the five groups of injury locations separately[18]. Analyses were performed in SPSS Statistics V.21 and p-values ≤ 0.05 were regarded as statistically significant.

RESULTS

Participants

Data collection for the INSPIRE trial started in October 2016 and was finalized in August 2017. In total, 5271 runners indicated that they were interested in participation in the INSPIRE trial when they registered for one of the running events, of which 2378 runners were included in the trial (Figure 1). After randomisation, 1196 participants were allocated to the intervention group and 1182 participants to the control group. At baseline, the participants were on average 41.2 (SD 11.9) years old and the majority (52.6%) was male (Table 2). A total of 52.1% of the participants reported an RRI in the 12 months before inclusion and 22.7% of the participants still suffered an RRI at baseline. There were no significant differences in baseline characteristics between the intervention and control group.

Injuries during follow-up

Mean (SD) follow-up duration was 4.5 (1.6) months and 81.1% of the participants completed at least one of the follow-up questionnaires, while 60.0% completed all follow-up questionnaires (Figure 1). In total, 28.4% of all follow-up questionnaires were not completed. The majority of the participants in the intervention group (62.7%) indicated that they read at least one topic of the injury prevention program, of whom 8.2% read one topic, 11.0% read two topics, 4.7% read three topics and 38.8% read all four topics. Also, 44.1% of the participants indicated they applied the information of at least one topic into their training. During follow-up, 883 participants (37.1%, 95% CI 35.2;39.1) sustained 1483 new injuries (Table 3). The injury proportion for the intervention group was 37.5% (95% CI 34.8;40.4) and 36.7% (95% CI 34.0;39.6) for the control group, with no significant difference between groups (OR 1.08, 95% CI 0.90;1.29) (Table 2). In both the intervention and control group most injuries were in the knee (10.8% and 12.5%, respectively), calf (6.9% and 6.3%, respectively) and foot (5.9% and 5.8%, respectively) (Appendix 1). Analyses of the clustered injury locations showed no significant differences between the intervention group and control group (Table 3). The multivariate logistic regression analysis adjusting for main potential confounders (age, BMI and earlier RRI) showed no difference between study groups (OR 1.08, 95% CI 0.90;1.30). Subgroup analyses showed no significant differences in the injury proportions between the intervention and control group when divided by the distance of the running event, sex, running experience or an RRI in the 12 months before the trial (Table 4).

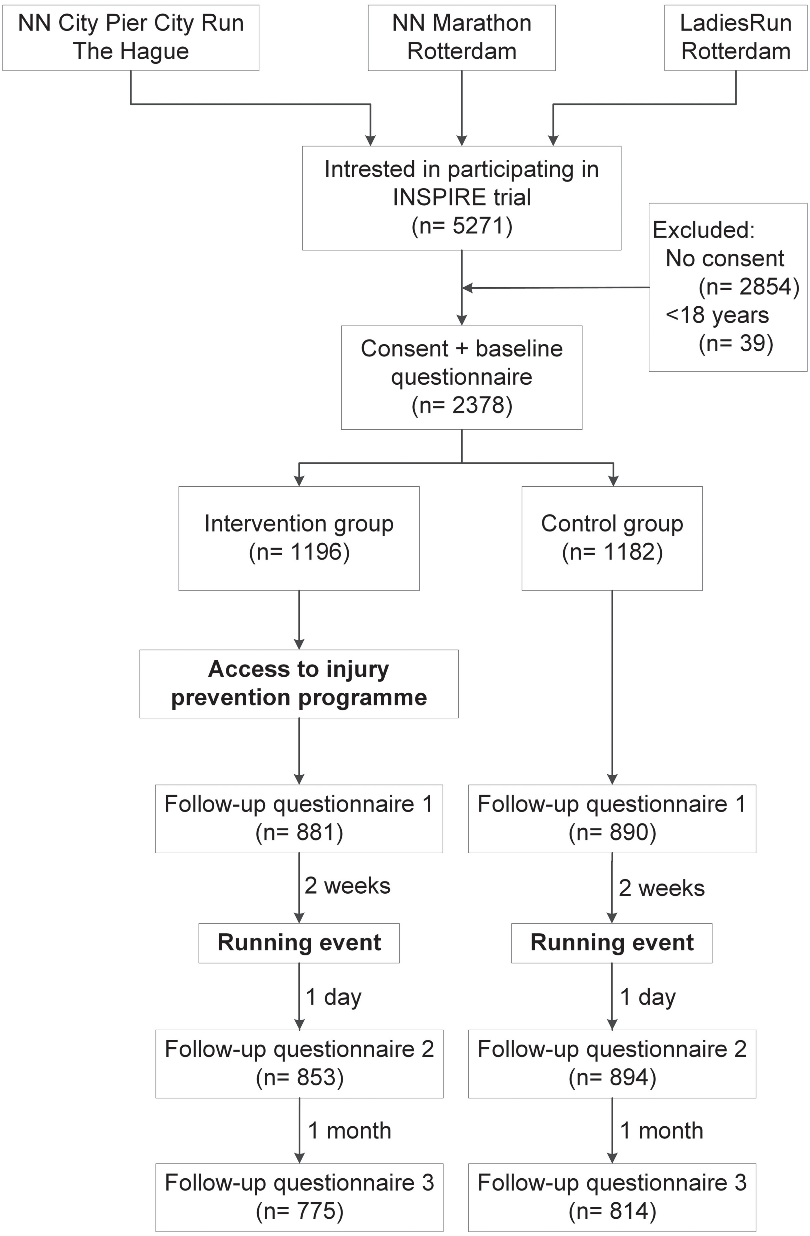

Figure 1. Flowchart of the INSPIRE trial

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Table 2. Baseline characteristics

	All participants		Intervention group		Control group	
	N	%/Mean (SD)	N	%/Mean (SD)	N	%/Mean (SD)
N	2378		1196	50.3%	1182	49.7%
Demographics						
Gender (male)	1252	52.6%	623	52.1%	629	53.2%
Age (years)		41.2 (11.9)		41.0 (11.7)		41.4 (12.0)
BMI (kg/m^2)		23.7 (2.9)		23.6 (2.9)		23.7 (2.8)
Training						
Running experience (years)		6.5 (7.8)		6.6 (7.9)		6.4 (7.8)
Running frequency per week		2.5 (1.5)		2.5 (1.5)		2.5 (1.4)
Running time per week (hours)		3.1 (3.3)		3.1 (3.3)		3.1 (3.3)
Running distance per week (km)		22.2 (19.0)		22.3 (19.0)		22.1 (19.0)
Training speed (min/km)		6:04 (1:07)		6:03 (1:07)		6:05 (1:07)
Type of training (%)						
Endurance training		68.6 (24.1)		68.5 (24.2)		68.8 (23.9)
Interval training		23.9 (20.9)		24.2 (21.2)		23.6 (20.6)
Exercises		7.4 (10.4)		7.3 (9.7)		7.8 (11.0)
Member of athletic association (yes)	715	30.1%	352	29.4%	363	30.7%
Running event						
Distance registered for:[a]						
5/7.5 km	139	5.8%	75	6.3%	64	5.4%
10/10.55 km	905	38.1%	440	36.8%	465	39.3%
Half marathon	711	29.9%	367	30.7%	344	29.1%
Marathon	625	26.3%	317	26.5%	308	26.1%
Participated in a running event before (yes)	2168	91.2%	1092	91.3%	1076	91.0%
Average participations per year		4.2 (5.1)		4.2 (4.7)		4.2 (4.9)
Lifestyle						
Smoking (yes)	107	4.5%	57	4.8%	50	4.2%
Alcohol use (glasses per week)		4.2 (4.8)		4.1 (4.7)		4.3 (4.9)
Previous RRIs						
Previous RRI in in previous 12 months (yes)	1238	52.1%	611	51.1%	627	53.0%
Reported RRI at baseline (yes)	540	22.7%	281	23.5%	259	21.9%

[a]: Running distance was missing for two participants, while two participants registered for two and one participants for three running distances of one running event

Table 3. Total number of injuries and number of injured runners per clustered injury locations and the differences between the intervention group (n=1196) and control group (n=1182) and results of univariate logistic regression analysis for the effect of study group on the injury risk and the risk ratio of the intervention group

	Intervention group		**Control group**		**Difference**	**OR (95% CI) [a]**	**Risk ratio (95% CI)**
	N	%	N	%	% (95% CI)		
Participants reporting new injuries during follow-up (yes)	449	37.5	434	36.7	0.8 (-3.1;4.8)	1.08 (0.90;1.29)	1.02 (0.92;1.14)
Number of new injuries	736		747				
Clustered injury locations							
Lower back	49	4.1	48	4.1	0.0 (-1.6;1.7)	1.03 (0.68;1.55)	1.01 (0.68;1.49)
Buttock/hip/groin	110	9.2	104	8.8	0.4 (-2.0;2.8)	1.07 (0.81;1.43)	1.05 (0.81;1.35)
Upper leg/knee	171	14.3	200	16.9	-2.6 (-5.6;0.36)	0.83 (0.66;1.04)	0.85 (0.70;1.02)
Lower leg	191	16.0	178	15.1	0.9 (-2.1;3.9)	1.10 (0.88;1.38)	1.06 (0.88;1.28)
Foot/toe	78	6.5	75	6.3	0.2 (-1.9;2.2)	1.05 (0.76;1.46)	1.03 (0.76;1.40)

[a] Control group is reference

Table 4. Results of the subgroup analyses (injury proportions for the intervention and control group and results of univariate logistic regression analysis for the effect of study group on the injury risk and the risk ratio of the intervention group)

	N		**Injury proportion (%)**		**Difference (%) (95% CI)**	**OR (95% CI) [a]**	**Risk ratio (95%CI)**
	Intervention group	Control group	Intervention group	Control group			
Distance running event [b,c]							
Marathon	317	308	41.3	41.2	0.1 (-7.8;8.0)	0.97 (0.67;1.39)	1.00 (0.83;1.20)
Half-marathon	367	344	42.2	38.1	4.2 (-3.3;11.5)	1.21 (0.88;1.66)	1.11 (0.93;1.32)
10/10.55 km	439	464	32.3	33.8	-1.5 (-7.8;4.8)	1.02 (0.76;1.37)	0.96 (0.79;1.15)
5/7.5 km	73	64	28.8	28.1	0.7 (-15.4;16.4)	1.13 (0.52;2.48)	1.02 (0.60;1.74)
Sex							
Male	623	629	39.2	38.3	0.9 (-4.7;6.3)	1.10 (0.86;1.41)	1.02 (0.89;1.18)
Female	573	553	35.8	34.9	0.9 (-4.8;6.6)	1.06 (0.81;1.38)	1.03 (0.88;1.20)
Running experience [d]							
≤1 year	224	211	36.6	39.3	-2.7 (-12.1;6.6)	0.90 (0.58;1.38)	0.93 (0.73;1.18)
>1 year	969	964	37.8	36.3	1.5 (-2.9;5.8)	1.12 (0.92;1.36)	1.04 (0.93;1.17)
Earlier injury [e]							
Yes	611	627	43.9	44.7	-0.8 (-6.4;4.8)	0.92 (0.72;1.19)	0.98 (0.87;1.11)
No	585	555	30.9	27.7	3.2 (-2.2;8.6)	1.30 (0.99;1.70)	1.12 (0.93;1.34)

[a] Control group is reference; [b] Running event is missing for 2 participants; [c] The four participants who registered for multiple distances of one running event were assigned to the longest distance they registered for; [d] Running experience is missing for 10 participants; [e] Running injury in year before INSPIRE trial

DISCUSSION

This study aimed to reduce running injuries in recreational runners by providing online advice on modifying known risk factors. This multifactorial, easy accessible prevention programme did not decrease the overall number of RRIs in recreational runners. Neither were any differences found in any of the predefined subgroups of runners.

In contrast to previous trials, targeting one single risk factor only, this study investigated the effect of a multifactorial injury prevention programme in runners[12,13,18]. However, this multifactorial programme did not reduce the overall number of RRIs. This result seems opposite to the effects of multicomponent prevention programs in team sports (eg floorball and soccer) that have shown to be effective[20-22]. One large difference with these types of sports is that runners tend to train individually and often without a trainer or coach. Therefore, the runners were offered an online programme from which they could extract the information of their interest. Almost two-thirds (62.7%) of the participants in the intervention group indicated that they read at least one topic of the prevention programme and 44.1% indicated that they also applied the information into their training. This relatively low engagement rate may have influenced the results. The injury prevention programme was designed to be implementable in large populations of runners. However, the fact that about one third of the participants did not read any topics of the prevention programme reflects the feasibility of the prevention program. It may indicate that the participants had problems to extract the relevant information and to apply this into their usual training sessions or may be associated with the attractiveness of the programme. Perhaps runners need more personalised information or more directed practical information (e.g. detailed day-to-day training schedules) on injury prevention. Furthermore, stationary websites may no longer be engaged well with and mobile applications might be more successful[23]. Future analyses and research should therefore focus on the effects of compliance and the feasibility and effectiveness of these types of interventions offered to runners.

With the participants in the intervention group, there was a trend towards less injuries (2.6%) in the upper leg/knee than participants in the control group. In contrast, runners in the intervention group showed a trend to report more injuries in the calf, Achilles tendon, ankle and foot. It is possible that this may be related to the information presented on biomechanics in the injury prevention programme. This section included information regarding forefoot striking resulting in reduced impact forces on the knee and thereby potentially reducing the chance on a knee injury[24-26].

However, a transition to a forefoot strike increases the loading on the lower leg and foot and may increase the injury risk in these areas[27,28]. To prevent this, a training programme aimed at strengthening the foot and calf for the transition to a forefoot strike and minimalistic shoes was included in the injury prevention programme[27]. This training program also included a gradual progression in the use of a forefoot strike and minimalistic shoes. It is therefore interesting to observe that participants in the intervention group who indicated that they used the biomechanics section reported significantly more lower leg injuries during follow-up than participants in the control group (OR 1.74, 95% CI 1.28;2.37) (Appendix 2). It can be hypothesized that these runners used the information from the prevention program, consequently changed their stride pattern and got injured. This may suggest that changing to a forefoot strike may not be an effective way to prevent RRIs or that the way the training program and information on stride pattern was offered is not optimal in order to prevent the injuries, also in the lower leg, and might even be harmful to the runners when applied with these methods. Therefore, we suggest not to provide advices on biomechanics if no personal guidance (eg, from a physiotherapist) is available.

The adjusted logistic regression analysis showed that adjustment for main risk factors (age, BMI and previous RRIs) had no influence on the overall effect of the prevention program (OR 1.08, 95% CI 0.90;1.30). This analysis also showed that an RRI in the 12 months before the study was the only factor with a significant effect on the occurrence of new RRIs (OR 2.21, 95% CI 1.84;2.65). The majority of the new RRIs (76.6%) occurred at a different location than the previous RRI. This showed again that runners with an RRI in the past have a higher chance of sustaining a new RRI, regardless of the location of the RRI.[9-11] The subgroup analyses also showed a trend towards more RRIs in the intervention group in runners who did not have an RRI in the 12 months preceding the trial (OR 1.30, 95% CI 0.99;1.70). This may suggest that offering injury prevention measures to runners not prone to injuries may result in more new-onset injuries. Possibly these runners already ran and trained in the right way and therefore changing something resulted in injuries. Furthermore, runners who suffered an RRI in the previous 12 months appeared to be more interested in injury prevention. Additional analyses showed that significantly more participants who suffered an RRI in the 12 months before the study indicated that they read at least one of the topics of the intervention program compared to those without an RRI in the past 12 months (65.6% vs. 59.7%, $p = 0.033$). Based on the aforementioned information, injury prevention advices should possibly be geared towards the runner's RRI history. For example, runners with a history of Achilles tendinopathy may benefit from limiting exposure to running on soft surfaces[29]. However, more research on tailored programs is necessary. Furthermore, we suggest that future prevention studies on RRIs should specifically aim at runners with an RRI in the past.

Strengths and limitations

A strength of the current study is the large sample size. With 2378 participants, it is the largest RCT on RRI prevention so far. Also, the loss to follow-up was relatively low; more than 80% of the participants filled in at least one of the follow-up questionnaires. A limitation of this study is that we had only little insight in the use of the online injury prevention program. Self-registered information on the use of the prevention programme was collected. It would have been more accurate if the exact use per participant could have been retrieved from the personal visitors statistics of the website. Another limitation is that the RRIs were self-diagnosed, which may have influenced the number of RRIs and the accuracy of the RRIs reported. Also, we had no insight in the severity and impact of the reported RRIs. Furthermore, the definition of an RRI was slightly different from the consensus definition proposed by Yamato et al[30]. We did not use this definition, as it was not available at the time we designed this study in 2015. We based our definition on methods used in previous prospective trials[19,31] and due to our randomized study design, this chosen definition will not have affected our primary outcome. Finally, in our protocol we intended to perform multiple imputation when more than 5% of the data were missing[18]. Main outcome data during follow-up was missing in 28.4% of the cases. The imputation of an RRI during follow-up had no effect on the main outcome (OR 1.16, 95% CI 0.93;1.44). We therefore decided to report the outcomes without the imputation.

CONCLUSION

A multifactorial, online injury prevention programme offered to recreational runners who registered for a running event was not effective in the prevention of RRIs. We hypothesize that this may be related to the way the information on injury prevention was presented to the runners. Perhaps runners need more personalised information or more directed practical information on injury prevention. Furthermore, it may be related to the heterogeneity in the study population, especially in previous injuries. It is again shown that runners who had an RRI before had a higher chance to sustain a new RRI. Furthermore, the prevention program seemed to have negative impact on the occurrence of new RRIs in the subgroup of runners with no injuries in the 12 months preceding the trial. Therefore, future studies on running injury prevention measures may specifically aim at this high-risk group of runners who had an RRI before.

REFERENCES

1. van der Worp MP, de Wijer A, van Cingel R, et al. The 5- or 10-km Marikenloop Run: A Prospective Study of the Etiology of Running-Related Injuries in Women. *J Orthop Sports Phys Ther.* 2016; 46(6):462-470.
2. VeiligheidNL. Hardloopblessures Blessurecijfers 2014. Amsterdam: VeiligheidNL; 2016
3. Lee DC, Brellenthin AG, Thompson PD, et al. Running as a Key Lifestyle Medicine for Longevity. *Prog Cardiovasc Dis.* 2017.
4. Kluitenberg B, van Middelkoop M, Diercks R, van der Worp H. What are the Differences in Injury Proportions Between Different Populations of Runners? A Systematic Review and Meta-Analysis. *Sports Med.* 2015; 45(8):1143-1161.
5. Buist I, Bredeweg SW, Bessem B, et al. Incidence and risk factors of running-related injuries during preparation for a 4-mile recreational running event. *Br J Sports Med.* 2010; 44(8):598-604.
6. Macera CA, Pate RR, Powell KE, et al. Predicting lower-extremity injuries among habitual runners. *Arch Intern Med.* 1989; 149(11):2565-2568.
7. Schubert AG, Kempf J, Heiderscheit BC. Influence of stride frequency and length on running mechanics: a systematic review. *Sports Health.* 2014; 6(3):210-217.
8. Taunton JE, Ryan MB, Clement DB, et al. A prospective study of running injuries: the Vancouver Sun Run "In Training" clinics. *Br J Sports Med.* 2003; 37(3):239-244.
9. van Gent RN, Siem D, van Middelkoop M, et al. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med.* 2007; 41(8):469-480; discussion 480.
10. van der Worp MP, ten Haaf DS, van Cingel R, et al. Injuries in runners; a systematic review on risk factors and sex differences. *PLoS One.* 2015; 10(2):e0114937.
11. Saragiotto BT, Yamato TP, Hespanhol Junior LC, et al. What are the main risk factors for running-related injuries? *Sports Med.* 2014; 44(8):1153-1163.
12. Buist I, Bredeweg SW, van Mechelen W, et al. No effect of a graded training program on the number of running-related injuries in novice runners. *Am J Sport Med.* 2008; 36(1):35-41.
13. Bredeweg SW, Zijlstra S, Bessem B, Buist I. The effectiveness of a preconditioning programme on preventing running-related injuries in novice runners: a randomised controlled trial. *Br J Sports Med.* 2012; 46(12):865-870.
14. Malisoux L, Chambon N, Delattre N, et al. Injury risk in runners using standard or motion control shoes: a randomised controlled trial with participant and assessor blinding. *Br J Sport Med.* 2016; 50(8):481-487.
15. Malisoux L, Chambon N, Urhausen A, Theisen D. Influence of the Heel-to-Toe Drop of Standard Cushioned Running Shoes on Injury Risk in Leisure-Time Runners: A Randomized Controlled Trial With 6-Month Follow-up. *Am J Sports Med.* 2016; 44(11):2933-2940.
16. Theisen D, Malisoux L, Genin J, et al. Influence of midsole hardness of standard cushioned shoes on running-related injury risk. *Br J Sport Med.* 2014; 48(5).
17. Vanmechelen W, Hlobil H, Kemper HCG, et al. Prevention of Running Injuries by Warm-up, Cool-down, and Stretching Exercises. *Am J Sport Med.* 1993; 21(5):711-719.
18. Fokkema T, de Vos RJ, van Ochten JM, et al. Preventing running-related injuries using evidence-based online advice: the design of a randomised-controlled trial. *BMJ Open Sport Exerc Med.* 2017; 3(1):e000265.
19. Kluitenberg B, van Middelkoop M, Smits DW, et al. The NLstart2run study: Incidence and risk factors of running-related injuries in novice runners. *Scand J Med Sci Sports.* 2015; 25(5):e515-523.
20. Pasanen K, Parkkari J, Pasanen M, et al. Neuromuscular training and the risk of leg injuries in female floorball players: cluster randomised controlled study. *BMJ.* 2008; 337:a295.

21. Lauersen JB, Bertelsen DM, Andersen LB. The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. *Br J Sports Med*. 2014; 48(11):871-877.
22. Ekstrand J, Gillquist J, Liljedahl SO. Prevention of soccer injuries. Supervision by doctor and physiotherapist. *Am J Sports Med.* 1983; 11(3):116-120.
23. Wang J, Wang Y, Wei C, et al. Smartphone interventions for long-term health management of chronic diseases: an integrative review. *Telemed J E Health*. 2014; 20(6):570-583.
24. Davis IS, Bowser BJ, Mullineaux DR. Greater vertical impact loading in female runners with medically diagnosed injuries: a prospective investigation. *Br J Sports Med*. 2016; 50(14):887-892.
25. Zadpoor AA, Nikooyan AA. The relationship between lower-extremity stress fractures and the ground reaction force: a systematic review. *Clin Biomech (Bristol, Avon)*. 2011; 26(1):23-28.
26. Tam N, Astephen Wilson JL, Noakes TD, Tucker R. Barefoot running: an evaluation of current hypothesis, future research and clinical applications. *Br J Sports Med.* 2014; 48(5):349-355.
27. Davis IS. The Re-emergence of the Minimal Running Shoe. *J Orthop Sports Phys Ther.* 2014; 44(10):775-784.
28. Vannatta CN, Kernozek TW. Patellofemoral joint stress during running with alterations in foot strike pattern. *Med Sci Sports Exerc*. 2015; 47(5):1001-1008.
29. Knobloch K, Yoon U, Vogt PM. Acute and overuse injuries correlated to hours of training in master running athletes. *Foot Ankle Int.* 2008; 29(7):671-676.
30. Yamato TP, Saragiotto BT, Lopes AD. A consensus definition of running-related injury in recreational runners: a modified Delphi approach. *J Orthop Sports Phys Ther*. 2015; 45(5):375-380.
31. Kluitenberg B, van Middelkoop M, Diercks RL, et al. The NLstart2run study: health effects of a running promotion program in novice runners, design of a prospective cohort study. *BMC Public Health*. 2013; 13:685.

Appendix 1. Number of injured runners per anatomical side and the differences between the intervention group (n=1196) and control group (n=1182)

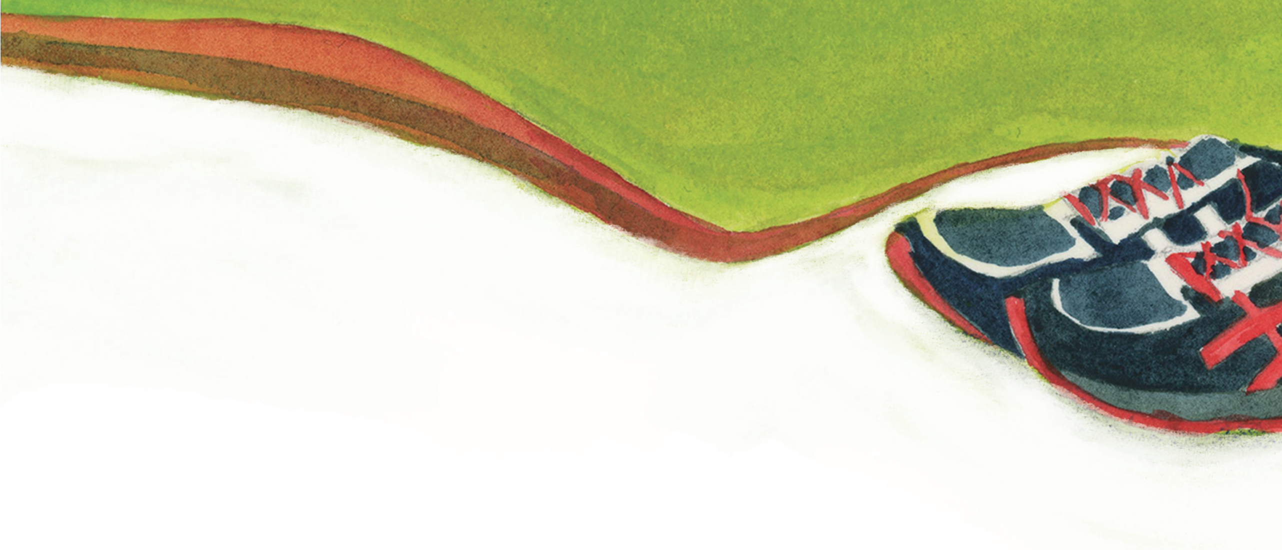
Injury location	All participants		Intervention group		Control group		Difference	OR (95% CI) [a]	Risk ratio (95% CI)
	N	%	N	%	N	%	% (95% CI)		
Lower back	97	4.1	49	4.1	48	4.1	0.0 (-1.6;1.7)	1.03 (0.68;1.54)	1.01 (0.68;1.49)
Buttock	77	3.2	39	3.3	38	3.2	0.1 (-1.5;1.6)	1.04 (0.66;1.63)	1.01 (0.65;1.60)
Hip	115	4.8	57	4.8	58	4.9	-0.1 (-1.9;1.8)	0.99 (0.68;1.44)	0.97 (0.68;1.39)
Groin	65	2.7	35	2.9	30	2.5	0.4 (-1.0;1.8)	1.18 (0.72;1.94)	1.15 (0.71;1.87)
Ventral thigh	44	1.9	18	1.5	26	2.2	-0.7 (-1.9;0.5)	0.69 (0.38;1.27)	0.68 (0.38;1.24)
Dorsal thigh	83	3.5	33	2.8	50	4.2	-1.4 (-3.0;0.1)	0.65 (0.42;1.02)	0.65 (0.42;1.01)
Knee	277	11.6	129	10.8	148	12.5	-1.7 (-4.3;1.0)	0.86 (0.67;1.11)	0.86 (0.69;1.08)
Shin	75	3.2	36	3.0	39	3.3	-0.3 (-1.8;1.2)	0.93 (0.58;1.47)	0.91 (0.58;1.43)
Calf	156	6.6	82	6.9	74	6.3	0.6 (-1.5;2.7)	1.13 (0.81;1.56)	1.10 (0.81;1.48)
Achilles tendon	100	4.2	52	4.3	48	4.1	0.2 (-1.4;2.0)	1.10 (0.73;1.64)	1.08 (0.73;1.57)
Ankle	114	4.8	62	5.2	52	4.4	0.8 (-1.0;2.6)	1.22 (0.83;1.78)	1.18 (0.82;1.69)
Foot	140	5.9	71	5.9	69	5.8	0.1 (-1.9;2.1)	1.04 (0.74;1.47)	1.02 (0.74;1.40)
Toe	26	1.1	12	1.0	14	1.2	-0.2 (-1.2;0.7)	0.86 (0.40;1.87)	0.85 (0.39;1.82)

[a] Control group is reference

Appendix 2. Lower leg injuries in runners who indicated that used the biomechanics section (N=273) compared to the control group (N=1182)

Intervention group		Control group		Difference	OR (95% CI) [a]	Risk ratio (95% CI)
N	%	N	%	% (95% CI)		
77	28.2	178	15.1	13.2 (7.7;19.1)	1.74 (1.28;2.37)	1.87 (1.48;2.36)

[a] Control group is reference



6

Training for a marathon and half-marathon: training volume and longest endurance run in relation to performance and running-related injuries

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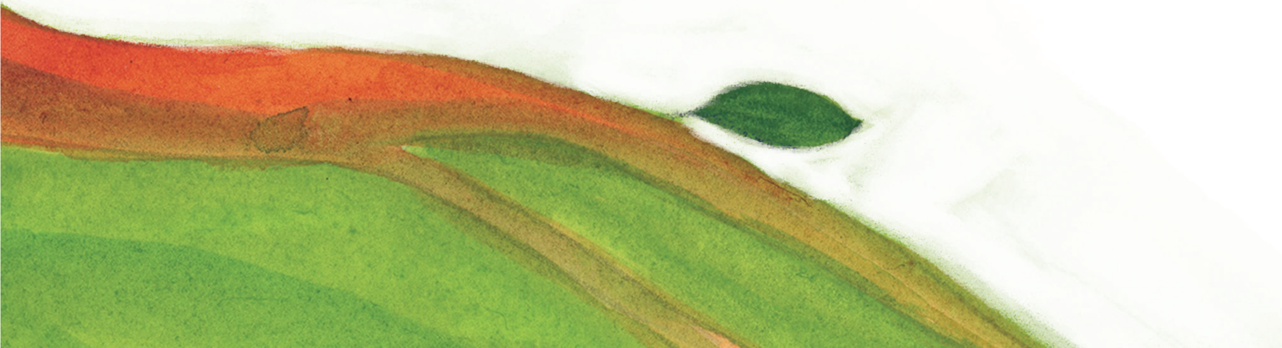

ABSTRACT

Objectives

Examine the associations of training volume and longest endurance run with (half-) marathon performance and running-related injuries (RRIs) in recreational runners.

Design

Prospective cohort study

Methods

During the preparation for and directly after the running event, participants of a half-marathon and marathon completed 3 questionnaires on RRIs, average weekly training volume and the longest endurance run. With finish time, decline in pace during the running event and RRIs as dependent variables, linear and logistic regression analyses were performed to test the associations with weekly training volume and the longest endurance run.

Results

In the 556 included half-marathon runners, a high training volume 2-6 weeks before the running event (>32 km/week) (B -4.19, 95% CI -6.52;-1.85) and a long endurance run (>21 km) (B -3.87, 95% CI -6.31;-1.44) were associated with a faster finish time, while a high training volume was also related to less decline in pace (B -2.29, 95% CI -4.08;-0.51). In the 441 included marathon runners, a low training volume (<40 km/week) was related to a slower finish time (B 6.33, 95% CI 0.18;12.48) and a high training volume (>65 km/week) to a faster finish time (B -14.09, 95% CI -22.47;-5.72), while a longest endurance run of less than 25 km was associated with a slower finish time (B 13.44, 95% CI 5.34;21.55). No associations between training characteristics and RRIs were identified.

Conclusions

Preparation for a (half-)marathon with a relatively high training volume and long endurance runs associates with a faster finish time, but does not seem related to an increased injury risk.

INTRODUCTION

Over the last few decades long-distance running grew in popularity, with more athletes participating in running events like marathons and half-marathons[1,2]. For example, 15.450 athletes ran the Dutch Rotterdam Marathon in 2017, compared to only 200 in 1981. Traditionally, training for a (half-) marathon involves a high training volume and long endurance runs. This way of training seems beneficial for (half-) marathon performance, since a high training volume is, together with a high training pace, related to a better marathon performance time[3,4]. However, a high training volume is also associated with a higher risk of running-related injuries (RRIs)[5]. Running more than 65 km per week for men and between 48 and 63 km for women were found to be related to a higher risk of RRIs in recreational runners[5]. It has therefore been suggested that injuries may be prevented by reducing the training volume[6,7].

For runners and their trainers it is a challenge to find a training volume that is high enough for an optimal (half-) marathon performance, but not that high it will increase the risk on injuries. More scientific knowledge on the associations between training, performance and RRIs may help them to find this optimal training volume. However, so far most studies aimed to investigate the association between training and performance or between training and RRIs. To our best knowledge, performance and injury risk are not yet investigated together in 1 study. Therefore, the aim of th is study was to examine the associations of training volume and longest endurance run with (half-)marathon performance and RRIs in recreational runners participating in a half-marathon or marathon.

METHODS

The present study was part of the INSPIRE-trial, a randomized-controlled trial on the effectiveness of an online injury prevention program[8,9]. Because the injury prevention program had no effect on the number of RRIs, this study can be interpreted as a cohort[9]. The INSPIRE-trial was funded by the Netherlands Organization for Health Research and Development (ZonMW, 536001001) and was performed in collaboration with Golazo Sports, an organization of large running events in the Netherlands. The trial was approved by the Medical Ethical Committee of the Erasmus MC University Medical Center Rotterdam, the Netherlands (MEC-2016-292).

Potential participants of this study were runners who registered for the half-marathon of the NN City Pier City Run The Hague or the NN Marathon Rotterdam in 2017. On the online registration form for these running events, runners were informed about the study and were asked to indicate if they were interested in participating in the trial. If runners registered for both the half-marathon and marathon, only their first registration was taken into account. Runners who were interested in participating and met the inclusion criteria (aged 18 years and older and registration at least 2 months before the running event) received additional information about the study and were asked to give digital informed consent and subsequently complete the online baseline questionnaire. Two weeks before, 1 day after and 1 month after the running event follow-up questionnaires were sent to the participants by e-mail.

In the baseline questionnaire information on demographics (age, sex, weight and height) and training characteristics (running experience (years), being member of an athletics association (yes/no) and the type of training (percentage endurance training, interval training and exercises) and sustaining an RRI in the 12 months before baseline (yes/no)) was collected. In all 3 follow-up questionnaires, participants were asked to indicate if they sustained a new RRI since completing the previous questionnaire (yes/no) and if yes, the location of the RRI was recorded. An RRI was defined as an injury of the muscles, joints, tendons and/or bones in the lower back or lower extremities (hip, groin, thigh, knee, leg, ankle, foot and toes) that was caused by running. Furthermore, 1 of the following criteria had to be met: i) the injury was severe enough to cause a reduction in running distance, speed, duration or frequency for at least 1 week, ii) the injury led to a visit of a doctor and/or physiotherapist and/or iii) medication was necessary to reduce symptoms as a result of the injury. The first follow-up questionnaire (two weeks before the running event) also covered average training characteristics over the last month. These training characteristics included average weekly training volume (kilometers (km)), frequency (times per week) and duration (minutes). Furthermore, information on the longest endurance run before the running event (km) and average training pace (minutes per km) was collected.

Body Mass Index (BMI) was calculated using weight and height. Weekly training volume and longest endurance run were categorized following the existing literature[10-12]. When literature was lacking, averages were used as cut-off points. Consequently, for marathon runners, weekly training volume was categorized into <40 km, 40-65 km and >65 km and the longest endurance run into <25 km, 25-30 km, 30-35 km and >35 km. For half-marathon runners, weekly training volume was categorized into <20 km, 20-32 km and >32 km and the longest endurance run into <15 km, 15-21 km and >21 km. Performance times of the participants (finish time and interval times of every 5 km) were provided by the organization of the running events. The decline in pace during the running event was defined as the percentage difference in interval time from 5-10 km and 15-20 km for half-marathon runners and the percentage difference in interval time from 5-10 km and 35-40 km the marathon runners.

Only runners who completed both the baseline and the first follow-up questionnaire were included in the analyses. Differences in baseline characteristics between participants who did and did not complete the first follow-up questionnaire and between included half-marathon and marathon runners were tested using independent t-test, Mann-Whitney U tests and chi-square tests. For the analyses involving finish time and decline in pace during the running event, only runners who finished the running event were included. For the analyses of the RRIs, also runners that did not start and/or finish the running event were included.

Differences in characteristics of the participants within the weekly training volume, longest endurance and average training pace groups were determined with univariate linear and logistic regression analyses. To determine the associations between training characteristics and finish time and decline in pace, 2 separate multivariate linear regression analyses were performed with the training characteristics as independent variables and finish time and decline in pace, respectively, as dependent variable. The associations between the training characteristics and new RRIs during follow-up were determined using multivariate logistics regression analysis with the training characteristics as independent variables and a new RRI during follow-up as dependent variable. All regression analyses were adjusted for possible confounders including sex, age, BMI, running experience and RRI in 12 months before baseline. The analyses were performed separately for the half-marathon and marathon runners in SPSS Statistics 24. P-values below 0.05 were regarded as statistically significant.

RESULTS

A total of 1336 half-marathon and marathon runners participated in the INSPIRE trial and completed the baseline questionnaire (Appendix 1). Of these long-distance runners, 339 participants (25.4%) did not fill out the first follow-up questionnaire and were therefore excluded from the analyses of the current study. The runners that were included in the analyses were on average older (42.2 (SD 11.7) vs. 39.5 (SD 10.7) years, $p<0.01$), had a lower BMI (23.1 (SD 2.4) vs. 23.6 (SD 2.6) $kg.m^{-2}$, $p<0.01$), longer experience with running (7.8 (SD 8.3) vs. 6.8 (SD 7.3) years, p=0.02) and were more often member of an athletic association (36.5% vs. 27.7%, p<0.01) than the runners that were excluded from the analyses.

The 997 runners included in the analyses were on average 42.2 (SD 11.7) years old and the majority (65%) was male (Table 1). In total, 556 half-marathon runners were included in the analyses. They ran on average 29.9 (SD 19.4) km per week, with a training pace of 5:45 (SD 0:45) minutes per km and a longest endurance run of 19.3 (SD 6.5) km, and finished their race on average in 2:00:05 (SD 0:16:41) hours, with an average decline of 11.2% (SD 7.8). The 441 included marathon runners had an average weekly training volume of 43.6 (SD 27.3) km, a longest endurance run of 29.1 (SD 8.5) km and a training pace of 5:41 (SD 0:44) minutes per km. They finished their race in 4:17:54 (SD 0:37:14) hours with a decline of 24.3% (SD 20.2). The characteristics of the participants divided by the training characteristics are presented in Table 2.

The multivariate analyses showed that in half-marathon runners a training volume of more than 32 km per week, a longest endurance run of more than 21 km and a training pace of less than 5:15 minutes per km 2-6 weeks before the running event were associated with a faster finish time, while a training pace of more than 6:00 minutes per km was associated with a slower finish time (Table 3). Furthermore, a training volume of more than 32 km per week was associated with less decline in pace during the race. In marathon runners, a training volume of less than 40 km/week, a longest endurance run of less than 25 km and a training pace of more than 6:00 minutes per km were associated with a slower finish time, while a training volume of more than 65 km per week and training pace of less than 5:15 minutes per km were associated with a faster finish time. No significant associations between training characteristics and decline in pace were found in marathon runners. In both half-marathon and marathon runners, none of the training variables were associated with new RRIs.

Table 1. Characteristics of the participants

	All runners	Half-marathon runners	Marathon runners
N	997	556 (55.8%)	441 (44.2%)
Demographic characteristics			
Sex (male)	648 (65.0%)	339 (61.0%)	309 (70.1%)*
Age (years)	42.2 (11.7)	42.8 (12.1)	41.4 (11.1)
BMI (kg/m^2)	23.1 (2.4)	23.1 (2.3)	23.1 (2.5)
Training characteristics[a]			
Running experience (years)	7.8 (8.3)	8.0 (8.7)	7.5 (7.9)
Weekly training distance (km)	36.0 (24.2)	29.9 (19.4)	43.6 (27.3)*
Weekly training frequency	2.9 (1.3)	2.7 (1.2)	3.1 (1.3)*
Training pace (minutes per km)	5:43 (0:45)	5:45 (0:45)	5:41 (0:44)
Longest endurance before running event (km)	23.6 (8.9)	19.3 (6.5)	29.1 (8.5)*
Type of training (%)			
Endurance training	68.9 (21.1)	70.3 (21.5)	67.2 (20.5)*
Interval training	23.4 (17.9)	22.3 (18.4)	25.3 (17.3)*
Exercises	7.1 (8.9)	6.8 (8.9)	7.5 (8.8)*
Member of athletic association (yes)	364 (36.5%)	191 (34.4%)	173 (39.2%)
Injuries			
RRI in 12 months before baseline (yes)	532 (53.4%)	291 (52.3%)	241 (54.6%)
Running event			
Started running event (yes)	813 (81.5%)	444 (79.9%)	369 (83.7%)
Finished running event (yes)	773 (77.5%)	432 (77.7%)	341 (77.3%)
Finish time (hours)	3:00:52 (1:13:51)	2:00:05 (0:16:41)	4:17:54 (0:37:14)*
Decline during running event (%)	17.0 (16.0)	11.2 (7.8)	24.3 (20.2)*

* Significant different ($p<0.05$) from half-marathon runners; [a] 2-6 weeks before the running event

Table 2. Characteristics of the participants divided by the training characteristics

Half-marathon	Weekly training volume (km)[b]			Longest endurance run (km)			Training pace (minutes/km)[c]		
	< 20	20-32 (reference)	> 32	< 15	15-21 (reference)	> 21	< 5:15	5:15-6:00 (reference)	> 6:00
N	129	233	193	94	310	152	120	294	134
Sex (female)	61 (47.3%)	89 (38.2%)	67 (34.7%)	42 (44.6%)	135 (43.5%)	40 (26.3%)*	13 (10.8%)*	119 (40.5%)	83 (61.9%)*
Age (years)	38.7 (11.3)*	43.3 (12.0)	42.8 (12.1)	42.4 (11.6)	42.9 (12.6)	42.8 (11.4)	39.5 (11.0)*	42.9 (12.0)	45.5 (12.6)*
BMI (kg/m^2)	23.4 (2.3)	23.1 (2.3)	23.0 (2.3)	23.5 (2.2)	23.3 (2.3)	22.6 (2.3)*	22.1 (1.6)*	23.0 (2.2)	24.3 (2.5)*
Running experience (years)	6.7 (7.5)	8.1 (9.0)	8.7 (9.0)	8.3 (9.9)	7.8 (8.6)	8.3 (8.2)	8.7 (9.3)	8.1 (8.6)	7.0 (8.2)
RRI in 12 months before baseline (yes)	67 (51.9%)	124 (53.2%)	99 (51.3%)	51 (54.3%)	165 (53.2%)	75 (49.3%)	69 (57.5%)	150 (51.0%)	65 (48.5%)
Finish time (hours)[a]	2:05:32 (0:15:12)	2:02:03 (0:16:24)	1:55:26 (0:16:29)*	2:06:48 (0:17:28)	2:03:28 (0:15:35)	1:51:31 (0:15:16)*	1:41:31 (0:09:29)*	2:00:12 (0:11:55)	2:17:47 (0:11:23)*
Decline in pace during event (%)[a]	12.1 (8.7)	12.2 (8.2)	9.7 (6.7)*	10.3 (9.7)	12.1 (7.1)	9.8 (8.3)*	11.4 (7.6)	11.2 (7.7)	11.3 (8.3)
Running-related injury during follow-up (yes)	74 (57.3%)	109 (46.8%)	84 (43.5%)	55 (58.5%)	152 (49.0%)	61 (40.1%)	46 (38.3%)	143 (48.6%)	74 (55.2%)

Table 2. Continued

Marathon	**Weekly training volume (km)[b]**			**Longest endurance run (km)**				**Training pace (minutes/km)[d]**		
	< 40	40-65 (reference)	> 65	< 25	25-30	30-35 (reference)	> 35	< 5:15	5:15-6:00 (reference)	> 6:00
N	158	239	43	91	111	200	38	103	224	97
Sex (female)	48 (30.4%)	78 (32.6%)	6 (14.0%)*	28 (30.8%)	30 (27.0%)	68 (34.0%)	6 (15.8%)*	10 (9.7%)*	66 (29.5%)	52 (53.6%)*
Age (years)	39.7 (11.4)*	42.0 (11.1)	44.3 (9.9)	41.5 (11.0)	39.9 (12.1)	41.7 (10.7)	43.5 (10.7)	37.7 (10.0)*	41.9 (11.1)	44.4 (10.9)*
BMI (kg/m^2)	23.4 (2.6)	23.1 (2.4)	22.5 (2.8)	23.5 (2.8)	23.2 (2.5)	23.0 (2.4)	22.5 (2.4)	22.1 (2.1)*	23.1 (2.3)	24.1 (3.0)*
RRI in 12 months before baseline (yes)	83 (52.5%)	136 (56.9%)	22 (51.2%)	62 (68.1%)*	57 (51.4%)	105 (52.5%)	16 (42.1%)	49 (47.6%)	131 (58.5%)	49 (50.5%)
Running experience (years)	5.7 (5.8)*	8.6 (9.0)	7.7 (6.9)	6.6 (7.3)	7.1 (8.2)	7.7 (7.6)	9.2 (9.7)	7.2 (7.0)	8.3 (8.4)	6.0 (7.0)
Finish time (hours)[a]	4:31:03 (0:36:28)*	4:19:04 (0:33:20)	3:43:03 (0:35:43)*	4:37:43 (0:35:02)*	4:25:07 (0:39:14)*	4:15:26 (0:34:34)	3:50:18 (0:29:13)*	3:38:45 (0:22:55)*	4:21:05 (0:26:24)	4:58:59 (0:23:50)*
Decline in pace during event (%)[a]	26.4 (30.1)	23.9 (15.4)	21.9 (12.5)	28.8 (14.8)	23.3 (31.4)	24.5 (14.2)	20.1 (17.9)	21.4 (29.8)	25.4 (15.6)	24.6 (14.0)
Running-related injury during follow-up (yes)	98 (62.0%)	127 (53.1%)	18 (41.9%)	59 (64.8%)	66 (59.5%)	98 (49.0%)	19 (50.0%)	58 (56.3%)	117 (52.2%)	56 (57.7%)

* Signifcant different ($p<0.05$) from reference group; [a] Runners who did not finish the running event were removed from this analysis; [b] Weekly training volume missing for one participant; [c] Training pace missing for 8 participants; [d] Training pace missing for 17 participants

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Table 3. Results of the multivariate regression analyses on the associations of the training characteristics with (half-)marathon performance and running-related injuries

	Finish time (minutes)[a]		Decline in pace during event (%)[a]		Running-related injury	
	B	95% CI	B	95% CI	OR	95% CI
Half marathon						
Sex (female)	**7.63****	**5.05;10.21**	-1.32	-3.29;0.65	0.99	0.62;1.59
Age (years)	**0.22****	**0.11;0.32**	0.08	-0.01;0.16	1.00	0.98;1.02
BMI (kg/m^2)	**1.54****	**1.03;2.05**	0.34	-0.05;0.72	1.02	0.94;1.12
Running experience (years)	-0.07	-0.21;0.06	-0.06	-0.16;0.05	1.01	0.98;1.03
RRI in 12 months before baseline (yes)	1.38	-3.31;0.54	-0.09	-1.56;1.37	**2.12****	**1.49;2.99**
Weekly training volume (km)						
< 20	1.87	-0.96;4.70	0.53	-1.62;2.69	1.41	0.86;2.32
20-32	Reference		Reference		Reference	
> 32	**-4.19****	**-6.52;-1.85**	**-2.29***	**-4.08;-0.51**	0.97	0.63;1.50
Longest endurance run (km)						
< 15	0.09	-3.39;3.58	-2.29	-4.94;0.37	1.19	0.69;2.04
15-21	Reference		Reference		Reference	
> 21	**-3.87****	**-6.31;-1.44**	-1.33	-3.20;0.54	0.83	0.52;1.30
Training pace (minutes/km)						
< 5:15	**-13.63****	**-16.34;10.93**	0.61	-1.45;2.67	0.68	0.41;1.11
5:15-6:00	Reference		Reference		Reference	
> 6:00	**12.51****	**9.89;15.12**	-0.49	-2.49;1.51	1.23	0.77;1.98

Table 3. Continued

	Finish time (minutes)[a]		Decline in pace during event (%)[a]		Running-related injury	
	B	95% CI	B	95% CI	OR	95% CI
Marathon						
Sex (female)	**10.78****	**4.16;17.40**	-5.55	-11.42;0.31	1.00	0.59;1.70
Age (years)	0.25	-0.02;0.53	0.06	-0.18;0.30	1.00	0.98;1.02
BMI (kg/m^2)	**1.58***	**0.38;2.79**	0.13	-0.94;1.20	1.04	0.95;1.14
Running experience (years)	**-0.42***	**-0.77;-0.06**	**-0.32***	**-0.63;-0.01**	0.99	0.97;1.02
RRI in 12 months before baseline (yes)	-1.62	-6.70;3.46	1.97	-2.51;6.44	**2.59****	**1.71;3.91**
Weekly training volume (km)						
< 40	**6.33***	**0.18;12.48**	1.37	-4.06;6.78	1.29	0.79;2.09
40-65	Reference		Reference		Reference	
> 65	**-14.09****	**-22.47;-5.72**	-1.02	-8.30;6.25	0.58	0.28;1.19
Longest endurance run (km)						
< 25	**13.44****	**5.34;21.55**	2.07	-5.05;9.18	1.00	0.53;1.89
25-30	6.40	0.36;12.82	-1.90	-7.54;3.75	0.75	0.45;1.25
30-35	Reference		Reference		Reference	
> 35	-4.86	-13.51;3.79	-3.59	-11.11;3.93	1.01	0.44;2.32
Training pace (minutes/km)						
< 5:15	**-33.67****	**-40.40;-26.93**	-4.66	-10.52;1.20	1.56	0.90;2.71
5:15-6:00	Reference		Reference		Reference	
> 6:00	**30.47****	**23.52;37.42**	-0.86	-7.04;5.32	1.26	0.73;2.18

* $p<0.05$; ** $p<0.01$; [a] Runners who did not finish the running event were removed from these analyses

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DISCUSSION

The aim of this study was to examine the associations of training volume and longest endurance run with (half-)marathon performance and RRIs in recreational runners. The results showed that in half-marathon runners a higher training volume, longer longest endurance run and higher training pace were related to a faster finish time, while a higher training volume was also related to less decline during the race. These parameters were not associated with the onset of RRIs. In marathon runners, a lower weekly training volume, shorter longest endurance run and slower training pace were associated with a slower finish time, while a higher weekly training volume and faster training pace were related to a faster finish time. Also in marathon runners, no associations between training characteristics and RRIs were found.

Previous research on (half-)marathon performance focused primarily on the prediction of finish time based on a variety of demographic, physiological and training characteristics. Of the training characteristics, mean weekly training volume and training pace were strongly related to finish time[4,13,14]. The present study confirms these findings. A fast training pace and high weekly training volume were associated with a faster finish time in both half-marathon and marathon runners. One may expect that faster runners also tend to run with higher training volumes, which may affect the relation between training volume and finish time. However, the multivariable linear regression analysis also included training pace and a high weekly training volume was still strongly associated with finish time. Furthermore, additional analyses revealed only weak correlations between mean weekly training volume and training pace (half-marathon: r=-0.171; marathon: r=-0.201). These finding indicate that a high weekly training volume may be beneficial for the finish time, despite of the training pace of (half-)marathon runners. Also the length of the longest endurance run was associated with finish time. A longer endurance run was associated with better performance time in half-marathon runners. In marathon runners, shorter endurance runs were associated with worse performance, expressed in finish time. However, a longest endurance run of more than 35 km was not associated with better performance compared to a longest endurance run of 30 to 35 km. For a fast marathon finish time, it therefore seems important to train with a high weekly training volume, but it does not seem necessary to include an endurance run of more than 35 km. This suggests that the high training volume could be divided over multiple shorter endurance runs per week in preparation for a marathon.

In addition to (half-)marathon finish time, decline in pace during the event was also examined as a performance outcome. This was suggested as a proxy variable for running fatigue, since a positive association exists between decline in pace and muscle breakdown markers[15]. Haney et al. showed that slower marathon finishers had more decline in pace than faster marathon finishers[16]. This seems to suggest the relation between a high training volume and a fast finish time is due to less decline in pace. The results of the current study contradict this suggestion. In both half-marathon and marathon runners, only weak correlations existed between decline in pace and finish time (half-marathon: r=0.208; marathon: r=0.294). Furthermore, in the marathon runners there was a significant association between training volume and finish time, but not between training volume and decline in pace. However, in the half-marathon runners, a relation between training volume and decline in pace was found: a high training volume was associated with less decline in pace. Therefore, the results of this study indicate that decline in pace during a running event does not seem to be a good performance outcome measure in marathon runners.

In this study, no associations between the training characteristics and RRIs were found. This finding contradicts with some previous studies, in which a high training volume was related to a higher injury risk[5,10]. This may be partly explained by the relatively low number of marathon runners in the highest training volume and longest endurance run groups (n=43 and n=38, respectively). However, also in the half-marathon runners no associations between training characteristics and RRIs were identified, while these runners were more equally divided in training volume and longest endurance run. Furthermore, there have also been some other studies that found no associations between training volume and injury risk or a high training volume was even protective for RRIs[17,18]. These conflicting findings indicate that the relation between training volume is complex and may be confounded by other factors. It has been suggested that 'survival of the fittest' may be an important confounder of the relation between training volume and RRIs[17]. Possibly only runners who are least prone for RRIs prepare for a (half-)marathon with a high training volume and long endurance runs, while runners who are prone to RRIs may be forced to reduce their training volume due to beginning RRIs. However, additional analyses of our data showed no significant associations between training volume and previous RRIs in the 12 months before the INSPIRE-trial. Therefore, it cannot be confirmed that 'survival of the fittest' is a confounder for the relation between training volume and RRIs in the current study. Furthermore, there is evidence that the progression in training volume also plays an important role in the development of RRIs[5, 19]. Therefore, future research on the complex relation between training volume and RRIs should also take the progression in training volume into account. As suggested by Nielsen et al., time-to-event models could be used when analyzing these data, since these methods are well suited to deal with changes in training load as a time-varying exposure[20].

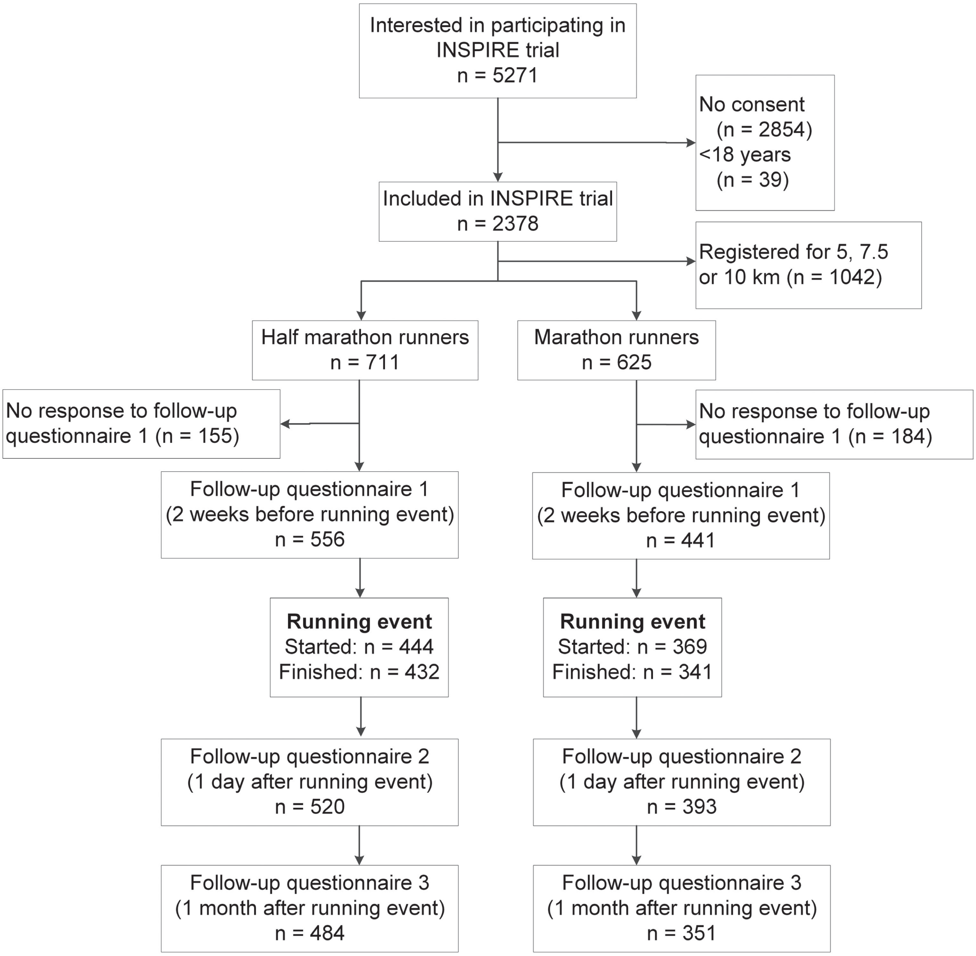
A strength of the current study is that it is the first study that investigated the relations of both (half-)marathon performance and RRIs with training characteristics. Furthermore, this study included a large sample of both half-marathon and marathon runners. However, some limitations should be taken into account when interpreting the results of this study. First, 82 (14.7%) of the runners included as half-marathon runners also participated in the marathon and were therefore actually preparing for a marathon. This is a potential source of bias, because significant differences between half-marathon and marathon runners existed in baseline and training characteristics. Performing the analyses without the half-marathon runners that participated in both events showed similar results as the analyses with these runners for finish time and RRIs. For decline in pace the results were slightly different: there was no significant association with training volume anymore when analyzing the data without the runners that participated in both running events. Another limitation is the relative high number of runners that were excluded from the analyses. The excluded runners had a higher BMI than the included runners. In previous literature, a higher BMI was associated with a slower half-marathon time and therefore results of the current study may be biased by excluding runners from the analyses[21,22]. Another possible limitation of this study is that the identified associations of training pace, training volume and the longest endurance run with finish time are possibly confounded by the intrinsic speed ('talent') of runners. Also, the efficacy of novel training schedules with lower training volume and higher training intensities cannot be assessed from these data, because of the limited contribution of these training methods in the sample. Future research would benefit from including intrinsic training intensity (e.g. heart rate) as a variable.

CONCLUSION

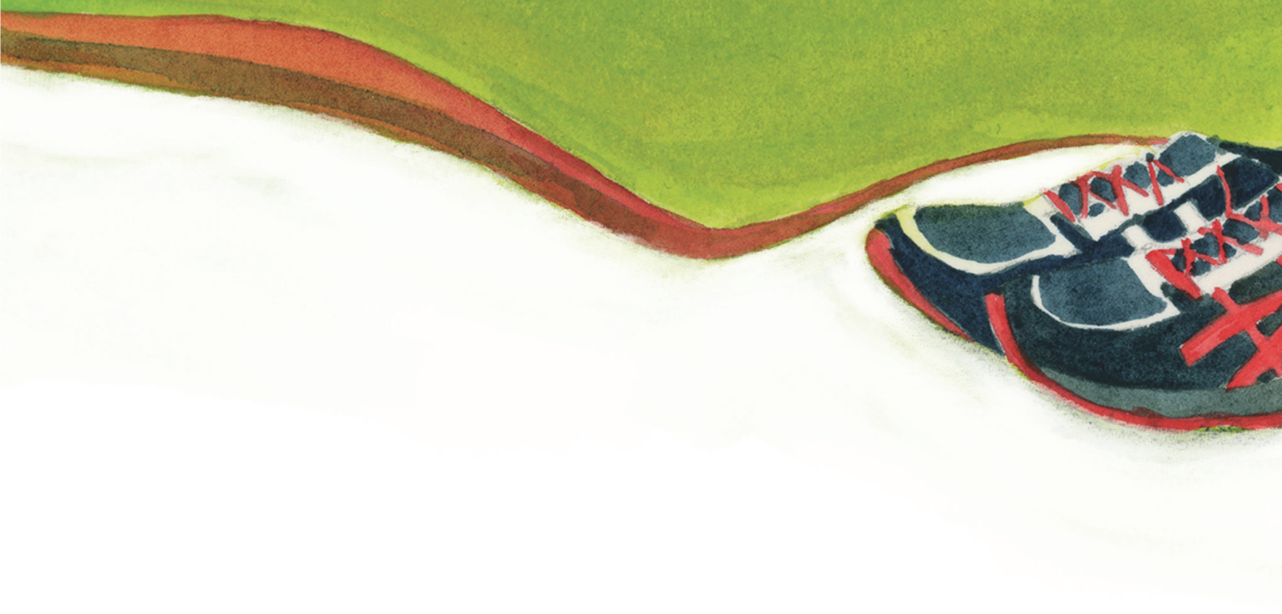
Results of this study indicate that preparation with a relatively high training volume and long endurance runs 2-6 weeks before a half-marathon running event is related to a faster finish time and less decline in pace during the event. For a fast marathon finish time, a high training volume of at least 30 km seems important. However, it does not seem necessary to include an endurance run of more than 35 km. In both half-marathon and marathon runners, training volume and the distance of the longest endurance run were not related to injury risk.

REFERENCES

1. Anthony D, Rust CA, Cribari M, et al. Differences in participation and performance trends in age group half and full marathoners. *Chin J Physiol*. 2014; 57(4):209-219.
2. Knechtle B, Nikolaidis PT, Zingg MA, et al. Half-marathoners are younger and slower than marathoners. *Springerplus*. 2016; 5:76.
3. Salinero JJ, Soriano ML, Lara B, et al. Predicting race time in male amateur marathon runners. *J Sports Med Phys Fitness*. 2017; 57(9):1169-1177.
4. Tanda G, Knechtle B. Effects of training and anthropometric factors on marathon and 100 km ultramarathon race performance. *Open Access J Sports Med*. 2015; 6:129-136.
5. van der Worp MP, ten Haaf DS, van Cingel R, et al. Injuries in runners; a systematic review on risk factors and sex differences. *PLoS One*. 2015; 10(2):e0114937.
6. Fields KB, Sykes JC, Walker KM, et al. Prevention of running injuries. *Curr Sports Med Rep*. 2010; 9(3):176-182.
7. Macera CA. Lower extremity injuries in runners. Advances in prediction. *Sports Med*. 1992; 13(1):50-57.
8. Fokkema T, de Vos RJ, van Ochten JM, et al. Preventing running-related injuries using evidence-based online advice: the design of a randomised-controlled trial. *BMJ Open Sport Exerc Med*. 2017; 3(1):e000265.
9. Fokkema T, de Vos RJ, van Ochten JM, et al. Online multifactorial prevention programme has no effect on the number of running-related injuries: a randomised controlled trial. *Br J Sports Med*. 2019.
10. Van Middelkoop M, Kolkman J, Van Ochten J, et al. Risk factors for lower extremity injuries among male marathon runners. *Scand J Med Sci Sports*. 2008; 18(6):691-697.
11. Fredericson M, Misra AK. Epidemiology and aetiology of marathon running injuries. *Sports Med*. 2007; 37(4-5):437-439.
12. Macera CA, Pate RR, Powell KE, et al. Predicting lower-extremity injuries among habitual runners. *Arch Intern Med*. 1989; 149(11):2565-2568.
13. Salinero JJ, Soriano ML, Lara B, et al. Predicting race time in male amateur marathon runners. *J Sports Med Phys Fitness*. 2016.
14. Hagan RD, Upton SJ, Duncan JJ, et al. Marathon performance in relation to maximal aerobic power and training indices in female distance runners. *Br J Sports Med*. 1987; 21(1):3-7.
15. Del Coso J, Fernandez D, Abian-Vicen J, et al. Running Pace Decrease during a Marathon Is Positively Related to Blood Markers of Muscle Damage. *Plos One*. 2013; 8(2).
16. Haney TA, Jr., Mercer JA. A Description of Variability of Pacing in Marathon Distance Running. *Int J Exerc Sci*. 2011; 4(2):133-140.
17. Kluitenberg B, van der Worp H, Huisstede BM, et al. The NLstart2run study: Training-related factors associated with running-related injuries in novice runners. *J Sci Med Sport*. 2015.
18. Dallinga J, Van Rijn R, Stubbe J, et al. Injury incidence and risk factors: a cohort study of 706 8-km or 16-km recreational runners. *BMJ Open Sport Exerc Med*. 2019; 5(1):e000489.
19. Nielsen RO, Parner ET, Nohr EA, et al. Excessive progression in weekly running distance and risk of running-related injuries: an association which varies according to type of injury. *J Orthop Sports Phys Ther*. 2014; 44(10):739-747.
20. Nielsen RO, Bertelsen ML, Ramskov D, et al. Time-to-event analysis for sports injury research part 1: time-varying exposures. *Br J Sports Med*. 2019; 53(1):61-68.
21. Gomez-Molina J, Ogueta-Alday A, Camara J, et al. Predictive Variables of Half-Marathon Performance for Male Runners. *J Sports Sci Med*. 2017; 16(2):187-194.
22. Rust CA, Knechtle B, Knechtle P, et al. Predictor variables for a half marathon race time in recreational male runners. *Open Access J Sports Med*. 2011; 2:113-119.



Appendix 1. Flowchart of the participants



7

Impact and prognosis of running-related knee injuries among recreational runners

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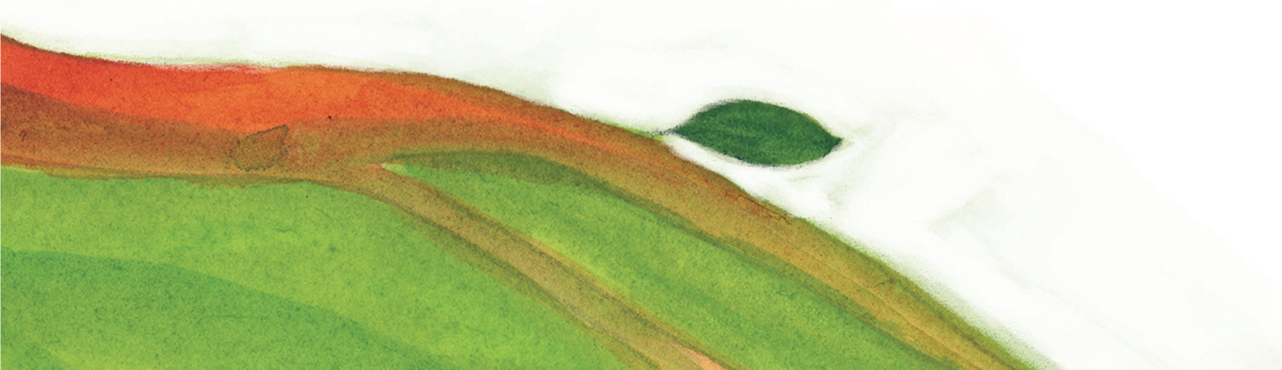

ABSTRACT

Objective

To investigate the impact and prognostic factors of running-related knee injuries (RRKIs) among recreational runners.

Design

Prospective cohort study.

Setting

This study is part of a randomized-controlled trial (RCT) on running injury prevention among recreational runners. At baseline during registration for a running event (5-42 km), demographic and training variables were collected. Participants who reported a new RRKI during follow-up were sent a knee-specific questionnaire at 16 months (range 11.7-18.6) after registration.

Participants

138 runners who reported a new RRKI during the RCT on injury prevention responded to the knee-specific questionnaire.

Assessment of Risk Factors

To determine the association between potential prognostic factors and time-to-recovery of an RRKI, a Cox regression analysis was performed.

Main Outcome Measures

Time-to-recovery and prognostic factors of RRKIs.

Results

At 16 months after registration, 71.0% of the participants reported full recovery, with an median time-to-recovery of 8.0 weeks. Most participants reported iliotibial band syndrome (23.2%) or osteoarthritis (OA)/degenerative meniscopathy (23.2%) as cause of their injury. Male sex was associated with a shorter time-to-recovery (HR 1.84, 95% CI 1.14;2.97), while suffering knee OA was associated with a longer time-to-recovery (HR 0.17, 95% CI 0.06;0.46).

Conclusions

The impact of RRKIs is large, as almost one third of the participants were not recovered at 16 months after registration. This emphasizes the need for injury prevention programs for runners. More knowledge on the impact of running with knee OA seems important, given the high number of runners with knee OA symptoms.

INTRODUCTION

Recreational running, with its accessibility and low monetary costs, has become increasingly popular among the general population as a primary form of exercise. In the Netherlands, around 12.5% of the total population participated in running activities in 2014[1]. Although several health benefits are attributed to running activities, the increased popularity of running has also led to an increase in running-related injuries (RRIs)[2].

The most common site of running injuries is the knee[3-5]. Running-related knee injury (RRKI) proportions in runners vary from 22.5% in cross-country runners to 30.6% in novice runners[6]. A one-year prospective follow-up study in novice runners demonstrated that median time to recover from RRKIs in novice runners was 75 up to 88 days for the most common RRKIs (i.e. patellofemoral pain, meniscopathy, iliotibial band syndrome and patellar tendinopathy)[7]. Furthermore, patellofemoral pain and meniscopathy were the second and third most common RRIs. Respectively 15.0% and 26.0% of runners with these injuries reported persistent complaints of their injury after one year follow-up[7].

Only a few studies evaluated prognostic factors of RRIs in runners, using different study populations and follow-up times[8,9]. The results of these studies were inconclusive. Van Middelkoop et al. performed a study on the course and 3-month prognosis of RRIs in male marathon runners and found that runners who reported non-musculoskeletal comorbidities were more likely to have prolonged complaints of their injury[8]. This while Fokkema et al. reported that a previous RRI was related to a poor prognosis of a new injury in novice runners[9]. To our knowledge, no studies have been designed to evaluate the impact and prognostic factors of RRKIs among recreational runners. When focused on only RRKIs, analysis will be made in a less heterogeneous study population. This will cause a higher chance to find specific factors predicting the course of RRKIs. Identification of these factors would provide practitioners with information about characteristics that may predict the prognosis of their patient's RRKI. Hereby, practitioners can inform their patients about the most likely clinical course of the RRKI and facilitate them with more realistic expectations of treatment outcomes[10]. Therefore, the aim of this study was to investigate the impact and prognostic factors of RRKIs among recreational runners during a 16-month follow-up period.

METHODS

Study design and setting

The current study was part of the INSPIRE trial (INtervention Study on Prevention of Injuries in Runners). The INSPIRE trial was a randomized-controlled trial among recreational runners with a minimum follow-up of three months, in which we investigated the effect of an evidence-based online injury prevention program on the number of RRIs[11]. The INSPIRE trial was funded by the Netherlands Organization for Health Research and Development (ZonMW, 536001001). Participants who reported a new RRKI during the study period were included in the current study and sent a follow-up questionnaire at a mean of 16-month (range 11.7-18.6). A flowchart of the design and follow-up is presented in Figure 1.

Subjects

Runners who registered for the running events NN City Pier City run The Hague (5 km, 10 km and 21.1 km), NN Marathon Rotterdam (10.55 km and 42.195 km) and the Ladies Run Rotterdam (5, 7.5 and 10 km) in 2017 were asked if they were interested in participating in the INSPIRE trial. Interested runners were sent additional online information. If they fulfilled the inclusion criteria, runners were asked to provide electronic informed consent and to complete the baseline questionnaire (T0). Both novice and more experienced runners, aged 18 years and older, who returned the baseline questionnaire were included in the INSPIRE trial. Exclusion criteria were no knowledge of the Dutch language and no access to internet and/or email. Participants received a follow-up questionnaire two weeks before the running event (T1), one day after the running event (T2) and one month after the running event (T3). Non-responders were sent a reminder by e-mail within one week. Runners who reported a new knee injury at one of the questionnaires (T1, T2 or T3) were sent an additional knee-specific follow-up questionnaire (T4) at a mean of 16 months (range 11.7 – 18.6) after baseline.

Questionnaires

The baseline questionnaire (T0) consisted of questions on demographic characteristics (sex, age, weight and height). Weight and height were used to calculate the body mass index (BMI). Participants were asked if they experienced non-musculoskeletal comorbidities (yes/no), had an RRI in the preceding 12 months (yes/no) and if this RRI was a knee injury (yes/no). Training-related information was administered with questions on running frequency, hours, distance and running speed (average per week over the last three months). Furthermore, participants were asked about their running experience (in years), membership of an athletics association (yes/no) and use of a training schedule (yes/no). Information about type of training surface (paved/unpaved), type of training (endurance/interval/specific exercises) and use of orthotics (yes/no) was also obtained. For the current study, running experience was categorized in 0-4 years, 4-10 years and ≥ 10 years and training distance in 0-15 km, 15-30 km and ≥ 30 km per week. Interval training was dichotomized in more or less than 50% of the training and training on paved surface in more or less than 75% of the training.

For the current study purpose, the follow-up questionnaires (T1-T3) were used to extract information about new RRKIs. Furthermore, severity of knee pain at onset was derived from the questionnaire in which the knee injury was first reported by the participant. Participants scored the severity of knee pain, at rest and while running, on an 11-point Numeric Rating Scale (NRS) ranging from 0 (no pain) to 10 (worst pain imaginable).

The additional knee-specific follow-up questionnaire (T4) obtained information on long-term consequences of RRKIs. Participants were asked if they were recovered from their RRKI (yes/no). Furthermore, time-to-recovery (weeks) was questioned. If participants were not recovered, they were asked to score the severity of present knee pain due to the RRKI. Information about the course of the knee pain (constant pain with slight fluctuations/constant pain with pain attacks/pain attacks, between attacks pain-free/pain attacks, between attacks constant pain) was obtained. The self-reported diagnoses were classified into patellofemoral pain (PFP), iliotibial band syndrome (ITBS), tendinopathy, knee osteoarthritis (OA)/degenerative meniscopathy, bursitis, traumatic injury and other/unknown. The self-reported diagnoses were leading, but when a diagnosis remained unclear or unknown, a sports physician gave the participant the most likely diagnosis using reported sub-locations of the knee pain and age of the participant. The National Institute for Health and Care Excellence (NICE) guideline was followed to diagnose knee OA. Following this guideline, a participant was diagnosed with knee OA when at least 45 years old, activity-related joint pain and either no morning joint-related stiffness or morning stiffness that lasted no longer than 30 minutes[12]. Information on medical consumption was obtained by the use of painkillers and/or NSAIDs, treatment by a health professional (general practitioner, medical specialist and/or physiotherapist), type of treatment received (stretching or exercises, adjustment of running shoes, use of orthotics and/or other) and imaging (radiography, MRI and/or ultrasound). In addition, participants were asked whether the RRKI restricted their running in terms of running speed, duration and/or frequency. The subscales symptoms and sports of the Knee Injury and Osteoarthritis Outcome Score (KOOS) were used to administer

OA specific outcomes at follow-up[13]. The Anterior Knee Pain Scale score (AKPS) was used to evaluate patellofemoral pain complaints[14]. The scores of the KOOS and AKPS both ranged from 0 (worst pain and/or disability) to 100 (no pain and/or disability).

Outcome measures

The primary outcome measure was time-to-recovery of a knee injury in weeks. An RRKI was defined as any self-reported musculoskeletal complaint of the knee due to running activities, which restricted the amount of running (distance, duration, speed or frequency) for at least one week or needed medical consultation[3,4,15].

Analysis

Descriptive statistics were used to describe baseline characteristics, expressed in frequency or mean and standard deviations (SDs). Baseline characteristics of responders and non-responders of the knee-specific 16-month follow-up questionnaire (T4) were compared using independent sample t-tests or chi-square tests. Recovered and non-recovered participants were compared on the impact of RRKIs using independent sample t-tests and chi-square tests. To test associations between potential prognostic factors and time-to-recovery from RRKIs a Cox regression analysis (enter-method) was performed with recovery of the RRKI as the event. Potential prognostic factors included sex, age, BMI, non-musculoskeletal comorbidities, RRI in the 12 months before baseline, diagnosis (suspected knee OA based on the NICE guideline, PFP and ITBS) and severity of knee pain at onset. Hazard ratios (HRs) and the corresponding 95% confidence intervals (CIs) were calculated. For participants who did not recover from their RRKI during follow-up, recovery time was set to the time in weeks of the knee complaint up to T4.

Before Cox regression analysis, multiple imputation techniques were performed due to missing data of knee pain at onset. 10 imputations were used in the model. The variables severity of knee pain at onset, at rest and while running, were imputed. Factors used as predictors included sex, age, BMI, non-musculoskeletal comorbidities, recovered (yes/no), recovery time and diagnosis (suspected knee OA based on the NICE guideline, PFP and ITBS). P-values < 0.05 were regarded as statistically significant. All analyses were performed using SPSS version 24.0 (SPSS Inc, Chicago, Illinois).

Ethical Considerations

This study was approved by the Medical Ethical Committee of the Erasmus Medical Centre (MEC-2016-292).

RESULTS

In total, 2378 runners participated in the INSPIRE trial (Figure 1). Of these, 277 (14.4%) runners reported a new RRKI during follow-up and were sent a knee-specific follow-up questionnaire (T4) after a mean of 16 months (range 11.7-18.6). A total of 138 (49.8%) participants responded to the final follow-up questionnaire and were consequently included in the current study. Compared to the group participants with a new RRKI that did not respond to the knee-specific follow-up questionnaire (T4), responders were on average significantly older (42.3 vs. 39.3 years, p=0.04). No other significant differences between responders and non-responders were found.

At baseline, study participants with an RRKI (n=277) were on average 42.3 (SD 12.2) years old, had an average BMI of 23.3 (SD 3.0) kg/m^2 and the majority was male (59.4%) (Table 1). Participants trained on average 2.2 (SD 0.9) times a week, spent 2.6 (SD 1.5) hours a week on training with an average running speed of 6.0 (SD 0.9) min/km. A total of 50 (36.2%) of the participants reported an RRKI in the previous 12 months. None of the participants sustained an RRKI at baseline.

After a mean of 16 months follow-up, 71.0% (N=98) of the runners were recovered from their knee injury (Table 2), with a median recovery time of 8.0 weeks. Non-recovered participants had complaints for 54.5 weeks up to T4. Following the self-reported diagnoses, most participants suffered from ITBS (23.2%) and knee OA/degenerative meniscopathy (23.2%). Following the NICE guideline, 13.8% of the participants were diagnosed with knee OA. A significant difference between recovered and non-recovered participants was found within the group of participants that had suspected knee OA based on the NICE guideline (5.1% vs. 35.0%, p<0.001).

More than half (56.5%) of the participants made training adjustments because of the RRKI, of which two-third (66.7%) on running speed and 61.5% on frequency (Table 3). Of the 71 participants who received treatment for their RRKI, 87.3% was treated by a physiotherapist. Significant differences between recovered and non-recovered participants were found in adjustment of running speed during training (75.0% vs. 50.0%, p=0.03), receiving knee radiography, MRI and/or ultrasound (11.2% vs. 30.0%, p=0.01), KOOS Symptoms (89.2 vs. 64.6, p=0.01), KOOS Sports (86.1 vs. 77.8, p<0.001) and AKPS (95.8 vs. 81.4, p<0.001).

The results of the Cox regression for time-to-recovery are presented in Table 4. Male sex (HR 1.84, 95% CI 1.14;2.97) was associated with a shorter recovery time, while participants diagnosed with suspected knee OA based on the NICE guideline (HR 0.17, 95% CI 0.06;0.46) had a longer time-to-recovery. None of the other included variables were significantly associated with time-to-recovery.

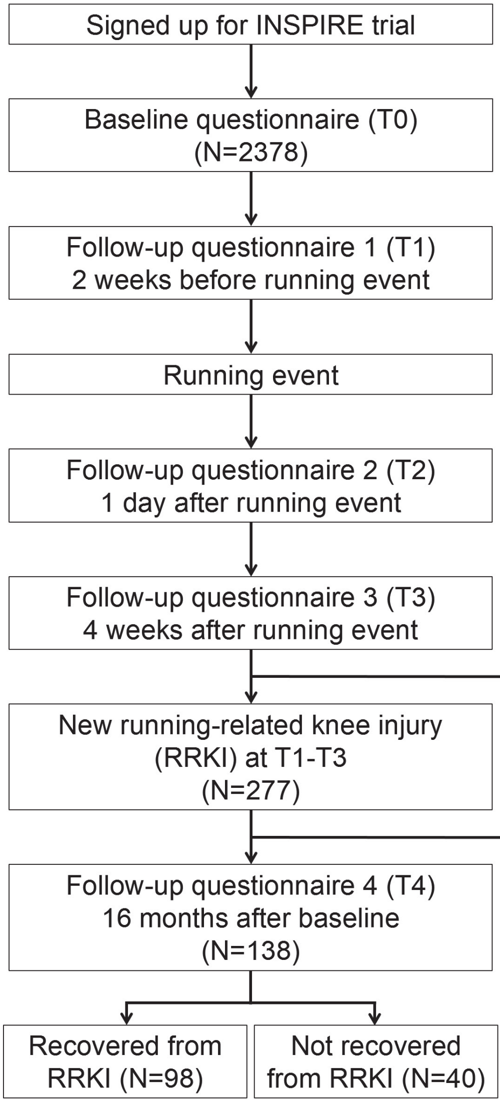

Figure 1. Flowchart of the participants

Table 1. Baseline characteristics of responders and non-responders

	Responded to follow-up questionnaire		
	Yes (N=138)	No (N=139)	Total (N=277)
Sex (male)	82 (59.4)	72 (51.8)	154 (55.6)
Age (years)*	42.3 (12.2)	39.3 (11.8)	40.8 (12.1)†
BMI (kg/m2)*‡	23.3 (3.0)	23.4 (2.7)	23.3 (2.8)
Non-musculoskeletal comorbidities	30 (21.7)	30 (21.6)	60 (21.7)
Running experience			
0-4 years	67 (48.6)	76 (54.7)	143 (51.6)
4-10 years	37 (26.8)	37 (26.6)	74 (26.7)
≥ 10 years	34 (24.6)	26 (18.7)	60 (21.7)
Weekly training frequency*	2.2 (0.9)	2.2 (1.0)	2.2 (1.0)
Weekly training hours*	2.6 (1.5)	2.6 (2.1)	2.6 (1.8)
Weekly training distance			
0-15 km	49 (35.8)	60 (43.2)	109 (39.5)
15-30 km	59 (43.1)	54 (38.8)	113 (40.9)
≥ 30 km	29 (21.2)	25 (18.0)	54 (19.6)
Running speed (min/km)*	6.0 (0.9)	6.0 (0.9)	6.0 (0.9)
Hard training surface (>75%)	115 (83.3)	116 (83.5)	231 (83.4)
Interval training (> 50%)	16 (11.6)	11 (7.9)	27 (9.7)
Member of an athletics association	37 (26.8)	42 (30.2)	79 (28.5)
Use of a training schedule	92 (66.7)	82 (59.0)	174 (62.8)
Use of orthotics	61 (44.2)	48 (34.5)	109 (39.4)
RRI§ 12 months before baseline			
Yes, RRKI‖	50 (36.2)	48 (34.5)	98 (35.4)
Yes, other RRI	39 (28.3)	32 (23.0)	71 (25.6)
No	49 (35.5)	59 (42.4)	108 (39.0)

Categorical data are presented as N (%) and continuous data (*) as mean (SD). † Statistically significant difference between responders and non-responders ($p<0.05$); ‡ Body Mass Index; § Running-related injury; || Running-related knee injury.

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Table 2. Severity and type of running-related knee injuries of recovered and non-recovered runners

		Recovered from knee injury	
	Total (N=138)	Yes (N=98)	No (N=40)
Severity of knee pain at onset*†			
Rest (NRS‡, 0-10)	3.2 (2.1)	3.0 (2.0)	3.8 (2.1)
Running (NRS, 0-10)	5.7 (2.7)	5.6 (2.7)	6.1 (2.7)
Knee pain at follow-up*			
Rest (NRS, 0-10)	-	-	3.1 (2.0)
Running (NRS, 0-10)	-	-	5.1 (2.4)
Diagnosis			
Patellofemoral pain	7 (5.1)	4 (4.1)	3 (7.5)
Iliotibial band syndrome	32 (23.2)	27 (27.6)	5 (12.5)
Tendinopathy	12 (8.7)	10 (10.2)	2 (5.0)
Knee OA / degenerative meniscopathy	32 (23.2)	21 (21.4)	11 (27.5)
Knee OA (NICE guideline§)	19 (13.8)	5 (5.1)	14 (35.0)||
Bursitis	3 (2.2)	3 (3.1)	0 (0.0)
Traumatic injury	5 (3.6)	1 (1.0)	4 (10.0)
Other / unknown	47 (34.1)	32 (32.7)	15 (37.5)
Course of knee pain			
Constant pain with slight fluctuations	60 (43.5)	45 (45.9)	15 (37.5)
Constant pain with pain attacks	2 (1.4)	2 (2.0)	0 (0.0)
Pain attacks, between attacks pain-free	72 (52.2)	48 (49.0)	24 (60.0)
Pain attacks, between attacks constant pain	4 (2.9)	3 (3.1)	1 (2.5)
Same knee injury in the past	48 (34.8)	32 (32.7)	16 (40.0)

Categorical data are presented as N (%) and continuous data (*) as mean (SD). † Severity of knee pain at onset derived from the questionnaire in which the knee injury was first reported. ‡ Numeric Rating Scale; § National Institute for Health and Care Excellence. || = statistically significant difference between recovered and non-recovered runners ($p<0.05$).

Table 3. Consequences of running-related knee injuries of recovered and non-recovered runners after 16 months follow-up

		Recovered from knee injury	
	Total (N=138)	Yes (N=98)	No (N=40)
Use of painkillers and/or NSAIDs	15 (10.9)	10 (10.2)	5 (12.5)
Adjustment of training	78 (56.5)	52 (53.1)	26 (65.0)
Running speed	52 (66.7)	39 (75.0)	13 (50.0)*
Hours	25 (32.1)	15 (28.8)	10 (38.5)
Frequency	48 (61.5)	29 (55.8)	19 (73.1)
Treatment of health professional	71 (51.4)	48 (49.0)	23 (57.5)
General practitioner	4 (5.6)	2 (4.2)	2 (8.7)
Medical specialist	7 (9.9)	4 (8.3)	3 (13.0)
Physiotherapist	62 (87.3)	43 (89.6)	19 (82.6)
Kind of treatment			
Stretching or exercises	42 (59.2)	28 (58.3)	14 (60.9)
Adjustment of running shoes	4 (5.6)	3 (6.3)	1 (4.3)
Use of orthotics	5 (7.0)	4 (8.3)	1 (4.3)
Other	23 (32.4)	7 (30.4)	16 (33.3)
Knee radiography, MRI and/or ultrasound	23 (16.7)	11 (11.2)	12 (30.0)*
KOOS (0-100)†‡			
Symptoms	82.1 (21.1)	89.2 (15.8)	64.6 (22.4)*
Sports	83.7 (18.0)	86.1 (17.8)	77.8 (17.3)*
AKPS (0-100)†§	91.6 (10.6)	95.8 (6.7)	81.4 (11.6)*

Categorical data are presented as N (%) and continuous data (†) as means (SD). * Statistically significant difference between recovered and non-recovered runners ($p<0.05$); ‡ Knee Injury and Osteoarthritis Outcome; § Anterior Knee Pain Scale.

Table 4. Cox Regression Model of prognostic factors associated with a faster recovery from running-related knee injuries

	HR (95% CI)	**p-value**
Sex (male)	1.84 (1.14;2.97)*	0.01
Age (years)	1.00 (0.98;1.02)	0.78
BMI (kg/m2)†	0.95 (0.89;1.03)	0.22
Non-musculoskeletal comorbidities	1.31 (0.74;2.32)	0.35
RRI‡ previous 12 months		
No	Reference	
Yes, RRKI§	0.86 (0.52;1.42)	0.56
Yes, other RRI	1.45 (0.85;2.47)	0.17
Diagnosis		
Knee osteoarthritis (NICE guideline‖)	0.17 (0.06;0.46)*	<0.001
Patellofemoral pain	0.72 (0.20;2.60)	0.62
Iliotibial band syndrome	1.02 (0.60;1.72)	0.95
Knee pain at onset		
Rest (NRS¶, 0-10)	0.93 (0.83;1.05)	0.25
Running (NRS, 0-10)	0.96 (0.85;1.07)	0.44

* Statistically significant association with time-to-recovery ($p<0.05$); † Body Mass Index; ‡ Running-related injury; § Running-related knee injury; || National Institute for Health and Care Excellence; ¶ Numeric Rating Scale.

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DISCUSSION

The aim of this study was to investigate possible prognostic factors for time-to-recovery from RRKIs in recreational runners. At follow-up, almost one third of the participants were not recovered from their RRKI. Male runners were more likely to have a faster recovery from RRKIs compared to females. Runners diagnosed with suspected knee OA based on the NICE guideline were more likely to have a longer time-to-recovery.

In the current study, 71.0% of the runners with an RRKI were recovered after 16 months, with a median time of 8.0 weeks. The median time-to-recovery of 8.0 weeks is comparable with a recent study of Mulvad et al., who described a median time-to-recovery of 7.0 and 8.0 weeks for respectively PFP and ITBS[16]. This while Nielsen et al. reported a median recovery time of 10.7 to 12.6 weeks for the most frequent RRKIs (PFP, meniscopathy, ITBS and patellar tendinopathy)[3]. A possible explanation for this small difference might be the use of different study populations, since Nielsen et al. performed the study in novice runners. It seems that it can be concluded that runners with an RRKI have to take into account a recovery time of 7 till 13 weeks assuming that they respond to the initial treatment.

The percentage of participants with knee OA was relatively high, since 19 (13.8%) participants were diagnosed with knee OA following the NICE guideline and even 32 (23.3%) participants reported the diagnosis knee OA. When including all participants with knee OA (suspected knee OA based on the NICE guideline and self-reported knee OA), diagnosis knee OA was still significantly associated with a longer time-to-recovery from RRKIs (HR 0.43, 95% CI 0.24;0.77, $p<0.001$). This association is in line with the fact that knee OA is a chronic progressive condition and a major cause of musculoskeletal disability in older populations. Treatments are restricted to pain alleviation by a combination of pharmacological and exercise interventions[17]. In this study, 31.6% of the runners diagnosed with knee OA did not make any training adjustments because of their RRKI. Current clinical guidelines for the management of knee OA recommend exercise among the primary treatments, but do not clearly describe recommendations on running[18-20]. A recent study of Lo et al. reported that self-selected running is associated with improved knee pain and not with worsening knee pain or radiographically defined structural progression[21]. However, a systematic review concluded that it is not possible to determine the role of running in knee OA and more evidence from well-designed, prospective studies is needed[22]. Therefore, the impact of running on knee OA is still unclear.

Using a Cox regression model, male runners were found to have a faster recovery from RRKIs compared to females. Male runners recovered from their knee injury with a median recovery time of 6.0 weeks, while females recovered with a median recovery time of 10.0 weeks. In none of the other studies about prognostic factors of RRIs, sex was significantly associated with time-to-recovery[8, 9]. Furthermore, no literature has been found to explain the faster recovery in male runners compared to females. Therefore, it remains unknown how to explain the difference in recovery time between male and female runners.

Strengths and limitations

This study has a number of strengths. This is the first study providing data on prognostic factors of time to recover from RRKIs, the most common injury in runners. Furthermore, a prospective study design was applied. However, some limitations have to be taken into account when interpreting the results of this study.

Information was collected through self-reported questionnaires with a follow-up time of 16 months (range 11.7-18.6), which may have caused recall bias with regard to the injury characteristics. Furthermore, about 43.5% of the participants reported two or more RRIs during the follow-up period. It is likely that given answers were based on all running injuries and not only on the knee injury. For example, an individual could have been recovered from a knee injury but not yet participating in running activities due to another injury. This may have led to an overestimation of the RRKI duration.

Of the participants, 40 (29.0%) did not recover from their RRKI before the end of follow-up. Because time-to-recovery was unknown, recovery time was defined as the duration of symptoms in weeks up to the knee-specific follow-up questionnaire (T4). However, this may have led to an underestimation of the RRKI duration, since part of the study population was followed shorter than time-to-recovery.

Finally, the percentage loss-to-follow-up (50.2%) was relatively high. Compared to the group participants with a new RRKI that did not respond to the knee-specific follow-up questionnaire (T4), responders were on average significantly older (42.3 vs. 39.3, p=0.04). This difference in age is, however, not clinically relevant as the mean difference of three years between responders and non-responders is unlikely to explain the association with knee OA and prolonged recovery time.

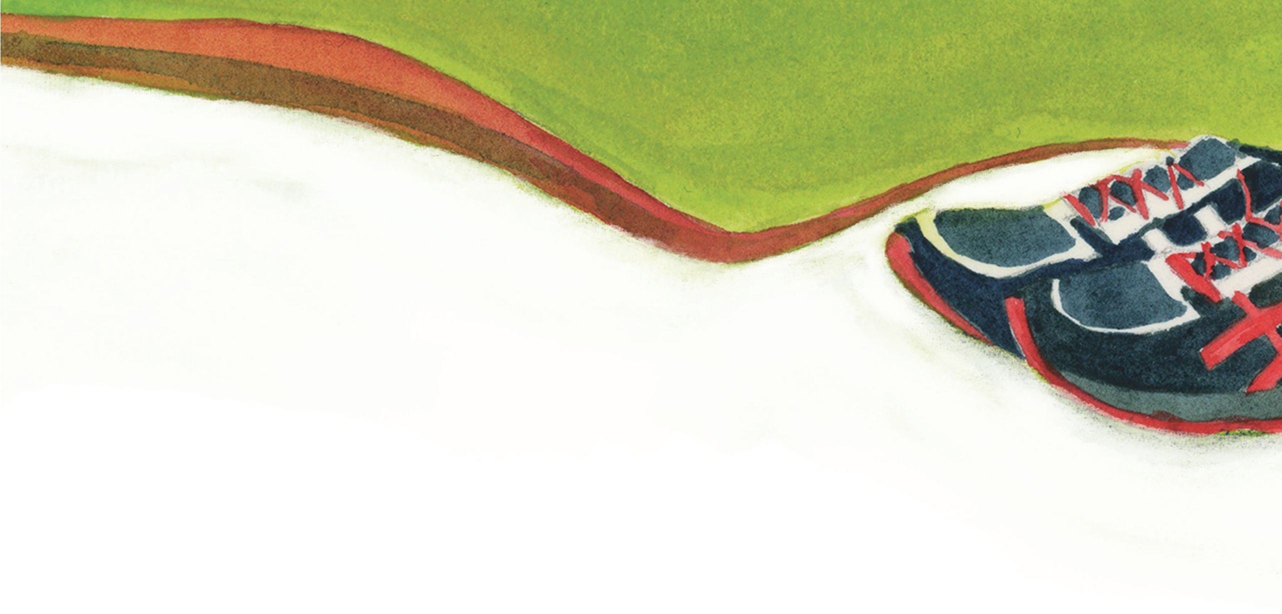
CONCLUSION

In conclusion, the impact of RRKIs is large as almost one third of the participants were not recovered at 16 months after baseline. Male runners with an RRKI seem to be more likely to have a faster recovery compared to females. The relatively long duration of knee symptoms after an injury emphasizes the need for optimal treatment, education and injury prevention programs for recreational runners. More knowledge on the impact of running with knee OA seems especially important, given the high number of runners with knee OA symptoms.

REFERENCES

1. VeiligheidNL. Hardloopblessures Blessurecijfers 2014. Amsterdam: VeiligheidNL; 2016
2. Fries JF, Singh G, Morfeld D, et al. Running and the development of disability with age. *Ann Intern Med.* 1994; 121(7):502-509.
3. Nielsen RO, Ronnow L, Rasmussen S, Lind M. A prospective study on time to recovery in 254 injured novice runners. *PLoS One.* 2014; 9(6):e99877.
4. van Poppel D, Scholten-Peeters GG, van Middelkoop M, Verhagen AP. Prevalence, incidence and course of lower extremity injuries in runners during a 12-month follow-up period. *Scand J Med Sci Sports.* 2014; 24(6):943-949.
5. van Gent RN, Siem D, van Middelkoop M, et al. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med.* 2007; 41(8):469-480; discussion 480.
6. Kluitenberg B, van Middelkoop M, Diercks R, van der Worp H. What are the Differences in Injury Proportions Between Different Populations of Runners? A Systematic Review and Meta-Analysis. *Sports Med.* 2015; 45(8):1143-1161.
7. Nielsen RO, Buist I, Parner ET, et al. Predictors of Running-Related Injuries Among 930 Novice Runners: A 1-Year Prospective Follow-up Study. *Orthop J Sports Med.* 2013; 1(1):2325967113487316.
8. van Middelkoop M, Kolkman J, van Ochten J, et al. Course and predicting factors of lower-extremity injuries after running a marathon. *Clin J Sport Med.* 2007; 17(1):25-30.
9. Fokkema T, Burggraaff R, Hartgens F, et al. Prognosis and prognostic factors of running-related injuries in novice runners: A prospective cohort study. *J Sci Med Sport.* 2018.
10. Mallen CD, Peat G, Thomas E, et al. Prognostic factors for musculoskeletal pain in primary care: a systematic review. *Br J Gen Pract.* 2007; 57(541):655-661.
11. Fokkema T, de Vos RJ, van Ochten JM, et al. Preventing running-related injuries using evidence-based online advice: the design of a randomised-controlled trial. *BMJ Open Sport Exerc Med.* 2017; 3(1):e000265.
12. (UK) NCGC. Osteoarthritis: Care and Management in Adults. London: National Institute for Health and Clinical Excellence (UK); 2014.
13. Collins NJ, Misra D, Felson DT, et al. Measures of knee function: International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, Knee Injury and Osteoarthritis Outcome Score (KOOS), Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form (KOOS-PS), Knee Outcome Survey Activities of Daily Living Scale (KOS-ADL), Lysholm Knee Scoring Scale, Oxford Knee Score (OKS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Activity Rating Scale (ARS), and Tegner Activity Score (TAS). *Arthritis Care Res (Hoboken).* 2011; 63 Suppl 11:S208-228.
14. Crossley KM, Bennell KL, Cowan SM, Green S. Analysis of outcome measures for persons with patellofemoral pain: which are reliable and valid? *Arch Phys Med Rehabil.* 2004; 85(5):815-822.
15. Van Middelkoop M, Kolkman J, Van Ochten J, et al. Risk factors for lower extremity injuries among male marathon runners. *Scand J Med Sci Sports.* 2008; 18(6):691-697.
16. Mulvad B, Nielsen RO, Lind M, Ramskov D. Diagnoses and time to recovery among injured recreational runners in the RUN CLEVER trial. *PLoS One.* 2018; 13(10):e0204742.
17. Ondresik M, Azevedo Maia FR, da Silva Morais A, et al. Management of knee osteoarthritis. Current status and future trends. *Biotechnol Bioeng.* 2017; 114(4):717-739.
18. Fernandes L, Hagen KB, Bijlsma JW, et al. EULAR recommendations for the non-pharmacological core management of hip and knee osteoarthritis. *Ann Rheum Dis.* 2013; 72(7):1125-1135.
19. McAlindon TE, Bannuru RR, Sullivan MC, et al. OARSI guidelines for the non-surgical management of knee osteoarthritis. *Osteoarthritis Cartilage.* 2014; 22(3):363-388.

20. Hochberg MC, Altman RD, April KT, et al. American College of Rheumatology 2012 recommendations for the use of nonpharmacologic and pharmacologic therapies in osteoarthritis of the hand, hip, and knee. *Arthritis Care Res (Hoboken).* 2012; 64(4):465-474.
21. Lo GH, Musa SM, Driban JB, et al. Running does not increase symptoms or structural progression in people with knee osteoarthritis: data from the osteoarthritis initiative. *Clin Rheumatol.* 2018; 37(9):2497-2504.
22. Timmins KA, Leech RD, Batt ME, Edwards KL. Running and Knee Osteoarthritis: A Systematic Review and Meta-analysis. *Am J Sports Med.* 2017; 45(6):1447-1457.



8

Opinions, barriers, and facilitators of injury prevention in recreational runners

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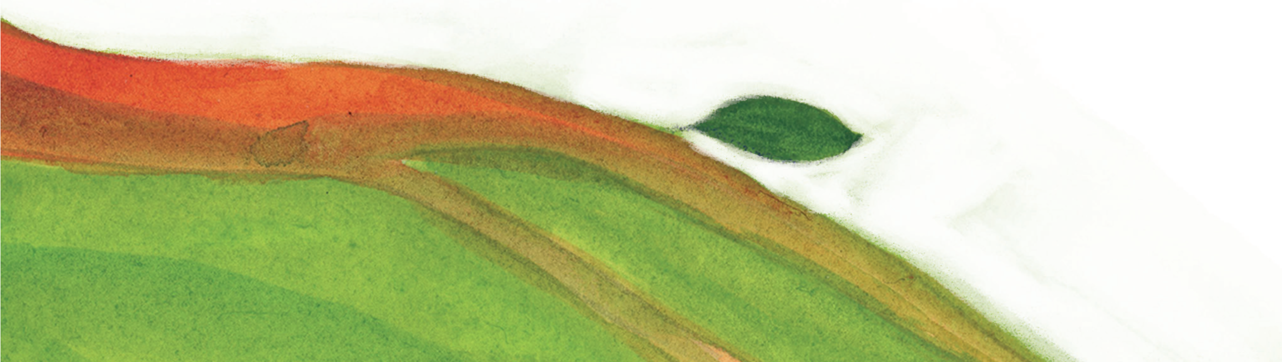


ABSTRACT

Study design

Comparative cross-sectional study

Background

Effective injury prevention measures for running-related injuries (RRIs) have not yet been identified. More insight into the opinions of runners about injury prevention might help to develop effective injury prevention programs that are supported by the target population.

Objectives

To describe the opinions of recreational runners on different components of injury prevention and to identify the barriers to and facilitators of injury prevention in adult recreational runners.

Methods

A single questionnaire was sent to 2378 recreational runners. The questionnaire contained questions about their interests, actions undertaken, and perceived barriers to and facilitators of injury prevention. Descriptive analyses were used to examine differences with regard to sex, age, and previous RRIs.

Results

1034 adult recreational runners (43.5%) responded to the questionnaire. Runners with previous RRIs were more likely to rate injury prevention as very useful than runners who had never sustained an RRI (76.8% vs. 63.6%, $p<0.001$). In total, 81.8% of the participants indicated that they already performed preventive measures, including changes to training schedules (65.4%) and warming-up (57.8%). Most frequently reported barriers to injury prevention were 'not knowing what to do' (45.2%) and 'no history of RRI' (34.6%). The most important facilitator was an injury (60.1%). Women more often preferred information via a trainer or running store than did men, while men more frequently preferred websites or e-mail.

Conclusion

The majority of runners rated injury prevention as important. To increase effectiveness, future prevention programs should be developed with an awareness of the barriers and facilitators experienced by adult runners.

INTRODUCTION

Running is a sport that is practiced frequently and is still growing in popularity[1]. This is probably because running is an easily accessible and inexpensive sport that can yield fast improvements in physical fitness[2,3]. However, a major drawback of running is the high number of running-related injuries (RRIs). A systematic review from 2015 showed that injury proportions range from 3.2-84.9% in adult runners in studies with a follow-up time or recall period between 1 day and lifetime. These percentages indicate a necessity for effective RRI prevention measures[4]. In the last few decades, several randomized trials on RRI prevention have been performed[5-11]. However, in most trials no significant reduction in the number of RRIs was effectuated.

According to the Translating Research into Injury Prevention Practice (TRIPP) framework of Finch, identifying etiologic factors that are readily modifiable and consistent with a biological mechanism is important to preventing RRIs[12]. As suggested by Bertelsen et al, insights into how factors influence the dose-response relationship between running participation and injuries will likely increase the understanding of the etiology of RRIs[13]. However, insight into the behavioral context in which injury prevention measures will be implemented is necessary for running injury prevention[12]. Taking the attitudes about, barriers to, and facilitators of injury prevention of athletes into account when designing and implementing injury prevention measures may increase the odds of successful injury prevention. Saragiotto et al. explored the beliefs of recreational runners about the most important risk factors for RRIs[14]. They found that runners think that RRIs are mainly related to i) training, ii) running shoes and iii) exceeding the limits of the body, and suggested that these factors should be considered when developing new injury prevention strategies. To increase our understanding of the attitudes about, barriers to and facilitators of injury prevention, this exploratory study aimed to i) describe the opinions of adult recreational runners on different components of injury prevention and compare the opinions of different subgroups of runners, and to ii) identify the barriers to and facilitators of injury prevention in these runners.

METHODS

This study is part of the INtervention Study on Prevention of Injuries in Runners at Erasmus [Medical Center] (INSPIRE) trial, a randomized-controlled trial (RCT) on the effectiveness of a multifactorial online RRI prevention program[15]. Recreational runners 18 years or older who registered in 2017 for one of three selected running events (distances ranging from 5-42.2 km) were invited to participate in the trial. Participants in the intervention group were given access to the online injury prevention program, which consisted of information on evidence-based risk factors and advice on how to reduce injury risk. Participants in the control group followed their regular preparation for the running event. With three follow-up questionnaires, the effectiveness of the prevention program on the number of RRIs was evaluated. In the INSPIRE trial an RRI was defined as an injury of the muscles, joints, tendons and/or bones in the lower back or lower extremities (hip, groin, thigh, knee, leg, ankle, foot and toes) that was caused by running. Furthermore, one of the following criteria had to be met: i) the injury was severe enough to cause a reduction in running distance, speed, duration or frequency for at least 1 week; ii) the injury led to a visit to a doctor and/or physiotherapist; or iii) medication was necessary to reduce symptoms as a result of the injury. More details on the INSPIRE-trial are published elsewhere[15]. The INSPIRE trial was funded by the Netherlands Organization for Health Research and Development (ZonMW, 536001001) and was performed in collaboration with Golazo Sports, a company that organizes large running events in the Netherlands This study was approved by the Medical Ethics Committee of the Erasmus University Medical Center Rotterdam (MEC-2016-292). The participants signed an informed-consent form before participating and their rights were protected.

Approximately seven months after the running event, all participants in both the intervention group and control group received an implementation questionnaire containing questions about their interests, preventive actions undertaken, and barriers to and facilitators of injury prevention. For the present study, only data from these implementation questionnaires were used.

The implementation questionnaire consisted of four sections. First, information about the runners was collected: sex, date of birth, years of running experience, average running frequency and training volume per week and previous RRIs. The second section contained questions on RRI prevention. The runners were asked about the factors they thought were important in RRI prevention: healthy lifestyle, running clothes, running shoes, progression of the training program, running technique, running surface and/or other. The attitude towards the usefulness of RRI prevention was also captured in this section (very useful, a little useful, or not useful). The participants were asked whether they ever searched for RRI prevention measures (yes or no). Next, they were asked whether they actively performed RRI prevention measures themselves (yes or no). If so, more information on the type of measures was obtained: healthier lifestyle, changes to the training schedule, warming-up/cooling-down, stretching, changes to clothes, changes to shoes, insoles/orthotics, bandages/braces/taping, compression socks, running surface, changes in running technique and/or other. In the last section, information on barriers to and facilitators of RRI prevention was obtained. The runners who did not perform preventive measures were asked about the most important barriers to injury prevention (never had an injury, no time, not useful, not amusing, not motivated, does not fit into my training schedule, do not know what to do and/or other) and facilitators of injury prevention (an RRI, attractive offer of information on prevention, better access to information on RRI prevention, integration into daily training, more knowledge of effectiveness, improving running performance, financial compensation, free supplies for RRI prevention and/or other). Finally, participants were asked for their preferred ways to receive information on RRI prevention (mobile application, website, e-mail, trainer, running store, magazine, health professional and/or other).

Differences in characteristics between the participants in the INSPIRE-trial who did and did not respond to the implementation questionnaire were determined using independent sample t-tests and chi-square tests. For all data collected, means and standard deviations (SD) (continuous data), or frequencies and percentages (categorical data) were calculated. To test the impact of the injury prevention program of the INSPIRE-trial on the answers to the implementation questionnaire, the responses of participants in the intervention group were compared with those of the control group. Furthermore, subgroup analyses were performed for sex, age (younger than 35 years, 35 to 50 years and older than 50 years), and previous injuries (yes or no). Subgroup differences were tested using chi-square tests. Analyses were performed in SPSS Statistics 24 (IBM Corporation, Armonk, NY), and a p-value less than .05 was regarded as statistically significant.

RESULTS

In total, 2378 adult recreational runners participated in the INSPIRE-trial, of whom 43.5% (1034 runners) completed the implementation questionnaire. The runners who completed the questionnaire were on average older [44.1 (SD 12.5) vs. 39.8 (SD 11.2) years, $p<0.001$], had more running experience [7.5 (SD 8.8) vs. 5.8 (SD 6.9) years, $p<0.001$] and were more often male (55.5% vs. 50.4%, $p=0.014$) than the runners who did not respond to this questionnaire. The characteristics of the participants in this study are shown in Table 1.

Almost three quarters of the participants (74.1%; 95% confidence interval [CI] 71.3, 76.7%) rated injury prevention as very useful (Table 2). Progression of the training program (94.4%, 95% CI 92.8;95.7%), running shoes (76.4%, 95% CI 73.7;78.9%) and running technique (55.8%, 95% CI 52.7; 58.9%) were reported to be the most important aspects of injury prevention. The majority of the participants (68.4%, 95% CI 65.4;71.2%) actively searched for information on injury prevention and 81.8% (95% CI 79.3;84.1%) performed preventive measures themselves. These preventive measures most often included changes to training schedules (65.4%, 95% CI 62.0;68.6%), warming-up and cooling-down (57.8%, 95% CI 54.4;61.1%), and stretching (49.8%, 95% CI 46.3;53.2%). The most important barriers reported by runners who did not perform injury prevention were 'not knowing what to do' (45.2%, 95% CI 38.0;52.6%) and no history of RRI (34.6%, 95% CI 27.9;41.9%) (Table 3). Their most important reported reason to start injury prevention was an RRI (60.1%, 95% CI 52.7;67.1%). The most important ways to receive information on injury prevention were through mobile applications (49.3%, 95% CI 46.2;52.4%) and websites (45.4%, 95% CI 42.3;48.5%).

Of all responses, only two showed a significant difference between participants in the intervention group and those in the control group of the INSPIRE-trial: runners in the intervention group performed injury prevention measures more often than participants in the control group (84.4% vs. 79.5%, $p=0.041$) and more often preferred to receive information through an app (52.7% vs. 46.2%, $p=0.036$).

The results of the subgroup analyses are presented in Tables 2 and 3. Men more often preferred to receive information on injury prevention through websites (49.2% vs. 40.5%, $p=0.005$) or e-mail (36.4% vs. 29.3%, $p=0.017$) than women, while women more frequently preferred to receive the information personally via a trainer (43.5% vs. 31.0%, $p<0.001$) or at a running store (19.0% vs. 11.8%, $p=0.001$). More runners aged under 35 years would start taking injury prevention measures if they would receive financial compensation (15.2% vs. 0.0% and 1.8%, $p<0.001$) or free supplies (34.8% vs. 9.2% and 12.3%, $p<0.001$) for injury prevention. Runners with a history of RRI more often experienced a lack of motivation (25.2% vs. 12.3%, $p=0.032$) and 'not knowing what to do' (59.1% vs. 23.3%, $p<0.001$) as barriers to injury prevention than did runners who had not suffered an RRI in the past.

Table 1. Characteristics of the study participants (n = 1034)*

	All	**Sex**		**Age (years)**			**History of RRI***	
		Male	Female	≤35	35-50	≥50	Yes	No
Total, n (%)	1034	577 (55.8%)	457 (44.2%)	303 (29.3%)	381(36.8%)	350 (33.8%)	820 (79.3%)	214 (20.7%)
Sex (male), n (%)	577 (55.8%)	577 (100%)	0 (0.0%)	108 (35.3%)	214 (56.2%)	255 (72.9%)	471 (57.4%)	106 (49.5%)
Age (years)	44.1 (12.5)	47.8 (11.9)	39.4 (23.1)	28.7 (4.0)	43.5 (4.4)	58.0 (5.5)	44.6 (12.5)	42.2 (12.4)
BMI (kg/m^2)	23.7 (2.9)	24.1 (2.7)	23.1 (3.1)	23.1 (3.0)	23.7 (3.1)	24.1 (2.6)	23.8 (3.0)	23.4 (2.9)
Running experience (years)	7.5 (8.8)	9.1 (10.1)	5.4 (6.2)	3.7 (3.5)	6.1 (6.3)	12.3 (11.8)	7.8 (9.2)	6.2 (6.9)
Running frequency (times/week)	2.4 (1.2)	2.5 (1.2)	2.3 (1.2)	2.1 (1.1)	2.5 (1.3)	2.6 (1.0)	2.5 (1.2)	2.1 (1.1)
Running distance (km/week)	22.7 (15.8)	25.6 (16.8)	19.1 (13.5)	18.3 (14.6)	23.5 (16.7)	25.8 (14.7)	23.6 (15.7)	19.5 (15.4)
Previous RRI (yes), n (%)	820 (79.3%)	471 (81.6%)	349 (76.4%)	236 (77.9%)	292 (76.6%)	292 (83.4%)	820 (100%)	0 (0.0%)

Abbreviations: BMI, body mass index; RRI, running-related injury.
* Values are mean (SD) unless otherwise indicated.

Table 2. Opinions of the participants about the importance of running injury prevention and performing preventive measures*

	All participants	Sex			Age (years)				History of RRI*		
		Male	Female		≤35	35-50	≥50		Yes	No	
	N=1034	N=577	N=457	p-value	N=303	N=381	N=350	p-value	N=820	N=214	p-value
How useful is injury prevention?											
Very	74.1	75.0	72.9		69.0	74.8	77.7		76.8	63.6	
A little	25.0	23.7	26.5	0.418	29.7	24.4	21.4	0.147	22.4	34.6	<0.001
Not	1.0	1.2	0.7		1.3	0.8	0.9		0.7	1.9	
What is important for injury prevention?											
Healthy lifestyle	44.8	45.2	44.2	0.740	44.6	42.8	47.1	0.494	43.0	51.4	0.029
Clothes	7.6	6.6	9.0	0.152	10.9	7.9	4.6	0.010	7.7	7.5	0.919
Shoes	76.4	72.1	81.8	<0.001	82.2	75.1	72.9	0.015	75.7	79.0	0.320
Progression of the training schedule	94.4	93.9	95.0	0.473	96.7	93.7	93.1	0.110	94.6	93.5	0.505
Technique	55.8	53.2	59.1	0.059	62.7	56.7	48.9	0.002	56.3	53.7	0.495
Surface	36.5	35.5	37.6	0.484	43.9	32.0	34.9	0.004	37.3	33.2	0.263
Other	7.4	9.0	5.5	0.509	4.6	6.8	10.6	0.322	7.1	8.9	0.199
Do you actively search for injury prevention measures yourself?											
Yes	68.4	67.6	69.4	0.542	66.3	68.5	70.0	0.603	73.9	47.2	<0.001
Do you take injury prevention measures yourself?											
Yes	81.8	80.6	83.4	0.250	78.2	82.9	83.7	0.149	86.0	65.9	<0.001
Which injury prevention measures do you take?†											
Healthier lifestyle	37.0	38.3	35.4	0.394	32.9	34.5	43.0	0.029	36.6	39.0	0.588
Changes to the training schedule	65.4	63.0	68.2	0.112	65.0	61.7	69.6	0.121	66.8	58.2	0.049
Warming-up and cooling-down	57.8	55.9	60.1	0.219	53.6	52.5	66.9	<0.001	57.4	59.6	0.641
Stretching	49.8	48.0	52.0	0.246	48.5	48.4	52.2	0.582	49.2	52.5	0.479
Changes to clothes	9.2	8.8	9.7	0.655	8.0	8.2	11.3	0.326	8.9	10.6	0.524
Changes to shoes	41.1	32.5	51.7	<0.001	49.4	38.6	37.2	0.009	40.6	44.0	0.453
Insoles or orthotics	26.2	28.8	23.1	0.060	18.6	23.7	35.2	<0.001	28.4	15.6	0.002
Bandages, brace or taping	7.3	4.9	10.2	0.003	8.9	6.3	7.2	0.523	8.1	3.5	0.059
Compression socks	21.4	21.9	20.7	0.672	20.3	22.2	21.5	0.864	22.3	17.0	0.165
Changes in running surface	24.9	26.2	23.4	0.336	29.1	21.2	25.6	0.099	25.1	24.1	0.804
Changes in running technique	24.2	27.1	20.7	0.032	21.9	24.4	25.9	0.564	25.2	19.1	0.123
Other	12.9	12.9	12.9	0.496	11.4	17.4	9.2	0.517	12.9	12.8	0.352

Abbreviation: RRI, running-related injury;* Values are percent unless otherwise indicated; † Only participants who reported taking injury prevention measures (n=846) were asked this question

Table 3. Opinions of the participants on barriers and facilitators for injury prevention*

	All participants	Sex			Age (years)				History of RRI*		
		Male	Female		≤35	35-50	≥50		Yes	No	
	N=1034	N=577	N=457	p-value	N=303	N=381	N=350	p-value	N=820	N=214	p-value
What are barriers for injury prevention?†											
No history of RRI	34.6	28.6	43.4	0.036	33.3	36.9	33.3	0.886	1.7	86.3	<0.001
No time	11.7	8.0	17.1	0.058	18.2	9.2	7.0	0.118	13.9	8.2	0.237
Not effective	5.9	6.3	5.3	0.777	6.1	6.2	5.3	0.974	7.8	2.7	0.148
Not amusing	11.7	12.5	10.5	0.679	13.6	7.7	14.0	0.461	14.8	6.8	0.099
Not motivated	20.2	21.4	18.4	0.614	22.7	12.3	26.3	0.129	25.2	12.3	0.032
Does not fit in training schedule	7.4	6.3	9.2	0.448	7.6	7.7	7.0	0.989	8.7	5.5	0.413
Not knowing what to do	45.2	46.4	43.4	0.684	48.5	43.1	43.9	0.800	59.1	23.3	<0.001
Other	9.0	8.1	9.2	0.447	6.1	9.2	12.3	0.422	10.4	6.8	0.555
What are facilitators for injury prevention?†											
An injury	60.1	58.0	63.2	0.482	68.2	61.5	49.1	0.095	46.1	82.2	<0.001
Attractive information	17.6	20.5	13.2	0.192	19.7	16.9	15.8	0.839	23.5	8.2	0.007
Better access to information	28.7	31.3	25.0	0.353	31.8	24.6	29.8	0.645	35.7	17.8	0.008
Integration in daily training	28.2	27.7	28.9	0.850	24.2	30.8	29.8	0.671	30.4	24.7	0.391
More knowledge on effectiveness	31.9	33.9	28.9	0.472	27.3	27.7	42.1	0.141	37.4	23.3	0.043
Also improvement in performance	28.2	30.4	25.0	0.423	27.3	24.6	33.3	0.554	26.1	31.5	0.421
Financial compensation	5.9	7.1	3.9	0.360	15.2	0.0	1.8	<0.001	3.5	9.6	0.082
Free supplies for injury prevention	19.1	17.9	21.1	0.585	34.8	9.2	12.3	<0.001	23.5	12.3	0.058
Other	1.6	2.7	0.0	0.558	1.5	1.5	1.8	0.419	0.0	4.1	0.187
What are your preferred ways to receive information on injury prevention?											
Mobile application	49.3	48.0	51.0	0.342	50.2	54.9	42.6	0.004	49.4	49.1	0.933
Website	45.4	49.2	40.5	0.005	44.6	44.1	47.4	0.628	44.9	47.2	0.544
E-mail	33.3	36.4	29.3	0.017	30.0	27.6	42.3	<0.001	34.1	29.9	0.241
Trainer	36.6	31.0	43.5	<0.001	39.9	33.3	37.1	0.197	37.8	31.8	0.103
Running store	15.0	11.8	19.0	0.001	22.4	14.4	9.1	<0.001	15.5	13.1	0.380
Running magazine	13.7	13.2	14.4	0.556	13.2	13.9	14.0	0.950	13.9	13.1	0.757
Health professional	12.9	12.0	14.0	0.329	15.8	10.0	13.4	0.069	14.0	8.4	0.029
Other	4.0	4.3	3.5	0.454	3.3	5.0	3.4	0.538	4.1	3.3	0.530

Abbreviation: RRI, running-related injury; * Values are percent unless otherwise indicated; † Only participants who reported not to take injury prevention measures (n=188) were asked this question

DISCUSSION

The aims of this study were to describe the opinions of adult recreational runners on different components of injury prevention and compare the opinions of different subgroups of runners, and to identify the barriers to and facilitators of injury prevention in these runners. The large majority of participants regarded injury prevention as very useful. The most important barriers for injury prevention were 'not knowing what to do' and 'no history of RRI', while sustaining an RRI was the most important facilitator of injury prevention. Mobile applications and websites were the most preferred ways to receive information on injury prevention.

Injury prevention is important to recreational runners. In the present study, almost 70% of the runners reported actively searching for information on injury prevention, and over 80% reported performing injury prevention measures themselves. However, the number of RRIs among recreational runners is high, indicating that the injury prevention measures undertaken may not have the intended effect[4]. In this study, recreational runners' opinions on the most important aspects of injury prevention were comparable to those reported by Saragiotto et al. regarding risk factors[14]. In both studies, training, running technique and running shoes were regarded as important aspects for injury prevention. Some of these aspects correspond to the actual risk factors for RRIs; for example, different aspects of training and running technique are known to be risk factors for sustaining an RRI[16-18]. However, the fact that running shoes were also regarded as an important aspect for injury prevention is probably because shoe manufacturers and running stores generally aim to make runners believe that wearing a certain type of shoe can prevent injuries. There is an ongoing debate regarding the relationship between running shoes and RRIs; nevertheless it has never been demonstrated that RRIs can be prevented by wearing a certain type of shoe or by matching shoe type to foot morphology[19,20]. According to the TRIPP framework of Finch, injury prevention measures should be implemented with awareness of the attitudes of runners toward injury prevention[12]. Therefore, future injury prevention programs should be designed with awareness of the above-mentioned ideas of runners themselves about the most important aspects of injury prevention. Runners should also be informed that there is evidence against the effectiveness of injury prevention via the 'prescription' of specific shoes based on the runner's foot type[19]. However, more research is needed to increase our understanding of how and why RRIs occur and to optimize both the content and context of injury prevention measures[13].

In the present study, compared with runners who had suffered an RRI, runners without a history of RRI seemed less interested in injury prevention than runners who had an RRI in the past (ie, they rated the usefulness of injury prevention lower and performed fewer preventive actions themselves). Furthermore, an RRI was rated as the most important facilitator for injury prevention. Therefore, runners with a history of RRI seem to have a higher intrinsic motivation for injury prevention. However, runners with a history of RRI may also benefit most from injury prevention measures, because a previous RRI is the most important risk factor for a new RRI[1,3,21]. Therefore, future research on injury prevention could possibly target runners with a previous RRI.

In this study a relatively high percentage of runners (81.8%) performed injury prevention measures. This may be partly related to the fact that the runners participated in an RCT on injury prevention. Runners who are not interested in injury prevention would probably not have participated in this RCT and the injury prevention program may have motivated runners in the intervention group to perform injury prevention measures. However, the high percentage of runners in the control group (79.5%) who performed injury prevention measures indicates that many recreational runners perform injury prevention measures. This is important to realize when designing a new RCT on injury prevention. It might make it more difficult to test the effectiveness of injury prevention measures, as it is unlikely that a control group would include only runners who have never performed any injury prevention measure.

According to the TRIPP framework of Finch, injury prevention measures should be implemented with awareness of the most important barriers to and facilitators of injury prevention experienced by recreational runners[12]. Because the most frequently mentioned barrier was 'not knowing what to do', future prevention measures should include clear and practical information on injury prevention. An important facilitator was 'more knowledge on the effectiveness of the prevention program'. Unfortunately, it is impossible to provide such information on a new injury prevention measure that has yet to be tested. However, runners could be informed that the injury prevention measures are, for example, related to risk factors for RRIs and are therefore designed to decrease the number of RRIs. Also the preferred ways to receive information on injury prevention should be taken into account. Running is an individual sport and most runners preferred to receive information on injury prevention in an individual way. Mobile applications and websites were the preferred ways to receive information on injury prevention and, therefore, future injury prevention measures could be delivered via these mediums. Personal ways to deliver information (e.g. via a trainer or at a running store) might also be used when targeting women.

Strengths and limitations

A strength of this study is that, to our knowledge, it is the first to investigate the barriers to and facilitators of injury prevention in adult recreational runners. Another strength is the large sample size. Nevertheless, some limitations need to be addressed. First, only runners who registered for a running event were included in this study. Even though runners from all levels participated in the selected running event, participants of running events may be more fanatic runners than runners who do not participate in running events, which may have caused some bias in the results. Second, all runners in this study participated in an RCT on injury prevention, which may have biased the results. Because runners who are not interested in injury prevention would probably not participate in an RCT on injury prevention, the percentages of runners who rated injury prevention as useful and who performed injury prevention measures might be higher than in the general running population. Furthermore, runners in the intervention group of the INSPIRE-trial received information about injury prevention, which may have biased their opinion on important aspects of injury prevention. Another limitation is that the questionnaire used multiple-choice answers. These answer options might have biased the participants' answers to the questions on opinions, barriers, and facilitators by restricting them as opposed to open-ended questions. However, open-ended questions are known to have a higher rate of missing data[22]. Additionally, we provided an "other" option at the end of each question regarding opinions, barriers, and facilitators, which was open-ended and allowed the runners to reflect on their personal beliefs. A fourth limitation is that knowledge of some potential contributors to injury prevention, like nutrition and sleep, was not assessed[23,24]. Another limitation is the relatively low response rate to the implementation questionnaire. More than 50% of the participants in the INSPIRE-trial did not respond, which may have biased the results of the current study. There were significant differences between the runners who did and did not respond to the implementation questionnaire. Responders were more often male and relatively older runners. However, it should be mentioned that these differences were very small (less than four years in age and slightly more than 5% more men) and may therefore not be of relevance when designing a prevention program. Finally, we did not correct for multiple testing. However, all significant differences between subgroups were large (5.6-84.6%) and therefore relevant.

CONCLUSION

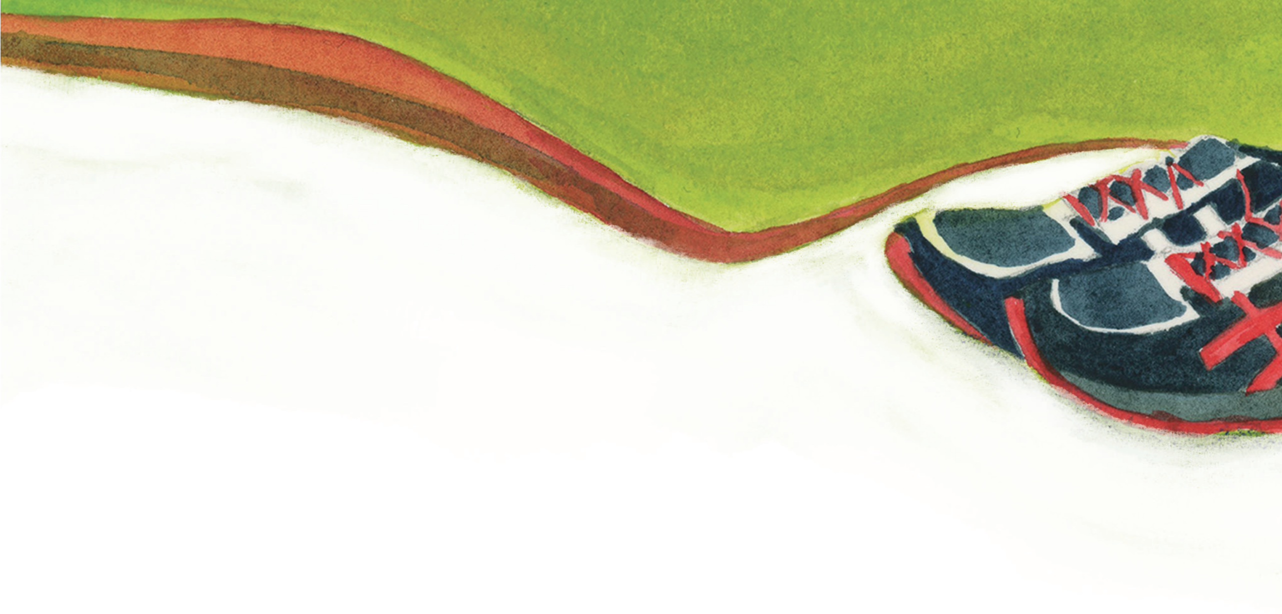
The majority of adult recreational runners reported that injury prevention is important and performed injury prevention measures themselves. According to the

TRIPP framework of Finch, it is important to take into account the ideas of runners about injury prevention, as well as the experienced barriers to and facilitators of the implementation of injury prevention measures. Based on the present study, we suggest presenting future injury prevention programs on a mobile application and/or website. For women it might be beneficial to also offer the opportunity to receive information on injury prevention personally (eg, via a trainer or at a running store. Because 'not knowing what to do' was the most important reported barrier to injury prevention, future injury prevention programs should contain clear and practical information that runners can easily apply to their training. Finally, future injury prevention programs may primarily target runners with a history of RRI, because these runners seem more motivated to perform preventive measures than runners with no history of RRI.

REFERENCES

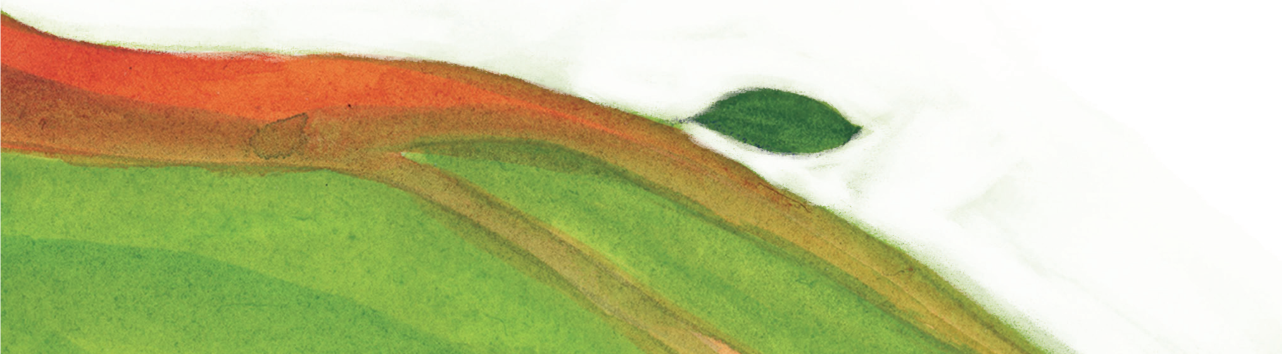
1. van der Worp MP, ten Haaf DS, van Cingel R, et al. Injuries in runners; a systematic review on risk factors and sex differences. *PLoS One.* 2015; 10(2):e0114937.
2. Verhagen E. Prevention of running-related injuries in novice runners: are we running on empty? *Br J Sports Med.* 2012; 46(12):836-837.
3. van Gent RN, Siem D, van Middelkoop M, et al. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med.* 2007; 41(8):469-480; discussion 480.
4. Kluitenberg B, van Middelkoop M, Diercks R, van der Worp H. What are the Differences in Injury Proportions Between Different Populations of Runners? A Systematic Review and Meta-Analysis. *Sports Med.* 2015; 45(8):1143-1161.
5. Buist I, Bredeweg SW, van Mechelen W, et al. No effect of a graded training program on the number of running-related injuries in novice runners. *Am J Sport Med.* 2008; 36(1):35-41.
6. Bredeweg SW, Zijlstra S, Bessem B, Buist I. The effectiveness of a preconditioning programme on preventing running-related injuries in novice runners: a randomised controlled trial. *Br J Sports Med.* 2012; 46(12):865-870.
7. Vanmechelen W, Hlobil H, Kemper HCG, et al. Prevention of Running Injuries by Warm-up, Cool-down, and Stretching Exercises. *Am J Sport Med.* 1993; 21(5):711-719.
8. Malisoux L, Chambon N, Delattre N, et al. Injury risk in runners using standard or motion control shoes: a randomised controlled trial with participant and assessor blinding. *Br J Sport Med.* 2016; 50(8):481-487.
9. Malisoux L, Chambon N, Urhausen A, Theisen D. Influence of the heel-to-toe drop of standard cushioned running shoes on injury risk in leisure-time runners: a randomized controlled trial with 6-month follow-up. *Am J Sports Med.* 2016; 44(11):2933-2940.
10. Theisen D, Malisoux L, Genin J, et al. Influence of midsole hardness of standard cushioned shoes on running-related injury risk. *Br J Sport Med.* 2014; 48(5).
11. Hespanhol Junior LC, van Mechelen W, Verhagen E. Effectiveness of online tailored advice to prevent running-related injuries and promote preventive behaviour in Dutch trail runners: a pragmatic randomised controlled trial. *Br J Sports Med.* 2018; 52(13):851-858.
12. Finch C. A new framework for research leading to sports injury prevention. *J Sci Med Sport.* 2006; 9(1-2):3-9; discussion 10.
13. Bertelsen ML, Hulme A, Petersen J, et al. A framework for the etiology of running-related injuries. *Scand J Med Sci Sports.* 2017; 27(11):1170-1180.
14. Saragiotto BT, Yamato TP, Lopes AD. What do recreational runners think about risk factors for running injuries? A descriptive study of their beliefs and opinions. *J Orthop Sports Phys Ther.* 2014; 44(10):733-738.
15. Fokkema T, de Vos RJ, van Ochten JM, et al. Preventing running-related injuries using evidence-based online advice: the design of a randomised-controlled trial. *BMJ Open Sport Exerc Med.* 2017; 3(1):e000265.
16. Malisoux L, Nielsen RO, Urhausen A, Theisen D. A step towards understanding the mechanisms of running-related injuries. *J Sci Med Sport.* 2015; 18(5):523-528.
17. Nielsen RO, Buist I, Sorensen H, et al. Training errors and running related injuries: a systematic review. *Int J Sports Phys Ther.* 2012; 7(1):58-75.
18. Zadpoor AA, Nikooyan AA. The relationship between lower-extremity stress fractures and the ground reaction force: a systematic review. *Clin Biomech (Bristol, Avon).* 2011; 26(1):23-28.
19. Napier C, Willy RW. Logical fallacies in the running shoe debate: let the evidence guide prescription. *Br J Sports Med.* 2018; 52(24):1552-1553.

20. Knapik JJ, Trone DW, Tchandja J, Jones BH. Injury-reduction effectiveness of prescribing running shoes on the basis of foot arch height: summary of military investigations. *J Orthop Sports Phys Ther.* 2014; 44(10):805-812.
21. Saragiotto BT, Yamato TP, Hespanhol Junior LC, et al. What are the main risk factors for running-related injuries? *Sports Med.* 2014; 44(8):1153-1163.
22. Millar MM, Dillman DA. Do Mail and Internet Surveys Produce Different Item Nonresponse Rates? An Experiment Using Random Mode Assignment. *Survey Practice.* 2012; 5(2).
23. De Souza MJ, Williams NI, Nattiv A, et al. Misunderstanding the female athlete triad: refuting the IOC consensus statement on Relative Energy Deficiency in Sport (RED-S). *Br J Sports Med.* 2014; 48(20):1461-1465.
24. Mountjoy M, Sundgot-Borgen JK, Burke LM, et al. IOC consensus statement on relative energy deficiency in sport (RED-S): 2018 update. *Br J Sports Med.* 2018; 52(11):687-697.



9

General discussion



Injuries are very common among runners. In the past decades, many studies investigated these running-related injuries (RRIs). However, important gaps in scientific literature still exist, for example on time-to-recovery and prognostic factors of RRIs in specific subgroups of runners or injury locations. Also, no effective prevention measures have been identified yet. Therefore, the aim of this thesis was to gain more insight in the prognosis and prevention of RRIs. In this chapter, the main results will be discussed and implications for future research and practice will be presented.

MAIN FINDINGS OF THIS THESIS

This thesis consisted of two parts. The first part focused on discontinuation of running and the prognosis of RRIs in novice runners participating in 'Start to Run', a 6-weeks running program for novice runners organized by the Dutch Athletics Association. About one-third of the novice runners participating in the 'Start to run' program stopped running within six months after the start of the program (chapter 2). An RRI was the main reason to stop running. Especially women with a low perceived physical functioning and no previous running experience were prone to stop running. Almost half of the participants (48.8%) of the 'Start to run' program sustained an RRI (chapter 3). The median duration of these RRIs in novice runners was 8 weeks. A previous RRI was associated with a poor prognosis (>10 weeks), while an RRI in the anatomical region of the calf was related to a good prognosis (≤10 weeks).

The second part of this thesis focused on prevention and prognosis of RRIs in recreational runners (INSPIRE-trial). These runners had multiple months to years of running experience and all registered for a running event (5 to 42.2 km). A multifactorial online injury prevention program, that consisted of information on evidence-based risk factors and advices how to reduce injury risk, did not reduce the number of RRIs in these runners: 37.5% of the runners in the intervention group and 36.7% of the runners in the control group sustained a new RRI during the study period (chapter 4 and 5). There was a tendency towards a negative effect of the prevention program in runners that did not have an RRI before: as a consequence of the program, their injury risk seemed to have increased. In the subgroup of recreational half-marathon and marathon runners, preparation for the running event with a relatively high training volume and long endurance runs was associated with a better finish time, but these factors were not related to injury risk (chapter 6). A knee injury was most frequently reported by the recreational runners of the INSPIRE-trial (chapter 7). The median duration of these knee injuries was 8 weeks, and women recovered slower than men. Furthermore, the self-reported diagnosis knee osteoarthritis was associated with a slower recovery. Finally, the opinions, barriers and facilitators of injury prevention in the recreational runners was investigated (chapter 8). The majority of runners rated RRI prevention as very important and already performed RRI prevention measures. The most important barriers for injury prevention were 'not knowing what to do' and 'no history of RRI', while sustaining an RRI was the most important facilitator for performing injury prevention. Mobile applications and websites were the most preferred ways to receive information on injury prevention.

RRI DEFINITION

A self-reported RRI was the main outcome measure in most chapters of this thesis. This is a difficult outcome measure, because it is subject to interpretation. Some runners may already rate mild pain as an RRI, while for others only severe pain that limits their running for several weeks is an RRI. For this reason, many studies included a detailed definition of an RRI in their questionnaires[1,2]. These definitions provided runners with criteria on, for example, how long running should be restricted or how severe the pain should be. Also in the studies described in this thesis, runners were provided with a detailed definition of an RRI. In the Start2Run-study the definition was "any musculoskeletal ailment of the lower extremity or back that the participant attributed to running and hampers running ability for at least one week"[3], while in the INSPIRE-trial an RRI was defined as "an injury of the muscles, joints, tendons and/or bones in the lower back or lower extremities (hip, groin, thigh, knee, leg, ankle, foot and toes) that was caused by running and one of the following criteria had to be met: i) the injury was severe enough to cause a reduction in running distance, speed, duration or frequency for at least 1 week, ii) the injury led to a visit of a doctor and/or physiotherapist and/or iii) medication was necessary to reduce symptoms as a result of the injury (Chapter 4). It is known that different definitions have great impact on study outcomes. Kluitenberg et al. showed that the proportion of new RRIs in a group of novice runners ranged between 7.5% and 58.0%, depending on the RRI definition used[2]. As a consequence it is hard to compare study results on RRIs. To solve this problem, a consensus definition of RRIs was determined through a Delphi method in 2016[1]. Following this consensus, an RRI was defined as: "running-related (training or competition) musculoskeletal pain in the lower limbs that causes a restriction on or stoppage of running (distance, speed, duration, or training) for at least 7 days or 3 consecutive scheduled training sessions, or that requires the runner to consult a physician or other health professional"[1]. Though, this consensus

definition was not yet available when both the Start2Run-study and the INSPIRE-trial were designed and was therefore not used in these studies.
The consensus definition is a first step towards more equality between studies and the possibility to compare the results of studies. However, it does not solve the problem of a self-reported main outcome measure and also this proposed consensus definition may be subject to interpretation. There will likely be differences between runners in when they will consult a health professional and therefore similar complaints can be interpreted as an RRI by one runner, but not by another. This could possibly be solved by including multiple questions on the severity and impact of the musculoskeletal pain instead of only asking if the runners sustained an RRI (yes or no). With the answers to these questions, the researchers could determine if the musculoskeletal pain should be classified as an RRI. A questionnaire that may be used for this is the Oslo Trauma Research Centre (OSTRC) Overuse Injury Questionnaire[4]. This questionnaire includes four questions on the severity of musculoskeletal pain and the extent this affected sports participation, training volume and performance. The OSTRC Overuse Injury Questionnaire is validated and used in several types of sports. In running it was, to our best knowledge, so far only used in one study[5]. More research on the use of the OSTRC Overuse Injury Questionnaire or a similar questionnaire for RRIs may eventually lead to more accurate registration of RRIs and the possibility to compare results of different studies.

RISK FACTORS FOR RRIS

Previous injuries

Even though several factors have been associated with RRIs, a previous RRI is the most important risk factor for sustaining a new RRI[6-8]. Also in this thesis, the important role of previous RRIs was shown. For example, a previous RRI was the only factor associated with sustaining a new RRI in half-marathon and marathon runners (chapter 6). Moreover, we showed that a previous RRI was also a risk factor for a new RRI with a poor prognosis in novice runners (chapter 3). Despite the obvious role of previous RRIs, it is still unclear why a previous RRI is associated with a higher chance of sustaining a new RRI. Theories about the etiology of this relation include that there may be genetic predisposition, which makes some runners more prone for RRIs than others, or that often injured runners have structural 'errors' in their training or gait characteristics, increasing their injury risk[9]. Furthermore, it was hypothesized that a previous RRI causes changes in gait characteristics, which in turn changes the loading of the body during running and therefore increases the injury risk[10]. Finally, it was suggested that many runners start running again when they are not completely recovered from their previous RRI, causing the previous RRI to 'come back'[10,11]. For part of the proposed theories some evidence exists and for others not. Prospective studies showed differences in gait characteristics of runners who did and did not sustain an RRI, which would argue for the theory of structural errors in running[12,13]. However, these differences in gait characteristics were so far only related to a first RRI. It is unclear if they also play a role in recurrent RRIs. Furthermore, it is unknown if gait characteristics change due to an RRI. Also the role of incomplete recovery and returning to sport too fast in sustaining a 'new' RRI is unknown. The results of the INSPIRE-trial actually contradict the theory of incomplete recovery, since 76.6% of the new RRIs in runners with a history of RRI was on a different location than the previous RRI, indicating that the new RRI is not the previous RRI coming back (chapter 5). More insight in the etiology of the strong association between a previous RRI and a new RRI may eventually help in decreasing the number of RRIs. Therefore, future research should possibly aim at understanding the relation between previous and new RRIs by examining differences in training and gait characteristics in runners with a history of RRI that sustain and do not sustain a new RRI. Furthermore, more insight in changes in gait characteristics due to an RRI and the role of incomplete recovery when returning to sport may be valuable. More knowledge of the characteristics of the subgroup of runners with a history of RRI may also help in understanding why a previous RRI is associated with sustaining a new RRI. It would be good to examine the risk factors for sustaining a new RRI in this group of runners.

Because no history of RRIs significantly decreases the chances of sustaining an RRI, one may expect that RRI prevention should aim at preventing the first RRI and therefore at runners without a history of RRIs[6-8]. However, the results of the INSPIRE-trial showed that injury prevention should probably not be aimed at these runners (chapter 5). There was a trend towards more RRIs in runners without a history of RRI who had access to the injury prevention program than runners without previous RRIs who had no access to the prevention program. We hypothesized that runners without a history of RRI already train in the, for them, right manner. As a consequence of the prevention program, they may have made changes to their running technique or training schedule and therefore their injury risk may have increased. These results indicate that secondary prevention may be more useful than prevention of the first RRI and therefore RRI prevention should possibly specifically aim at runners with a history of RRIs. Furthermore, runners with previous RRIs rated injury prevention as more important than runners without previous RRIs (chapter 8). Therefore, they may be more motivated towards RRI prevention and their adherence to preventive measures may be better, increasing the odds of successfully decreasing the number of RRIs[14]. Runners without previous RRIs may be advised to continue their training the way they usually do. It should, however, be mentioned that this only applies to more experienced runners. Novice runners may have no injury history, because they just started running, but they do have a relatively high injury risk[15]. Therefore, all novice runners should be advised on RRI prevention. However, the most effective way to advise novice runners is not identified yet. Currently, a study on injury prevention in novice runners is performed by the Dutch Consumer Safety Institute (VeiligheidNL)[16]. This study may give valuable insight on how to advise novice runners about injury prevention in the future.

Training load

Generally, injuries are assumed to be the result of an imbalance between training load and recovery[17-19]. Therefore, in scientific literature quite a lot of attention is paid to the relationship between training load and RRIs[20-22]. Several prospective and retrospective studies investigated which training characteristics are risk factors for RRIs and found, for example, an increased injury risk when participants ran more than 64 km per week or more than 3 times per week[23-25]. However, other studies found no significant associations between training characteristics and RRIs (chapter 6,[21,22]). These conflicting results may be related to differences in study populations and methodological differences between studies, but also to the way the training characteristics are usually determined. Most studies determined training characteristics by means of questionnaires that asked runners for average training distance, frequency and speed over a certain time period[21,23,25]. Although it can give a first impression of the relation between training and RRIs, there are some drawbacks of collecting training characteristics like this. First of all, the data are collected retrospectively, which may lead to recall bias resulting in inaccurate data[26]. Furthermore, one cannot examine specific training sessions or weeks if averages over a certain time period are collected. Asking runners to fill out a training log may be a way to get more accurate and detailed insight in training characteristics. A disadvantage is that this method also includes inaccuracy of runners due to recall bias when filling out the training logs[27]. Therefore, the use of GPS-data may be a more accurate method. Nowadays, approximately 75% of the runners track their training sessions with GPS on their smartphone or sport watch[28]. Accordingly, these devices accurately register training characteristics like training distance, speed and frequency[29,30]. Asking runners to share these data for scientific research minimizes the chance of errors in training characteristics. Furthermore, using GPS-data training characteristics can be extracted over any desired time period. This offers the opportunity to investigate changes in training characteristics in the weeks before an RRI and determine the relation between training load and RRIs more accurately. Many studies on training and RRIs used training characteristics in absolute terms, like running distance in kilometers per week[9,31]. A problem with using these absolute training characteristics is that many differences in performance level exist between runners[32]. A training distance of 10 km is long for novice runners and may increase their RRI risk, while it is short for marathon runners and may be a recovery run for them. Consequently, it is hard to determine to which runners risk factors like a training distance of more than 40 km per week apply[23]. There is need for insight in the relation between adding the so-called internal training intensity (the intensity experienced by the runner) and RRIs[33]. This could be done by collecting heart rate data of training sessions or runners could be asked to rate the intensity of their training session, for example with the rating of perceived exertion scale [34]. With these internal training sessions it could be determined which heart rates or ratings of perceived exertion, combined with the external training load (e.g. running distance), are related to an increased RRI risk and all runners could be advised on the most desired training intensities, regardless of their running experience or performance level.

Another aspect of training that may play a role in the occurrence of RRIs is the progression in training. These changes in training load are usually determined by calculating the acute:chronic workload ratio (ACWR)[35,36]. To calculate this ACWR, training load of a certain week (the acute training load) is divided by the average training load over the previous weeks (the chronic training load). ACWR values below 0.8 (much less training than in the previous weeks) and above 1.5 (much more training than in the previous weeks) were associated with an increased injury risk in several other sports (mainly team sports), meaning that large, sudden changes in training load may increase injury risk[37-39]. This indicates that in order to prevent injuries team athletes should change training load gradually, both when building up and reducing training load. It is unknown if this relationship also applies in individual sports. Johnston et al. (2019) collected information on training characteristics in a group of 95 runners, triathletes, swimmers, cyclists and rowers with online training diaries and identified an association between training load and injuries[40]. No relation between ACWR and injuries was established. However, they did identify a relationship between injury risk and the ACWR when the ACWR was reported using an exponentially weighted moving average method. The authors concluded that endurance athletes could minimize their injury risk by avoiding high spikes in acute training load, while keeping their chronic training loads moderate to high[40]. More and large studies on the relationship between ACWR and injuries in runners are needed, in which the previously mentioned GPS-data could be used to calculate the ACWR.

Running biomechanics

In current research on RRIs, much emphasize is placed on biomechanics. For example, at annual meeting of the American College of Sports Medicine in 2019 the session on distance running included only studies on running biomechanics. Most of the studies on running biomechanics focus on small details of the gait pattern (e.g. the amount of plantarflexion or inversion at foot strike) of recreational runners[41,42]. The ultimate goal of these studies is to identify a gait pattern that decreases the chances of sustaining an RRI[43]. There are some problems with these biomechanical studies. First of all, most biomechanical studies do not have RRIs as primary outcome, but a parameter that is associated with an increased RRI risk (e.g. the amount of loading at foot strike)[44,45]. However, in literature there are conflicting results on the associations between these outcome measures and RRI risk and therefore it is unclear if changes in the gait characteristics really decrease RRI risk[46]. Furthermore, it is clear that making changes to the gait pattern increases the risk of sustaining an RRI at some specific locations, because the body is loaded differently during running[47]. Therefore, it is possible that gait retraining actually increases the RRI risk. Also are gait characteristics known to change with fatigue[48,49]. More research on the effect of gait characteristics on RRI risk should be done before the results of biomechanical running research can be implemented to recreational runners. This research should include large prospective cohort studies, in which RRIs sustained during follow-up is the primary outcome. Also the effects of fatigue should be included in these studies. Once the biomechanical risk factors for RRIs are established, randomized-controlled trials should indicate if changing these biomechanical factors decreases the injury risk.

The implementation of the results is a second problem of biomechanical running research. First of all, because many biomechanical studies focus on small changes in gait characteristics that often cannot be seen visually. Expensive and time-consuming measurements in a biomechanics lab are necessary to identify these gait characteristics and determine which characteristics to change during gait retraining. Although wearable technologies and sensors may offer a solution in the future, these are not yet available and need further development[50]. Furthermore, the results of the INSPIRE-trial indicate that runners should not change their gait characteristics individually (chapter 5). Guidance from for example a trainer or physiotherapist seems necessary to make sure that runners apply the changes gradually and in the right manner. Because there are around 2 million runners only in the Netherlands already, it is impossible that all runners get personal guidance in gait retraining[15]. Besides, one of the reasons for the popularity of running is that running is an individual sport that can be done where and when one likes[51,52]. Therefore, many runners may not have a need for personal guidance during running.

INJURY PREVENTION: ADHERENCE, IMPLEMENTATION AND EFFECTIVENESS

In the INSPIRE-trial the effectiveness of an online injury prevention program was tested. This prevention program consisted of information on risk factors for RRIs and advices to reduce the injury risk (chapter 4). The program had no effect on the number of RRIs in recreational runners (chapter 5). This may have had multiple reasons, e.g. the way the information on injury prevention was presented and perhaps the advices were too non-committal. Another important reason may be that a relative large proportion of the participants in the intervention group did not read (37.3%) and/or apply (55.9%) the information from the prevention program (chapter 5). Next to reflecting the practicability of the prevention program, the low adherence also gives uncertainty on the ineffectiveness of the injury prevention program tested in the INSPIRE-trial. When adherence to an intervention is low, it is unclear if the ineffectiveness of the intervention was due to low adherence or because the injury prevention measure was indeed not effective. To counteract this, Finch developed the TRIPP framework for injury prevention research[53]. For this framework, she added two steps to the well-known sequence of prevention framework of Van Mechelen et al.[54]. According to the TRIPP framework, injury prevention measures should first be tested under 'ideal conditions'. By testing prevention measures this way, one knows if the prevention measure in itself is effective or not. If a measure proved effective, it should be implemented and tested in practice (the 'real' world), at which for example barriers and facilitators for injury prevention among athletes should be taken into account. For runners, testing under ideal circumstances might for example include performing strengthening exercises under supervision of a trainer. By having every training session under supervision, one can be certain that all exercises have been performed in the right manner and the effectiveness of the strengthening exercises in itself can be tested. Testing injury prevention measures under ideal circumstances first has many advantages and this should ideally be applied in running research as well. However, practice should already be taken into account when designing injury prevention measures. Even though a prevention measure is effective under ideal conditions, it must be implementable into practice. Otherwise, it will never help athletes in injury prevention. An example of such an injury prevention measure is the Nordic hamstring curl exercise. This is a hamstring exercise program for team athletes, that is proven to be effective in preventing hamstring injuries in the ideal world[55-57]. However, it seems hard to implement this exercise program into practice. Adherence with the Nordic hamstring curl exercise is low, because of a lack of time, onset of delayed muscle soreness, the need to sit on the ground and because the exercise is not sport-specific enough to incorporate in the warming-up[58,59]. Therefore, the hamstring curl may not be suitable for preventing hamstring injuries in team athletes, even though it is effective under ideal circumstances.

In unorganized sports like running, the implementation of injury prevention measures may be more difficult than in organized sports. In organized sports, a trainer or club can implement the prevention measures into the group training sessions, while in unorganized sports athletes have to carry out the prevention measures without supervision. Therefore, especially in unorganized sports prevention measures should be developed with awareness of behaviors and attitudes of the athletes. To be able to do so in recreational running, more insight in these behaviors and attitudes is necessary. So far, only one study on runners' attitudes on RRI prevention investigated what runners think are the main risk factors for RRIs[60]. Therefore, this thesis provided insight in the opinions, preferences and experienced barriers and facilitators for injury prevention in recreational runners (chapter 8). The large majority of the runners regarded injury prevention as very useful and performed injury prevention measures. The most important barriers for injury prevention were 'not knowing what to do' and 'no history of RRI', while sustaining an RRI was the most important facilitator for injury prevention. Mobile applications and websites were the most preferred ways to receive information on injury prevention. Due to the low entry level of running, many different types of people run[51,52]. Therefore, this thesis also analyzed attitudes towards injury prevention of subgroups of runners based on sex, age and running experience (chapter 8). The results of these analyses showed that there are differences in attitudes and experienced barriers and facilitators for injury prevention between subgroups of runners. For example, women more often preferred information via a trainer or running store than men, while men more frequently preferred websites or e-mail. However, in this study only three subgroups of runners were investigated, while more subgroups may exist. A distinction that has not been made is between runners who run 1 or 2 times a week to stay fit and the very fanatic runners, who run almost every day and for whom running is an important part of their life. Probably the first group will be less interested in and have less knowledge of injury prevention than the fanatic runners. Experience shows that the fanatic runners usually have a lot of knowledge and ideas about injury prevention already, which makes it hard to change their running behavior. Furthermore, many fanatic runners have an obsessive passion for their sport, which increases the chances that they will not take enough time for recovery, ignore pain and start running too early after an RRI [61]. Due to these differences in knowledge of RRI prevention and attitude towards running, more fanatic runners probably need a different approach in injury prevention than runners who run 1 or 2 times a week to stay fit. The findings presented in chapter 8 provide first directions towards the optimal implementation of RRI prevention and may help in the development of injury prevention measures that are implementable into running. Though, as acknowledged by the TRIPP framework, these measures should first be proven effective under 'ideal conditions' before they can be implemented [53].

PROGNOSIS OF RRIS AND RETURN-TO-SPORT

Due to the important role of a previous RRI in the development of new RRIs, the timing of return-to-sport after an RRI seems important. Recently, King and colleagues described a return-to-sport model that clinicians and practitioners can use to optimize the return-to-sport of injured athletes[62]. This model focuses on extensive involvement of athletes in their return-to-sport process and describes 4 habits that could be used to facilitate this involvement. One of these habits focuses on educating athletes about the possible course of their injury within the first days of injury and including the athletes' objectives in the return-to-sport process. Even though this protocol gives a good impression of important aspects for return-to-sport, it seems hard to apply to recreational runners. First of all, most RRI research focused on factors that play a role in sustaining an RRI and not on what happens after the RRI started, which makes it hard to educate runners about the possible course of their RRI. Only a small number of studies investigated the course and prognosis of RRIs, in which the median time-to-recovery in recreational runners was 8 weeks and 10 weeks in novice runners, while 25.5% of injured marathon runners still reported persistent symptoms after three months follow-up[63-65]. Furthermore, the large diversity in RRIs and injury locations probably results in differences in course and prognosis of RRIs. There is some specific knowledge about the course of certain diagnoses as medial tibial stress syndrome and patellofemoral pain syndrome[66,67]. However, there are still many diagnoses of which the course is still unknown. Furthermore, there will be many runners who do not know the exact diagnosis of their RRI, especially runners who do not seek medical assistance for their RRI. For these runners it may be more useful to know the course and prognosis of RRIs at a certain anatomical location. Therefore, the prognosis and prognostic factors of RRIs in the subgroup runners with the highest injury risk (novice runners) and the most frequently injured site (the knee) were investigated in this thesis (chapter 3 and 7). Even though more research in other subgroups of runners and RRI locations is necessary, the knowledge on the course and prognosis of RRIs could be used to educate runners about the possible course of their RRI. Runners may be informed about the 8 to 10 weeks median duration of RRIs, which can give them an indication of how long they cannot run or have to adapt their training. Furthermore, novice runners who had previous injuries may be advised to take extra rest and be extra cautious with return-to-sport after their RRI, since these runners have a higher chance of an RRI with a poor prognosis (chapter 3). Also runners with knee osteoarthritis have an increased chance of prolonged knee complaints due to running (chapter 7). However, it should be questioned whether these prolonged complaints were caused by running or because of the fact that knee osteoarthritis is irreversible. It is unknown if runners with knee osteoarthritis should continue running: it may be good or bad for the knee joint. Until more is known about this subject, it is hard to advice runners with knee osteoarthritis about running or return-to-sport. Finally, novice runners seem to have difficulties in finding the motivation to start running again after an RRI (chapter 2). Therefore, they may benefit from some guidance and external incentive to start running again.

A second problem of applying the return-to-sport protocol of King et al. to recreational runners is that it aims at clinicians or practitioners of injured athletes[62]. Runners training at an athletic club can be guided by their coach. However, as shown in the INSPIRE-trial, about 70% of the recreational runners trains individually (chapter 5). A large proportion of these runners will also return-to-sport individually and may therefore restart running again before complete recovery or increase their training load too fast. It is important that recreational runners are, despite the individual character of running, educated about return-to-sport. They should be educated about the average duration of RRIs and the need for full-recovery before returning to sport. Novice runners may also be encouraged to restart running, since they seem to have the tendency not to restart running again after an RRI (chapter 2). Health care professionals could play an important role in this education. In 2014, over 30% of the injured Dutch runners received medical treatment for their RRI, especially from a physiotherapist or general practitioner [15]. These health care professionals should be encouraged to educate about return-to-sport and possibly guide runners in the restart of running after the RRI is healed. However, a large proportion does not receive medical treatment for their RRI and consequently should be educated about return-to-sport through a different medium. Internet may be an important source as more than half of the internet users search the internet for health information[68].

Moreover, the majority of the runners preferred to receive information on injury prevention through websites or mobile applications (chapter 8). Therefore, a website and/or mobile application with well-funded and practical information on the course and prognosis of RRIs may help runners in making better choices concerning return-to-sport. Also existing training schedules that take pain during running into account could be advised on the website or mobile application to runners returning-to-sport. The training schedules provided for novice runners on sportzorg.nl are a good example.

FUTURE PERSPECTIVES

In the past decades, many studies on RRIs have been performed. However, important gaps in literature still exist. As mentioned earlier, these gaps include knowledge on the etiology of RRIs. Even though many risk factors for RRIs have been identified, it is still unknown what exactly causes RRIs. Especially, knowing why a previous RRI increases the risk of sustaining a new RRI may give valuable information for injury prevention. More knowledge on the relation between RRIs and training measures with accurate methods (e.g. GPS) or personalized training measures may provide important insight in the risk factors of RRIs and eventually on the prevention of RRIs. For successful implementation of injury prevention more knowledge on the behaviors and attitudes of (subgroups of) runners is necessary. In order to advise and guide injured runners, it is also important that more is known about the prognosis of RRIs in specific types of injuries or in subgroups of runners. With this information, injured runners and their trainers or health care professionals know better what to expect in terms of recovery and return-to-sport after an RRI.

Although the injury prevention program was not effective, we gained much knowledge about running injury prevention from the INSPIRE-trial (chapter 5). An important lesson from the INSPIRE-trial is that a multifactorial online prevention program may have a negative effect on the occurrence of RRIs in runners with no history of RRIs. Consequently, future research on RRI prevention should probably specifically aim at runners who had RRIs in the past. Furthermore, advices on biomechanics and stride pattern should not be given through a website. Probably changes to biomechanics and stride pattern should only be made under supervision of a trainer or physiotherapist. Another important lesson from the INSPIRE-trial is that injury prevention measures should include clear guidance and personalized training schedules. We assume that the advices in the INSPIRE-trial were too non-committal and may have given too little guidance in order to be structurally performed. Finally, the questionnaire from chapter 8 learned us more about the interests, opinions and perceived barriers and facilitators of recreational runners concerning injury prevention. We used these lessons learned to develop a new injury prevention program, called 'the 10 steps 2 outrun injuries'. As the name suggests, this program includes 10 steps that all deal with a different part of RRI prevention. The first step is specifically aimed at runners without RRIs in the past, in which they are advised not to change anything. The advices for the runners with previous RRIs include awareness of pain during or after running and taking enough time for recovery. To concretize these advices, the runners are advised to use scales like a pain ladder to determine whether or not they should take extra rest. The program also includes a tool that runners can use to monitor the buildup in their training. Based on the running distances the runners register, this tool calculates the ACWR and advises the runners if the buildup of their training is good or too fast. Furthermore, the program includes a detailed physical exercise program to improve strength, balance and running economy. We also took the ideas and preferences from chapter 8 into account when designing the program. Runners believe running shoes play an important role in the occurrence of RRIs. Therefore, this myth is questioned in the program and runners are advised to wear running shoes that feel comfortable. Furthermore is the program presented on a mobile application and website, which is in accordance with the preferences of the runners. Finally, we will ask runners who track their training sessions with GPS on their smartphone or sport watch to share these GPS-data with us. These GPS-data may give valuable information on the relation between training and RRIs. To test the effectiveness of the 10 steps 2 outrun injuries-program, the Netherlands Organisation for Health Research and Development (ZonMW) granted funding for a new randomized-controlled trial (RCT). The inclusion for this RCT started in August 2019 and the first results are expected by the end of 2020.

PRACTICAL IMPLICATIONS

So far, no effective RRI prevention measures have been identified[69-71]. Also the injury prevention program tested in this thesis was not effective (chapter 5). Consequently, it is not possible to come up with practical implications that have proven to be effective in the prevention of RRIs. However, previous studies and this thesis gave some insights on RRIs, that can be used to formulate advices for runners. These advices are mainly aimed at increasing the runners' knowledge on the injury risk of runners and the prognosis of RRIs. With more knowledge of RRIs, runners may be more aware of their injury risk, be more careful during running and therefore it may eventually help to decrease their injury risk. The main advice that can be given to runners is to listen to their body. The majority of the RRIs are overuse injuries[72]. These injuries usually start as an uncomfortable feeling or mild pain during running, that increases in severity over time. When runners experience these first signs of an RRI, they should adapt their training schedule accordingly or temporarily stop running. This may prevent a 'real' RRI. This thesis showed a high injury risk in runners with a history of RRIs and novice runners again (chapters 2, 3 and 5). Despite that a previous RRI and limited running experience are both non-modifiable factors, more awareness of RRIs and listening to their body may help to decrease the RRI risk in these groups of runners. Therefore, it is especially important to educate runners with a history of RRIs and novice runners about RRIs. Trainers at athletic clubs should be educated about RRIs, so they can pass this knowledge on to their runners. However, the education of runners that train individually is more complicated. Most runners prefer to receive information on RRI prevention through a website or mobile application (chapter 8). Therefore, education on RRIs could be done through a website or mobile application. By adding a link to this website and mobile application to frequently used running apps (e.g. Runkeeper and Strava) and websites of renowned running organizations (e.g. the national Athletics Union or Sportzorg.nl), runners that train individually can possibly be reached.

A hypothesized reason of the increased injury risk after a previous RRI is that runners start running again when the previous RRI is not completely recovered yet[10,11]. As previously mentioned, runners may expect a long RRI duration through more insight in the average injury duration and may therefore adjust their running for a longer time period than they would have done without knowledge of the average RRI duration. Therefore, it is important that runners are aware of the average RRI duration. Furthermore, runners should be advised to restart running slowly after an RRI. To make sure that runners have a slow build up in their training, they can be advised to use training programs for novice runners (e.g. the training schedule for novice runners on sportzorg.nl). This may decrease the chances of a long-lasting or recurring RRI. These advices for injured runners should be included in the previously mentioned mobile application and website. However, also health care professionals (e.g. physiotherapists or general practitioners) play an important role in the education of injured runners. When injured runners seek their help, they should educate them about the prognosis of RRIs and the importance of complete recovery. Furthermore, health care professionals should not only treat an RRI, but they should also guide runners in the phase afterwards, with return-to-sport. They could provide them with gradually building up training schedule or keep track of pain runners experience during the restart of running.

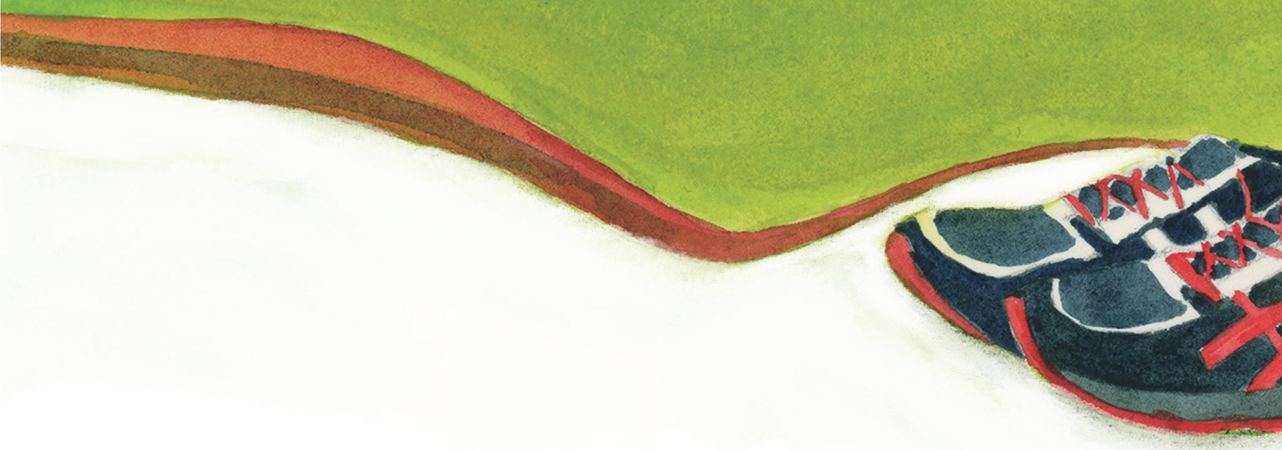
REFERENCES

1. Yamato TP, Saragiotto BT, Lopes AD. A consensus definition of running-related injury in recreational runners: a modified Delphi approach. *J Orthop Sports Phys Ther.* 2015; 45(5):375-380.
2. Kluitenberg B, van Middelkoop M, Verhagen E, et al. The impact of injury definition on injury surveillance in novice runners. *J Sci Med Sport.* 2016; 19(6):470-475.
3. Kluitenberg B, van Middelkoop M, Diercks RL, et al. The NLstart2run study: health effects of a running promotion program in novice runners, design of a prospective cohort study. *Bmc Public Health.* 2013; 13:685.
4. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. *BJSM online.* 2013; 47(8):495-502.
5. Hespanhol LC, Jr., van Mechelen W, Verhagen E. Effectiveness of online tailored advice to prevent running-related injuries and promote preventive behaviour in Dutch trail runners: a pragmatic randomised controlled trial. *Br J Sports Med.* 2018; 52(13):851-858.
6. van der Worp MP, ten Haaf DS, van Cingel R, et al. Injuries in runners; a systematic review on risk factors and sex differences. *PLoS One.* 2015; 10(2):e0114937.
7. van Gent RN, Siem D, van Middelkoop M, et al. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med.* 2007; 41(8):469-480; discussion 480.
8. Saragiotto BT, Yamato TP, Hespanhol Junior LC, et al. What are the main risk factors for running-related injuries? *Sports Med.* 2014; 44(8):1153-1163.
9. Rasmussen CH, Nielsen RO, Juul MS, Rasmussen S. Weekly running volume and risk of running-related injuries among marathon runners. *Int J Sports Phys Ther.* 2013; 8(2):111-120.
10. Hespanhol LC, Costa LOP, Lopes AD. Previous injuries and some training characteristics predict running-related injuries in recreational runners: a prospective cohort study. *J Physiother.* 2013; 59(4):263-269.
11. Bertelsen ML, Jensen JF, Nielsen MH, et al. Footstrike patterns among novice runners wearing a conventional, neutral running shoe. *Gait Posture.* 2013; 38(2):354-356.
12. Dudley RI, Pamukoff DN, Lynn SK, et al. A prospective comparison of lower extremity kinematics and kinetics between injured and non-injured collegiate cross country runners. *Hum Movement Sci.* 2017; 52:197-202.
13. Bredeweg SW, Kluitenberg B, Bessem B, Buist I. Differences in kinetic variables between injured and noninjured novice runners: A prospective cohort study. *Journal of Science and Medicine in Sport.* 2013; 16(3):205-210.
14. Deci EL, Ryan RM. The “what” and “why” of goal pursuits: Human needs and the self-determination of behavior. *Psychol Inq.* 2000; 11(4):227-268.
15. VeiligheidNL. Hardloopblessures Blessurecijfers 2014. Amsterdam: VeiligheidNL; 2016
16. Kemler E, Gouttebarge V. A Tailored Advice Tool to Prevent Injuries Among Novice Runners: Protocol for a Randomized Controlled Trial. *JMIR Res Protoc.* 2018; 7(12):e187.
17. Kellmann M, Bertollo M, Bosquet L, et al. Recovery and Performance in Sport: Consensus Statement. *Int J Sports Physiol Perform.* 2018; 13(2):240-245.
18. Soligard T, Schwellnus M, Alonso JM, et al. How much is too much? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. *Br J Sports Med.* 2016; 50(17):1030-1041.
19. Meeusen R, Duclos M, Foster C, et al. Prevention, diagnosis, and treatment of the overtraining syndrome: joint consensus statement of the European College of Sport Science and the American College of Sports Medicine. *Med Sci Sports Exerc.* 2013; 45(1):186-205.

20. Baltich J, Emery CA, Whittaker JL, Nigg BM. Running injuries in novice runners enrolled in different training interventions: a pilot randomized controlled trial. *Scand J Med Sci Sports*. 2017; 27(11):1372-1383.
21. Kluitenberg B, van der Worp H, Huisstede BM, et al. The NLstart2run study: Training-related factors associated with running-related injuries in novice runners. *J Sci Med Sport*. 2015.
22. Nielsen RO, Buist I, Sorensen H, et al. Training errors and running related injuries: a systematic review. *Int J Sports Phys Ther*. 2012; 7(1):58-75.
23. Macera CA, Pate RR, Powell KE, et al. Predicting lower-extremity injuries among habitual runners. *Arch Intern Med*. 1989; 149(11):2565-2568.
24. Walter SD, Hart LE, McIntosh JM, Sutton JR. The Ontario cohort study of running-related injuries. *Arch Intern Med*. 1989; 149(11):2561-2564.
25. McKean KA, Manson NA, Stanish WD. Musculoskeletal injury in the masters runners. *Clin J Sport Med*. 2006; 16(2):149-154.
26. Dideriksen M, Soegaard C, Nielsen RO. Validity of Self-Reported Running Distance. *Journal of Strength & Conditioning Research*. 2016; 30(6):1592-1596.
27. Stiles VH, Pearce M, Moore IS, et al. Wrist-worn Accelerometry for Runners: Objective Quantification of Training Load. *Med Sci Sports Exerc*. 2018; 50(11):2277-2284.
28. Pobiruchin M, Suleder J, Zowalla R, Wiesner M. Accuracy and Adoption of Wearable Technology Used by Active Citizens: A Marathon Event Field Study. *JMIR Mhealth Uhealth*. 2017; 5(2):e24.
29. Townshend AD, Worringham CJ, Stewart IB. Assessment of speed and position during human locomotion using nondifferential GPS. *Med Sci Sports Exerc*. 2008; 40(1):124-132.
30. Nielsen RO, Cederholm P, Buist I, et al. Can GPS be used to detect deleterious progression in training volume among runners? *Journal of Strength & Conditioning Research*. 2013; 27(6):1471-1478.
31. van der Worp MP, de Wijer A, van Cingel R, et al. The 5- or 10-km Marikenloop Run: A Prospective Study of the Etiology of Running-Related Injuries in Women. *J Orthop Sports Phys Ther*. 2016; 46(6):462-470.
32. Ogueta-Alday A, Morante JC, Gomez-Molina J, Garcia-Lopez J. Similarities and differences among half-marathon runners according to their performance level. *PLoS ONE*. 2018; 13(1):e0191688.
33. McLaren SJ, Macpherson TW, Coutts AJ, et al. The Relationships Between Internal and External Measures of Training Load and Intensity in Team Sports: A Meta-Analysis. *Sports Med*. 2018; 48(3):641-658.
34. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982; 14(5):377-381.
35. Murray NB, Gabbett TJ, Townshend AD, Blanch P. Calculating acute:chronic workload ratios using exponentially weighted moving averages provides a more sensitive indicator of injury likelihood than rolling averages. *Br J Sports Med*. 2017; 51(9):749-754.
36. Blanch P, Gabbett TJ. Has the athlete trained enough to return to play safely? The acute:chronic workload ratio permits clinicians to quantify a player's risk of subsequent injury. *Br J Sports Med*. 2016; 50(8):471-475.
37. Hulin BT, Gabbett TJ, Lawson DW, et al. The acute:chronic workload ratio predicts injury: high chronic workload may decrease injury risk in elite rugby league players. *Br J Sports Med*. 2016; 50(4):231-236.
38. Hulin BT, Gabbett TJ, Caputi P, et al. Low chronic workload and the acute:chronic workload ratio are more predictive of injury than between-match recovery time: a two-season prospective cohort study in elite rugby league players. *Br J Sports Med*. 2016; 50(16):1008-1012.
39. Gabbett TJ. The training-injury prevention paradox: should athletes be training smarter and harder? *Br J Sports Med*. 2016; 50(5):273-280.
40. Johnston R, Cahalan R, Bonnett L, et al. Training Load and Baseline Characteristics Associated With New Injury/Pain Within an Endurance Sporting Population: A Prospective Study. *Int J Sports Physiol Perform*. 2019; 14(5):590-597.

41. Almeida MO, Davis IS, Lopes AD. Biomechanical Differences of Foot-Strike Patterns During Running: A Systematic Review With Meta-analysis. *J Orthop Sports Phys Ther.* 2015; 45(10):738-755.
42. Dos Santos AF, Nakagawa TH, Nakashima GY, et al. The Effects of Forefoot Striking, Increasing Step Rate, and Forward Trunk Lean Running on Trunk and Lower Limb Kinematics and Comfort. *Int J Sports Med.* 2016; 37(5):369-373.
43. Napier C, Cochrane CK, Taunton JE, Hunt MA. Gait modifications to change lower extremity gait biomechanics in runners: a systematic review. *Br J Sports Med.* 2015; 49(21):1382-1388.
44. Knorz S, Kluge F, Gelse K, et al. Three-Dimensional Biomechanical Analysis of Rearfoot and Forefoot Running. *Orthop J Sports Med.* 2017; 5(7):2325967117719065.
45. Futrell EE, Jamison ST, Tenforde AS, Davis IS. Relationships between Habitual Cadence, Footstrike, and Vertical Load Rates in Runners. *Med Sci Sports Exerc.* 2018; 50(9):1837-1841.
46. van der Worp H, Vrielink JW, Bredeweg SW. Do runners who suffer injuries have higher vertical ground reaction forces than those who remain injury-free? A systematic review and meta-analysis. *Br J Sports Med.* 2016; 50(8):450-457.
47. Davis IS. The Re-emergence of the Minimal Running Shoe. *J Orthop Sport Phys.* 2014; 44(10):775-784.
48. Garrett JM, Gunn R, Eston RG, et al. The effects of fatigue on the running profile of elite team sport athletes. A systematic review and meta-analysis. *J Sports Med Phys Fitness.* 2019; 59(8):1328-1338.
49. Koblbauer IF, van Schooten KS, Verhagen EA, van Dieen JH. Kinematic changes during running-induced fatigue and relations with core endurance in novice runners. *J Sci Med Sport.* 2014; 17(4):419-424.
50. Napier C, Esculier JF, Hunt MA. Gait retraining: out of the lab and onto the streets with the benefit of wearables. *Br J Sports Med.* 2017; 51(23):1642-1643.
51. Buist I, Bredeweg SW, Lemmink KA, et al. Predictors of running-related injuries in novice runners enrolled in a systematic training program: a prospective cohort study. *Am J Sports Med.* 2010; 38(2):273-280.
52. Taunton JE, Ryan MB, Clement DB, et al. A retrospective case-control analysis of 2002 running injuries. *Br J Sports Med.* 2002; 36(2):95-101.
53. Finch C. A new framework for research leading to sports injury prevention. *J Sci Med Sport.* 2006; 9(1-2):3-9; discussion 10.
54. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med.* 1992; 14(2):82-99.
55. Arnason A, Andersen TE, Holme I, et al. Prevention of hamstring strains in elite soccer: an intervention study. *Scand J Med Sci Sports.* 2008; 18(1):40-48.
56. Petersen J, Thorborg K, Nielsen MB, et al. Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. *Am J Sports Med.* 2011; 39(11):2296-2303.
57. van der Horst N, Smits DW, Petersen J, et al. The preventive effect of the nordic hamstring exercise on hamstring injuries in amateur soccer players: a randomized controlled trial. *Am J Sports Med.* 2015; 43(6):1316-1323.
58. Bahr R, Thorborg K, Ekstrand J. Evidence-based hamstring injury prevention is not adopted by the majority of Champions League or Norwegian Premier League football teams: the Nordic Hamstring survey. *Br J Sports Med.* 2015; 49(22):1466-1471.
59. van de Hoef S, Huisstede BMA, Brink MS, et al. The preventive effect of the bounding exercise programme on hamstring injuries in amateur soccer players: the design of a randomized controlled trial. *BMC Musculoskelet Disord.* 2017; 18(1):355.
60. Saragiotto BT, Yamato TP, Lopes AD. What do recreational runners think about risk factors for running injuries? A descriptive study of their beliefs and opinions. *J Orthop Sports Phys Ther.* 2014; 44(10):733-738.

61. de Jonge J, van Iperen L, Gevers J, Vos S. 'Take a Mental Break!' study: Role of mental aspects in running-related injuries using a randomised controlled trial. *BMJ Open Sport Exerc Med.* 2018; 4(1):e000427.
62. King J, Roberts C, Hard S, Ardern CL. Want to improve return to sport outcomes following injury? Empower, engage, provide feedback and be transparent: 4 habits! *Br J Sports Med.* 2019; 53(9):526-527.
63. Nielsen RO, Ronnow L, Rasmussen S, Lind M. A prospective study on time to recovery in 254 injured novice runners. *PLoS One.* 2014; 9(6):e99877.
64. van Middelkoop M, Kolkman J, van Ochten J, et al. Course and predicting factors of lower-extremity injuries after running a marathon. *Clin J Sport Med.* 2007; 17(1):25-30.
65. Mulvad B, Nielsen RO, Lind M, Ramskov D. Diagnoses and time to recovery among injured recreational runners in the RUN CLEVER trial. *Plos One.* 2018; 13(10).
66. Kastelein M, Luijsterburg PA, Heintjes EM, et al. The 6-year trajectory of non-traumatic knee symptoms (including patellofemoral pain) in adolescents and young adults in general practice: a study of clinical predictors. *Br J Sports Med.* 2015; 49(6):400-405.
67. Moen MH, Bongers T, Bakker EW, et al. Risk factors and prognostic indicators for medial tibial stress syndrome. *Scand J Med Sci Sports.* 2012; 22(1):34-39.
68. Atkinson NL, Saperstein SL, Pleis J. Using the Internet for Health-Related Activities: Findings From a National Probability Sample. *J Med Internet Res.* 2009; 11(1).
69. Bredeweg SW, Zijlstra S, Bessem B, Buist I. The effectiveness of a preconditioning programme on preventing running-related injuries in novice runners: a randomised controlled trial. *Br J Sports Med.* 2012; 46(12):865-870.
70. Buist I, Bredeweg SW, van Mechelen W, et al. No effect of a graded training program on the number of running-related injuries in novice runners. *Am J Sport Med.* 2008; 36(1):35-41.
71. Vanmechelen W, Hlobil H, Kemper HCG, et al. Prevention of Running Injuries by Warm-up, Cool-down, and Stretching Exercises. *Am J Sport Med.* 1993; 21(5):711-719.
72. Knobloch K, Yoon U, Vogt PM. Acute and overuse injuries correlated to hours of training in master running athletes. *Foot Ankle Int.* 2008; 29(7):671-676.



10

Summary

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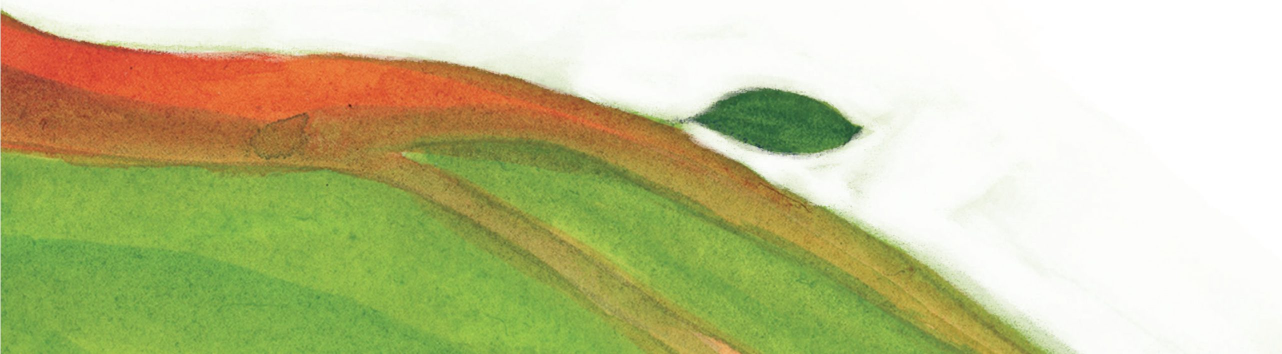

SUMMARY

Running is a sport that is frequently practiced and is still growing in popularity. Running has several positive effects on both the physical and mental well-being. However, a main drawback of running is the high number of running-related injuries (RRIs). Even though many studies on RRIs have been performed in the past decades, important gaps still exist in literature, for example on time-to-recovery and prognostic factors of RRIs in specific subgroups of runners or injury locations. Also, no effective prevention measures have been identified yet. Therefore, the aim of this thesis was to gain more insight in the prognosis and prevention of RRIs in recreational runners.

In **chapter 2** the proportion of participants of a running program for novice runners that discontinued running, the main reasons to discontinue and characteristics associated with discontinuation were determined. This prospective cohort study included 774 participants of the 'Start to Run' program, a 6-week running program for novice runners. Before the start of the program, participants filled-in a baseline questionnaire to collect information on demographics, physical activity and perceived health. A 26-weeks follow-up questionnaire was used to obtain information on the continuation of running (yes/no) and main reasons for discontinuation. To determine predictors for discontinuation of running, multivariable logistic regression was performed. The results showed that within 26 weeks after the start of the 6-week running program, 29.5% of the novice runners (n=225) had stopped running. The main reason for discontinuation was a RRI (n=108, 48%). Being female (OR 1.74; 95% CI 1.13;2.68), being unsure about the continuation of running after the program (OR 2.06; 95% CI 1.31;3.24) and (almost) no alcohol use (OR 1.62; 95%CI 1.11;2.37) were associated with a higher chance of discontinuation of running. Previous running experience less than one year previously (OR 0.46; 95% CI 0.26;0.83) and a higher score on the RAND-36 subscale physical functioning (OR 0.98; 95% CI 0.96;0.99) were associated with a lower chance of discontinuation. Therefore, it can be concluded that in a group of novice runners, almost one-third stops running within 6 months. An RRI is the main reason to stop running. Women with a low perceived physical functioning and without running experience are prone to discontinue running.

The aim of **chapter 3** was to investigate the prognosis and possible prognostic factors of RRIs in novice runners. Participants of the 'Start to Run' program were asked to participate in this prospective cohort study. Before the start of the course a

baseline questionnaire, on demographics, physical activity and perceived health, was sent to runners willing to participate. The 26- or 52-weeks follow-up questionnaires assessed information on RRIs and their duration. Only participants that sustained a RRI during follow-up were included in the analyses. An injury duration of 10 weeks or shorter was regarded as a relatively good prognosis, while an injury duration of more than 10 weeks was defined as a poor prognosis. To determine the associations between baseline characteristics and injury prognosis and between injury location and injury prognosis, multivariable logistic regression analyses were performed. During follow-up 347 participants (48.8%) sustained an RRI. The RRIs had an overall median duration of eight weeks (range: 1–52 weeks). Participants with a previous RRI were more likely to have a poor prognosis (OR 2.31; 95% CI 1.12;4.79), while a calf injury showed a trend towards an association with a relatively good prognosis (OR 0.49; 95%CI 0.22;1.11). In conclusion, the duration of RRIs in novice runners is relatively long, with only calf injuries being associated with a good prognosis. This emphasizes the need of injury prevention measures in novice runners and adequate support during and after an RRI, especially in runners with a previous injury.

Chapter 4 describes the design of the INSPIRE-trial, a randomized-controlled trial with a minimum follow-up of 3 months. The aim of this trial was to examine the effect of a multifactorial online injury prevention program on the number of RRIs. Both novice and more experienced runners, aged 18 years and older, who register for a running event (distances 5 km up to 42.195 km) were asked to participate in this study. After completing the baseline questionnaire, participants were randomized into either the intervention group or control group. Participants in the intervention group got access to the online injury prevention program. This prevention program consisted of information on risk factors for RRIs and advices to reduce the injury risk. Participants in the control group followed their regular preparation for the running event. The primary outcome measure was the number of self-reported RRIs in the time frame between registration for a running event and 1 month after the running event.

In **chapter 5** the results of the INSPIRE-trial are presented. The trial included 2378 recreational runners (1252 men; mean [SD] age 41.2 [11.9] years), of which 1196 were allocated to the intervention group and 1182 to the control group. Of the participants in the intervention group 37.5% (95% CI 34.8;40.4) sustained a new RRI during follow-up, compared with 36.7% (95% CI 34.0;39.6) in the control group. Univariate logistic regression analysis showed no significant difference between the intervention and control group (OR 1.08; 95% CI 0.90;1.30). Furthermore, the was a tendency towards more RRIs in runners without a history of injuries who had access to the prevention program (OR 1.30; 95% CI 0.99;1.70). From these results it can be concluded that a multifactorial, online injury prevention program did not decrease the total number of RRIs in recreational runners.

The prospective cohort study of **chapter 6** investigated the associations of training volume and the longest endurance with (half-) marathon performance and RRIs in recreational runners. The half-marathon and marathon runners participating in the INSPIRE-trial completed 3 questionnaires during the preparation for and directly after the running event. The questionnaires included questions on RRIs, average weekly training volume and the longest endurance run performed during preparation. With finish time, decline in pace during the running event and RRIs as dependent variables, linear and logistic regression analyses were performed to test the associations with weekly training volume and the longest endurance run. In the 556 included half-marathon runners, a high training volume 2-6 weeks before the running event (>32 km/week) (B -4.19, 95% CI -6.52;-1.85) and a long endurance run (>21 km) (B -3.87, 95% CI -6.31;-1.44) were associated with a faster finish time, while a high training volume was also related to less decline in pace (B -2.29, 95% CI -4.08;-0.51). In the 441 included marathon runners, a low training volume (<40 km/week) was related to a slower finish time (B 6.33, 95% CI 0.18;12.48) and a high training volume (>65 km/week) to a faster finish time (B -14.09, 95% CI -22.47;-5.72), while a longest endurance run of less than 25 km was associated with a slower finish time (B 13.44, 95% CI 5.34;21.55). No associations between training characteristics and RRIs were identified. Therefore, it can be concluded that preparation for a (half-) marathon with a relatively high training volume and long endurance runs associates with a faster finish time, but does not seem related to an increased injury risk.

In **chapter 7** the impact and prognostic factors of knee injuries, the most common site of running injuries, among recreational runners was investigated. This prospective cohort study was part of the INSPIRE-trial. Demographic characteristics and training variables were collected at registration for a running event (5-42.195 km). Participants who reported a new running-related knee injury (RRKI) during follow-up were asked to fill out a knee-specific online questionnaire at 16 months (range 11.7-18.6 months) after registration. To determine the association between potential prognostic factors and time-to-recovery, a Cox regression analysis was performed. In total 138 of 277 runners (49.8%) with an RRKI responded to the knee-specific questionnaire. At 16 months after registration, 71.0% of the participants reported full recovery, with an median time-to-recovery of 8.0 weeks. Most participants reported iliotibial band syndrome (23.2%) or osteoarthritis (OA)/degenerative meniscopathy (23.2%) as cause of their injury. Male sex was associated with a shorter time-to-recovery (HR 1.84; 95% CI 1.14;2.97), while suffering knee OA was associated with a longer time-to-recovery (HR 0.17; 95% CI 0.06;0.46). The results showed that the impact of RRKIs is large, as almost one third of the participants were not recovered at 16 months after registration. This emphasizes the need for injury prevention programs for runners. More knowledge on the impact of running with knee OA seems important, given the high number of runners with knee OA symptoms.

Chapter 8 describes the opinions of recreational runners on different components of injury prevention and identified the barriers and facilitators of injury prevention in adult recreational runners. For this comparative cross-sectional study, a questionnaire on their interests, actions undertaken, and perceived barriers and facilitators of injury prevention was sent to the 2378 recreational runners participating in the INSPIRE-trial. Descriptive analyses were used to examine differences with regard to sex and previous RRIs. In total, 1034 adult recreational runners (43.5%) responded to the questionnaire. Runners with previous RRIs were more likely to rate injury prevention as very useful than runners who had never sustained an RRI (76.8% vs. 63.6%, $p<0.001$). In total, 81.8% of the participants indicated that they already performed preventive measures, including changes to training schedules (65.4%) and warming-up (57.8%). Most frequently reported barriers for injury prevention were 'not knowing what to do' (45.2%) and 'no history of RRI' (34.6%). The most important facilitator was an injury (60.1%). Women more often preferred information via a trainer or running store than men, while men more frequently preferred websites or e-mail. This study showed that the majority of the runners rated injury prevention as important. To increase effectiveness, future prevention programs should be developed with awareness of experienced barriers and facilitators of adult runners.

Finally, **chapter 9** discusses the main findings and limitations of this thesis. Furthermore, implications for future research and practice are given.

SAMENVATTING

Hardlopen is een sport die veel beoefend wordt en die nog steeds groeit in populariteit. Hardlopen heeft vele positieve effecten op zowel de fysieke als mentale gezondheid. Een groot nadeel is echter het grote aantal blessures. Alhoewel er de afgelopen decennia veel studies naar hardloopblessures zijn gedaan, zijn er nog steeds belangrijke hiaten in de kennis van hardloopblessures, bijvoorbeeld over de hersteltijd en prognostische factoren in specifieke subgroepen hardlopers of blessurelocaties. Daarnaast zijn er nog geen effectieve blessurepreventiemaatregelen geïdentificeerd. Daarom was het doel van dit proefschrift om meer inzicht te verkrijgen in de prognose en preventie van blessure bij recreatieve hardlopers.

In **hoofdstuk 2** werd bepaald hoeveel deelnemers aan een cursus voor beginnende hardlopers stopten met hardlopen, wat de belangrijkste redenen waren om te stoppen en welke karakteristieken geassocieerd waren met het stoppen met hardlopen. Aan deze prospectieve cohort studie deden 774 hardlopers mee, allen deelnemers aan het 'Start to Run' programma, een 6-weekse cursus voor beginnende hardlopers. Voor de start van de cursus vulden de deelnemers een baselinevragenlijst in waarmee informatie werd verzameld over demografische eigenschappen, fysieke activiteit en ervaren gezondheid. Na 26 weken werd de deelnemers in een follow-up vragenlijst gevraagd of ze nog aan hardlopen deden (ja/nee) en zo niet, wat de belangrijkste reden was om te stoppen met hardlopen. Met multivariate logistische regressieanalyse werden de voorspellers van stoppen met hardlopen bepaald. De resultaten lieten zien dat na 26 weken 29.5% van de beginnende hardlopers (n=225) waren gestopt met hardlopen. De belangrijkste reden om te stoppen was een hardloopblessure (n=108, 48%). Vrouwen (OR 1,74; 95% CI 1,13;2,68), deelnemers die op baseline twijfelden of ze na de cursus door zouden gaan met hardlopen (OR 2,06; 95% CI 1,31;3,24) en deelnemers die (bijna) geen alcohol dronken (OR 1,62; 95% CI 1,11;2,37) hadden een grotere kans om te stoppen met hardlopen. Eerdere hardloopervaring in het afgelopen jaar (OR 0,46; 95% CI 0,26;0,83) en een hogere score op de RAND-36 subschaal fysiek functioneren op baseline (OR 0,98; 95% CI 0,96;0,99) waren geassocieerd met een kleinere kans om te stoppen met hardlopen. Daarom kan geconcludeerd worden dat in een groep beginnende hardlopers bijna een derde gestopt is met hardlopen na 26 weken. Een hardloopblessure is de belangrijkste reden om te stoppen. Vrouwen met een laag ervaren fysiek functioneren en zonder eerdere hardloopervaring hebben een verhoogde kans om te stoppen met hardlopen.

Het doel van **hoofdstuk 3** was om de prognose en mogelijke prognostische factoren van hardloopblessures bij beginnende hardlopers te onderzoeken. Deelnemers aan het 'Start to Run' programma zijn gevraagd om deel te nemen aan deze prospectieve cohort studie. Voor de start van de cursus werd een baselinevragenlijst over demografische kenmerken, fysieke activiteit en ervaren gezondheid naar de deelnemers gestuurd. Met de follow-up vragenlijst na 26 of 52 weken werd informatie over hardloopblessures verzameld. Alleen deelnemers die een hardloopblessure opliepen tijdens de follow-up zijn geïncludeerd in de analyses. Een blessureduur van 10 weken of minder werd gezien als een relatief goede prognose, terwijl een blessureduur van meer dan 10 weken werd gezien als een slechte prognose. Met multivariabele logistische regressieanalyse zijn de associaties tussen baselinekarakteristieken en blessureprognose en tussen blessurelocatie en blessureprognose bepaald. Tijdens follow-up hebben 347 deelnemers (48,8%) een hardloopblessure opgelopen. De blessures hadden een mediane duur van 8 weken (range: 1-52 weken). Deelnemers die eerder een hardloopblessure hadden gehad, hadden een verhoogde kans op een slechte prognose (OR 2,31; 95% CI 1,12;4,79), terwijl een kuitblessure een trend liet zien naar een associatie met een relatief goede prognose (OR 0,49; 95% CI 0,22;1,11). Er kan geconcludeerd worden dat de duur van hardloopblessures bij beginnende hardlopers relatief lang is, waarbij alleen kuitblessures geassocieerd waren met een goede prognose. Dit laat het belang zien van blessurepreventiemaatregelen bij beginnende hardlopers en van adequate ondersteuning tijdens en na een hardloopblessure, vooral bij hardlopers die al eerder een blessure hebben gehad.

Hoofdstuk 4 beschrijft het design van de INSPIRE-trial, een gerandomiseerd, gecontroleerd onderzoek met een minimale follow-up van 3 maanden. Het doel van deze trial was om het effect van een multifactorieel, online blessure-preventieprogramma op het aantal hardloopblessures te onderzoeken. Zowel beginnende als meer ervaren hardlopers, die 18 jaar of ouder waren en zich registreerden voor een hardloopevenement (afstanden van 5 tot en met 42,195 km) zijn gevraagd om mee te doen aan dit onderzoek. Nadat ze de baselinevragenlijst hadden ingevuld, werden de deelnemers gerandomiseerd in de interventiegroep of controlegroep. Deelnemers in de interventiegroep kregen toegang tot het online blessurepreventieprogramma. Dit preventieprogramma bestond uit informatie over risicofactoren voor hardloopblessures en adviezen om het blessurerisico te verlagen. Deelnemers in de controlegroep volgden hun normale voorbereiding voor het loopevenement. De primaire uitkomstmaat was het aantal zelf-gerapporteerde hardloopblessures in de tijd tussen het registreren voor het loopevenement en 1 maand na het loopevenement.

In **hoofdstuk 5** worden de resultaten van de INSPIRE-trial gepresenteerd. In deze trial zijn 2378 hardlopers gerandomiseerd (1252 mannen; gemiddelde [SD] leeftijd 41,2 [11,9] jaar), waarvan 1196 werden geloot in de interventiegroep en 1182 in de controlegroep. In de interventiegroep liep 37,5% (95% CI 34,8;40,4) een nieuwe blessure op, in vergelijking met 36,7% (95% CI 34,0;39,6) in de controlegroep. Univariate logistische regressieanalyse liet zien dat er geen significant verschil was tussen het aantal blessures in de interventiegroep en de controlegroep (OR 1,08; 95% CI 0,90;1,30). Daarnaast was er een tendens naar meer blessures bij hardlopers zonder blessuregeschiedenis die toegang hadden tot het preventieprogramma (OR 1,30; 95% CI 0,99;1,70). Uit deze resultaten kan geconcludeerd worden dat een multifactorieel, online blessurepreventieprogramma het aantal hardloopblessures bij recreatieve hardlopers niet heeft kunnen verminderen.

Het prospectieve cohort onderzoek van **hoofdstuk 6** onderzocht de associaties van trainingsvolume en de langste duurloop met (halve) marathonprestatie en hardloopblessures bij recreatieve hardlopers. De halve-marathon- en marathonlopers die deelnamen aan de INSPIRE-trial vulden 3 vragenlijsten in tijdens de voorbereiding op en direct na het loopevenement. Deze vragenlijsten bevatten vragen over hardloopblessures, gemiddeld wekelijks trainingsvolume en de langste duurloop tijdens de voorbereiding op het loopevenement. Met eindtijd, verval in snelheid tijdens het loopevenement en hardloopblessures als afhankelijke variabelen, werden lineaire en logistische regressieanalyses uitgevoerd om de associaties met wekelijks trainingsvolume en de langst duurloop te onderzoeken. Bij de 556 geïncludeerde halve-marathonlopers was een hoog trainingsvolume 2 tot 6 weken voor het loopevenement (>32 km/week) (B -4,19; 95%CI -6,52;-1,85) en een lange duurloop (>21 km) (B -3,87; 95% CI -6,31;-1,44) geassocieerd met een snellere eindtijd, terwijl een hoog trainingsvolume ook was gerelateerd aan minder verval in snelheid (B -2,29; 95% CI -4,08;-0,51). Bij de 441 geïncludeerde marathonlopers was een laag trainingsvolume (<40 km/week) gerelateerd aan een langzamere eindtijd (B 6,33; 95% CI 0,18;12,48) en een hoog trainingsvolume aan een snellere eindtijd (B -14,09; 95% CI -22,47;-5,72), terwijl een langste duurloop van minder dan 25 km was geassocieerd met een langzamere eindtijd (B 13,44; 95% CI 5,34;21,55). Er zijn geen associaties gevonden tussen de trainingskarakteristieken en hardloopblessures. Daarom kan geconcludeerd worden dat de voorbereiding voor een (halve-) marathon met een relatief hoog trainingsvolume en lange duurlopen is geassocieerd met een snellere eindtijd, maar geen invloed lijkt te hebben op het blessurerisico.

In **hoofdstuk 7** werden de impact en prognostische factoren van knieblessures, de meest voorkomende hardloopblessure, onderzocht bij recreatieve hardlopers. Deze prospectieve cohort studie was onderdeel van de INSPIRE-trial. Demografische gegevens en trainingskarakteristieken werden verzameld bij de registratie voor een hardloopevenement (5-42,195 km). Deelnemers die een nieuwe knieblessure rapporteerden tijdens de follow-up kregen een uitnodiging voor het invullen van een knie-specifieke online vragenlijst na gemiddeld 16 maanden (range 11,7-18,6 maanden) na registratie. Om de associaties te bepalen tussen mogelijke prognostische factoren en de hersteltijd werd een Cox-regressieanalyse gedaan. In totaal 138 van de 277 hardlopers (49,8%) met een knieblessures reageerden op de knie-specifieke vragenlijst. Zestien maanden na registratie voor het loopevenement rapporteerde 71,0% van de deelnemers dat ze volledig hersteld waren, met een mediane hersteltijd van 8,0 weken. De meeste deelnemers rapporteerden iliotibiaal bandsyndroom (23,2%) of artrose/degeneratieve meniscopathie (23,2%) als de oorzaak van hun blessure. Het mannelijke geslacht was geassocieerd met een kortere hersteltijd (HR 1,84; 95% CI 1,14;2,97), terwijl knieartrose was geassocieerd met een langere hersteltijd (HR 0,17; 95% CI 0,06;0,46). Deze resultaten laten zien dat de impact van knieblessures bij hardlopers groot is, aangezien bijna een derde van de hardlopers 16 maanden na registratie nog niet hersteld was. Dit geeft de noodzaak van blessurepreventie bij hardlopers aan. Daarnaast is meer kennis over de impact van hardlopen met knieartrose noodzakelijk, gezien het grote aantal hardlopers met symptomen van knieartrose.

Hoofdstuk 8 beschrijft de meningen van recreatieve hardlopers over verschillende componenten van blessurepreventie en heeft de barrières en facilitators voor hardloopblessurepreventie bij volwassen recreatieve hardlopers in kaart gebracht. Voor dit vergelijkende cross-sectionele onderzoek is een vragenlijst over interesses, ondernomen maatregelen en ervaren barrières en facilitators voor blessurepreventie naar de 2378 deelnemers van de INSPIRE-trial gestuurd. Beschrijvende analyses zijn gebruikt om de verschillen ten aanzien van geslacht en eerdere blessures te onderzoeken. In totaal reageerden 1034 volwassen hardlopers (43,5%) op de vragenlijst. Hardlopers die eerder een blessure hadden gehad, vonden blessurepreventie vaker zeer nuttig dan hardlopers die nooit een blessure hadden gehad (76,8% versus 63,6%, p<0,001). In totaal 81,8% van de deelnemers gaf aan dat ze blessurepreventiemaatregelen namen, zoals veranderingen aan het trainingsschema (65,4%) en warming-up (57,8%). De meest gerapporteerde barrières voor blessurepreventie zijn 'niet weten wat te doen' (45,2%) en 'geen geschiedenis van blessures' (34,6%). De belangrijkste facilitator was een blessure (60,1%). Vrouwen wilden vaker informatie over blessurepreventie ontvangen via een trainer of hardloopwinkel dan mannen, terwijl mannen vaker website of e-mail prefereerden. Dit onderzoek laat zien dat de meerderheid van de hardlopers blessurepreventie belangrijk vindt. Om de effectiviteit te vergroten is het belangrijk dat toekomstige blessurepreventieprogramma's worden ontworpen met bewustzijn van de ervaren barrières en facilitators van volwassen hardlopers.

Tot slot worden in **hoofdstuk 9** de belangrijkste bevindingen en tekortkomingen van dit proefschrift bediscussieerd. Daarnaast worden implicaties voor vervolgonderzoek en de praktijk gegeven.

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Although the paper is not in my PhD thesis, my time at the Spaulding National Running Center was very valuable to me. Not only did I learn a lot about running biomechanics, but also about myself and (research in) other countries. Thanks for having me!

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CURRICULUM VITAE

Tryntsje Fokkema was born on 16 January 1990 in Burdaard (the Netherlands). After finishing pre-university education at the Dockinga College in Dokkum, she started her study Human Movement Sciences at the University of Groningen in 2008. For her master research project, she studied the associations between training and physiological performance indicators in elite runners during 25 weeks of regular training. After graduating, Tryntsje worked as a junior-researcher at the Hanze University of Applied Sciences in Groningen, where she studied the use of activity trackers in health care settings. In June 2016, she started as a PhD-student at the Department of General Practice of the Erasmus MC University Medical Center Rotterdam. Her PhD focused on the prognosis and prevention of running-related injuries and she performed the in this thesis described INSPIRE-trial. As part of her PhD, she also worked for 4 months at the Spaulding National Running Center, Havard Medical School, Cambridge (USA) in 2018, where she conducted a study on the biomechanical differences between types of running shoes and footstrike patterns. Currently, Tryntsje is still working at the Department of General Practice of the Erasmus MC University Medical Center Rotterdam. She is responsible for the SPRINT-study, in which the effectiveness of a further developed running injury prevention program is tested.

PHD PORTFOLIO

Erasmus MC, Department of General Practice

PhD Period: June 2016 – September 2019

Promotor: prof. dr. S.M.A. Bierma-Zeinstra

Co-promotors: dr. M. van Middelkoop & dr. R.J. de Vos

	Year	Workload (ECTS)
International research visit		
Spaulding National Running Center, Harvard Medical School Cambridge USA	2018	20
Conferences		
Awards		
Best oral presentation, Sportmedisch Wetenschappelijk Jaarcongres Ermelo	2017	
Best poster presentation, Theme day Health Science Erasmus MC Rotterdam	2019	
Oral presentations		
Science day Orthopedics Erasmus MC Rotterdam	2017	2
Running injury science meeting Luxembourg	2017	2
Sportmedisch wetenschappelijk jaarcongres Ermelo (3x)	2017	6
Sportskongres Copenhagen Denmark	2018	2
ACE Bone & Joint meeting Erasmus MC Rotterdam	2018	2
Sportmedisch wetenschappelijk jaarcongres Ermelo	2018	2
Poster presentations		
VvBN PhD-day Rotterdam	2017	1
Sportskongres Copenhagen Denmark (2x)	2018	2
Sportskongres Copenhagen Denmark (2x)	2019	2
Theme day Health Science Erasmus MC Rotterdam	2019	1
ACE Bone & Joint Research day Erasmus MC Rotterdam	2019	1
Teaching activities		
Supervision of master research projects by medical students (2x)	2017	8
Supervision of master research project student Sports physiotherapy	2017-2018	4
Supervision of master research project student Biomedical sciences	2018	4
Organization		
PhD day, Dept. General Practice, Erasmus MC Rotterdam	2017	2
Weekly work meeting & critical reading, Dept. General Practice, Erasmus MC	2017-2018	2
Courses		
BROK course	2017	1.5
CPO Patient Oriented Research: design, conduct and analysis	2017	0.3
NIHES Joint Models for Longitudinal and Survival Data	2017	0.7
Research Integrity	2017	0.3
Peer review		
Journal of Science and Medicine in Sport (2x)	2017-2019	2
Gait & Posture	2019	1

LIST OF PUBLICATIONS

This thesis

Fokkema T, De Vos RJ, Bierma-Zeinstra SMA, Van Middelkoop M. Opinions, barriers, and facilitators of injury prevention in recreational runners. *J Orthop Sports Phys Ther* 2019;49(10):736-42.

Fokkema T, De Vos RJ, Van Ochten JM, Verhaar JAN, Davis IS, Bindels PJE, Bierma-Zeinstra SMA, Van Middelkoop M. Online multifactorial prevention programme has no effect on the number of running-related injuries: a randomised controlled trial. *Br J Sports Med* 2019;53:1479-1485.

Fokkema T, Burggraaff R, Hartgens F, Kluitenberg B, Verhagen E, Backx FJG, Van der Worp H, Bierma-Zeinstra SMA, Koes BW, Van Middelkoop M. Prognosis and prognostic factors of running-related injuries in novice runners: a prospective cohort study. *J Sci Med Sport* 2019;22(3):259-63.

Fokkema T, Hartgens F, Kluitenberg B, Verhagen E, Backx FJG, Van der Worp H, Bierma-Zeinstra SMA, Koes BW, Van Middelkoop M. Reasons and predictors of discontinuation of running after a running program for novice runners. *J Sci Med Sport* 2019;22(1):106-11.

Fokkema T, De Vos RJ, Van Ochten JM, Verhaar JAN, Davis IS, Bindels PJE, Bierma-Zeinstra SMA, Van Middelkoop M. Preventing running-related injuries using evidence-based online advice: the design of a randomised-controlled trial. *BMJ Open Sport Exerc Med* 2017;3(1):e000265.

Other publications

Tapia EE, Tameeris E, **Fokkema T**, Chiarotto A. Spinal cord stimulation for failed back surgery: all that glitters is not gold. *Pain* 2019;160(8):1903-04.

Fokkema T, Outerleys J, Bento Matias A, Clansey AC, Davis IS. Differences in foot kinematics between forefoot strikers in minimalist and conventional running shoes. *Med Sci Sports Exerc* 2019;51(supplement):774-775.

Van Middelkoop M, Cloosterman KLA, **Fokkema T**, De Vos RJ, Bierma-Zeinstra SMA. Prevalence and impact of knee osteoarthritis in runners. *Osteoarthritis Cartilage* 2019;27:S258.

Fokkema T, Van Middelkoop M. Preventie van hardloopblessures. *Huisarts en Wetenschap* 2019;7:18-20.

Geerars DH, Burggraaff R, **Fokkema T**, Festen DAM. Letter to the editor concerning the article "Relationship between school rhythm and physical activity in adolescents: the HELENA study" by Vanhelst et al. (2017). *J Sports Sci* 2018;36(16):1846.

Fokkema T, Kooiman TJM, Krijnen WP, Van der Schans CP, De Groot M. Reliability and validity of ten consumer activity trackers depend on walking speed. *Med Sci Sports Exerc* 2017;49(4):793-800.

Elferink-Gemser MT, De Roos I, Torenbeek M, **Fokkema T**, Jonker L, Visscher C. The importance of psychological constructs for training volume and performance improvement. A structural equation model for youth speed skaters. *Int J Sport Psychol* 2015;46(6):726-744.