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Incidence and risk factors of running-related injuries during preparation for a 4-mile recreational running event

I Buist,1,2 S W Bredeweg,1,2 B Bessem,2 W van Mechelen,3 K A P M Lemmink,1,4 R L Diercks1,2

ABSTRACT
Objective In this study, the incidence and the sex-specific predictors of running-related injury (RRI) among a group of recreational runners training for a 4-mile running event were determined and identified, respectively.
Design Prospective cohort study.
Methods Several potential risk factors were prospectively measured in 629 novice and recreational runners. They were observed during an 8-week training period for any running-related musculoskeletal injuries of the lower limbs and back. A running-related injury was defined as any musculoskeletal pain of the lower limb or back during preparation for a 4-mile recreational running event were determined and identified, respectively.

Results At least one RRI was reported by 25.9% of the runners during the 8-week observation period. The incidence of RRI was 30.1 (95% CI 25.4 to 34.7) per 1000 h of running exposure. Multivariable Cox regression showed that male participants were more prone to sustain a RRI than female participants (HR 1.4; 95% CI 1.0 to 2.0). No previous running experience was the most important risk factor in male (HR 2.6; 95% CI 1.2 to 5.5) and female (HR 2.1; 95% CI 1.2 to 3.7) participants.

Conclusions The incidence of running-related injuries in recreational runners preparing for a 4-mile running event is substantially high. Male and female participants have different risk profiles. Furthermore, the findings suggest that novice runners may benefit the most out of preventive interventions for RRI.

The popularity of running as a recreational activity is high and is still increasing. Nowadays, almost every city in Western society has its own marathon and recreational running events. The reason for novice runners to participate in a running programme is most likely to improve health and fitness and for intermediate runners to improve personal performance.

Apart from its beneficial health effects, running also puts runners at a risk of developing a running-related injury (RRI). In the literature, injury rate of RRI is expressed in number of RRIs (or injured runners) per 100 runners at risk, and when exposure is measured, the incidence of RRI in number of RRIs (or injured runners) per 1000 h of running is also included. Reported injury rates of RRIs per 100 runners at risk is high, and varies from 50% to 79%, and injury incidence from 7 to 59 RRIs per 1000 h of running. The wide disparity of incidence rates found in several studies on RRI is caused by variations in definition of injury, differences in population at risk (novice, recreational and elite runners with different training loads) and differences in the duration of follow-up periods (time at risk). Most of the RRIs (50%–75%) are injuries due to overuse located at the knee or below.

The aetiology of the RRIs is multifactorial, with both intrinsic (personal) and extrinsic (environmental) factors contributing. Intrinsic factors include age, sex, body mass index (BMI), physical fitness, previous injury and anatomical alignment. Extrinsic factors can be running distance and frequency per week, predominant running surface, running shoe age and running shoe type. In the literature, only four factors ((1) reported running experience, (2) previous injury, (3) running to compete and (4) excessive weekly running distance) have been associated consistently with RRI. A more recent systematic review on determinants of lower extremity running injuries in long-distance runners shows that higher training distance per week in male runners and a history of previous injuries in male and female runners were risk factors for sustaining an RRI. Conflicting or no evidence is found for other factors like age, BMI, static biomechanical alignment, running surface, running frequency, warm up and stretching. Furthermore, male and female runners have different risk profiles for RRI. In addition, risk factors can interact and therefore should be considered simultaneously to adjust for confounding. Eventually, a combination of intrinsic and extrinsic risk factors predisposes runners to develop an RRI.

Until now, most of the studies on incidence and risk factors of RRI are conducted on long-distance runners. Inclusion of novice runners in prospective cohort studies on the risk factors for RRI will reduce the healthy runner selection bias. Only a limited number of studies exist that control for the time at risk, that is, exposure time, and little is known about different risk profiles for RRI between male and female recreational runners. Therefore, the purpose of this study is to determine the incidence of RRI and to identify sex-specific predictors of RRI among a group of novice and recreational runners training during an 8-week period for a 4-mile running event.

METHODS
Study period and settings
A prospective cohort design was used for the study. A flowchart of the study is shown in fig 1. Potential participants for the study were 1459 recreational runners who signed up for the “4-mile

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A 8-week programme to prepare for the Groningen 4-mile. The Groningen 4-mile is a major recreational annual running event in the northern part of The Netherlands. Over 15 000 mainly novice and recreational runners participate in it each year in the first week of October.

**Study procedure and subjects**

All participants (n = 1459) who signed up for the 4-mile training programme were invited by mail to participate in the study. Information about the study, a baseline questionnaire, an informed consent form, and a running diary were sent along with the invitation. The only exclusion criterion was being younger than 18 years. The standardised baseline questionnaire covered demographic variables and questions on potential risk factors for RRI. The potential risk factors for RRI that were assessed by the baseline questionnaire were age, sex, BMI, current and past musculoskeletal injuries of the lower limb, running experience and current running routines (years of experience and frequency and duration in hours per week), participation in other sports (hours per week and type of sports: axial loading or non-axial loading) and motivation for entering the programme (health/fitness or competitive/personal performance). Running experience was assessed by the baseline questionnaire. The participants had to categorise themselves as novice runners, runners with previous experience who have taken up running again or runners who were already engaged in regular running.

During the programme, participants registered information on exposure to running and RRI in a personal running diary. The running diary consisted of eight sections (one for each training week). The total minutes of running and the occurrence of running-related pain during or after running were registered per day. The running-related pain was scored as pain after running, pain during running without a restriction in running, pain that caused a restriction in running mileage, running pace or running duration, or running not possible as a result of running-related pain. At the end of the programme, the participants returned their running diary by mail.

The study design, procedures and informed consent procedure were approved by the Medical Ethics Committee of University Medical Center Groningen (UMCG). All participants provided written informed consent.

**Training programme**

The training programme was developed by a coach of the Royal Dutch Athletics Association. Five training clinics were part of the training programme and were organised by local running clubs at the end of the third to seventh weeks. The 8-week training programme required participants to run three times per week in the first to seventh weeks and twice in the last week of the programme. The programme finished with the 4-mile running event at the end of the eighth week. Within the training programme for the Groningen 4-mile, deviations were made for novice and recreational runners. The training programme for novice runners started with ten 1-minute repetitions of running alternated by 1 minutes of walking. The training programme for experienced runners started with 30 minutes of continuous running. The exposure time of running in the training programmes for novice and recreational runners varied, respectively, between 10–40 and 20–60 minutes per training.

**Injury definition**

A running-related injury was defined as any musculoskeletal pain of the lower limb or back causing a restriction in running (mileage, pace or duration) for at least 1 day.

**Analyses**

Demographic variables and potential risk factors for RRI were analysed for differences between male and female participants at baseline using two-tailed t tests for normally distributed continuous variables. \( \chi^2 \) statistics were used for discrete variables. Differences were considered statistically significant at \( p < 0.05 \). Incidence of RRI was calculated for all participants and for men and women separately as the number of new injuries reported per 1000 h of running exposure. Exposure time (in hours of running exposure) was calculated from the time a participant started the running programme until he reported an RRI (injured runners) or until the end of the programme (non-injured runners).

Potential risk factors for RRI were first univariately analysed to see the independent relation with RRI. Variables independently associated (\( p \leq 0.25 \)) with RRI among either men or women were entered in sex-specific multivariate Cox regression prediction models. Hazard ratios (HR) and the corresponding 95% confidence intervals (CI) were calculated for the factors associated with RRI. All analyses were performed using SPSS V.14.0.

**RESULTS**

A total of 1459 recreational runners signed up for the 4-mile running clinics. Among them, 899 were willing to participate in the study and completed the baseline questionnaire. Of the 899 who consented to participate, 24 were younger than 18 years and were therefore excluded. Data of 629 of 875 participants were analysed, 207 men (35%) and 422 women (67%). Two hundred forty-six participants neither started running nor returned their running diary over the full 8-week period. Consequently, they were excluded from data analyses.

**Baseline characteristics**

Baseline characteristics of 629 recreational runners are shown in table 1. Most of the participants used the training programme to restart running (44%) or were already participating in running (25%). The main reason for participating in the training programme was to improve fitness and health (70%). Male participants (35%) were 4.2 years older (\( p < 0.05 \)) than female participants (67%) and showed a significantly higher BMI (25.9 vs 24.4, \( p < 0.05 \)). Furthermore, male participants
and female participants was 7.5 (95% CI to 17.6). The difference between the incidence of RRIs per 1000 h of running exposure was 30.1 (95% CI 25.4 to 34.7). The difference in running experience, exposure time until the first RRI was used. To estimate the incidence, ie, the number of RRIs per 1000 h of running (without restriction of running) was included in the definition of RRI, the number of RRIs per 100 runners at risk, was significantly higher in male participants than in female participants (31.4% vs 23.2%, p = 0.05). Higher BMI in female participants was related to the risk of sustaining an RRI (p<0.05). The univariate Cox regression analyses also showed that in female participants (non-axial), previous sports activity (HR 1.8; 95% CI 1.1 to 3.2) and no previous running experience (HR 2.3; 95% CI 1.3 to 4.0) were significantly associated with the risk of sustaining an RRI. The only significant difference between male and female participants was the percentage of RRIs localised at the knee, that is, 23% in female versus 39% in male participants.

Risk factors for RRI
All variables assessed at baseline were analysed to see the relation with the occurrence of an RRI. An overview of all potential risk factors and hazard ratios is shown in table 3.

Univariate Cox regression analyses
The univariate Cox regression analyses showed that male participants were not at higher risk than female participants (HR 1.3; 95% CI 1.0 to 1.8). The variable age was significantly related with sustaining an RRI in male participants—that is, younger male runners were at higher risk of sustaining an RRI (p<0.001). Furthermore, running experience was protective for sustaining an RRI. BMI, motivation for entering the programme, previous sports activity and previous injury of the lower extremity were not significantly associated with RRI (p>0.05).

Multivariate Cox regression analyses
Table 4 shows the significant factors of the multivariate Cox regression models for male and female participants separately. Sex (male), corrected for age, BMI, previous sports activities and running experience were significantly related to RRI (HR 1.4; 95% CI 1 to 2). Older age was associated with lower risk of RRI in male participants. Lack of running experience was the most important risk factor for RRI in men (HR 2.6; 95% CI 1.2 to 5.5) and in women (HR 2.1; 95% CI 1.2 to 3.7). Furthermore, female runners who reportedly engaged in non-axial sports activities at baseline were at a higher risk (HR 1.9; 95% CI 1.1 to 3.2) of restarting running.

were less active in sports (43% vs 62% in female participants) before the training programme (p<0.05).

Running diary analysis

Exposure of running
Over the 8-week period of the programme, mean exposure time of running among female participants was 9.1 (SD 5.5 h) versus 9.8 (SD 5.3 h) for male participants. The novice runners ran 7.1 (SD 5.9 h), while the experienced runners had an exposure time of 13.1 (SD 5.4 h) in the 8-week training period. The increase of weekly exposure is illustrated in fig 2A–C.

Incidence of RRI
A total of 163 new RRIs were recorded by 629 runners at risk. To estimate the incidence, ie, the number of RRIs per 1000 h of running exposure, exposure time until the first RRI was used. Therefore, the exposure time in table 2 is somewhat lower than the total exposure time. The incidence of RRIs per 1000 h of running exposure was 30.1 (95% CI 25.4 to 34.7). The difference between the incidence of RRIs per 1000 h of exposure in male and female participants was 7.5 (95% CI 2 to 17.6). The injury rate ie number of RRIs per 100 runners at risk, was significantly higher in male participants than in female (31.4% vs 23.2%, p = 0.05). If pain as a result of running (without restriction of running) was included in the definition of RRI, the number of RRIs per 100 runners at risk would be as high as 59.9% in male and 60.6% in female participants.

Of all runners sustaining an RRI, 39 of 98 (40%) female runners and 24 of 65 (37%) male runners did not restart running during the 8-week training period (p>0.05). Among novice runners, significantly more (p = 0.02), that is, 50 of 62 (81%) did not restart running after sustaining an RRI, compared with 8 of 33 (24%) among runners who were already engaged in regularly running at baseline. Among the runners with previous running experience who had taken up running again, 25 of 68 (37%) did not restart running.

The anatomical distribution of all RRIs is shown in fig 3. The lower leg (calf and shin) was the most frequently injured anatomical site in women (35 of 98), and the knee in men (25 of 65). Most of the RRIs appeared at the knee and below in female (67%) and in male participants (80%). The only significant difference between male and female participants was the percentage of RRIs localised at the knee, that is, 23% in female versus 39% in male participants.

Table 1 Baseline characteristics

| Age (years)* | 43.7 (9.5) | 46.5 (9.4) | 42.3 (9.2) |
| Body mass index (kg/m²) | 24.9 (3.3) | 25.9 (3.2) | 24.4 (3.2) |

| Motivation | Health-oriented | 439 (69.8%) | 144 (69.6%) | 295 (69.9%) |
| Personal performance | 190 (30.2%) | 63 (30.4%) | 127 (30.1%) |
| Not previously active* | 280 (44.5%) | 118 (57.0%) | 162 (38.4%) |
| Previously active* | 349 (55.5%) | 89 (43.0%) | 260 (61.6%) |
| Hours per week (n = 349) | 2.4 (1.7) | 2.7 (1.8) | 2.3 (1.7) |
| No previous running experience | 199 (31.6%) | 56 (27.1%) | 143 (33.9%) |
| Restarting running | 275 (43.7%) | 100 (48.3%) | 175 (41.5%) |
| Already participating in running | 155 (24.6%) | 51 (24.6%) | 104 (24.6%) |
| Previous weekly running frequency (n = 155) | 2.3 (0.7) | 2.4 (0.9) | 2.2 (0.6) |
| Previous running hours per week (n = 155) | 1.2 (0.8) | 1.5 (1.0) | 1.1 (0.7) |

Values are mean (SD) or n (%).

*Significant difference between male and female, p<0.05.
sustaining an RRI. Higher BMI was also a risk factor for RRI in female participants (HR 1.1; 95% CI 1.0 to 1.1).

**Discussion**

The aim of this prospective cohort study was to determine the incidence of RRI, expressed as the number of RRIs per 1000 h of running and per 100 runners at risk, and to determine the sex-specific risk factors associated with RRI in runners who are training for a 4-mile (6.7 km) recreational running event in an 8-week period. Information gathered by means of this study is used to determine who are at risk for developing an RRI.

**Incidence and characteristics of RRI**

The incidence of RRI of 25.9% in our cohort of 629 recreational runners at risk is comparable with the incidences found in other studies. The “Vancouver Sun Run” study1 showed an injury incidence of 29.5% in a group of runners following a 13-week training programme preparing for a 10 km running event. A second study, also on recreational runners, showed an incidence of 58%,3 with novice participants training for a 15 km run during a period of 28 weeks. Since our study had a shorter follow-up and therefore less time at risk, the smaller number of RRIs per 100 runners at risk may be obvious. If we defined RRI according to the definition of Taunton et al1—pain as a result of running—the number of RRIs per 100 runners at risk would be as high as 60.4%.

Only a few studies on RRIs have assessed exposure time in a way that the incidence per 1000 h of exposure to running could be calculated. The overall incidence of 30 per 1000 h of running exposure was higher than the incidence of 12 per 1000 h found by Bovens et al3 Although the definitions of RRI were identical, duration of follow-up and ultimate goal of training were different—training for a marathon versus a 4-mile race. Lun et al4 found an incidence rate of 59 per 1000 h of exposure during a follow-up of 6 months. The most important difference with this study is that participants were already running more than 20 km/week at baseline. Also, 46 participants were lost to follow-up, whereas only 87 runners were included in the analyses. Our study showed that more than 70% of the RRI were localised at the knee and below. This result is in line with other studies on RRI.137 Novice runners were the most disadvantaged by an RRI, that is, they did not start running after sustaining an RRI. This might not be such a strange finding. Novice runners have no experience, and a 4-mile run can be a big hurdle for a novice runner. In this manner, by sustaining an injury, it is likely that the runner thinks that the remaining training time is too short for him or her to be able to complete the 4-mile run. A more experienced (recreational) runner may be able to listen properly to the language of his or her body, better than a novice runner. An experienced runner might also be able to feel or know whether he or she is able to complete the race, even without the full 8 weeks of training. Furthermore, an experienced runner is used to running on a regular basis and may be addicted to running, and therefore more likely to keep running.

**Potential risk factors for RRI**

**Sex**

The multivariate Cox regression model showed that male participants were at a higher risk than female participants. On the other hand, when sex was analysed univariately, there was no significant relation with RRI. Macera62 1 stated that in population-based studies, the injury rate was the same for male

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**Figure 2** Mean exposure time per week for (A) novice runners, (B) runners with previous experience who have taken up running again, and (C) runners who were already engaged in regular running.
and female recreational and elite runners. This finding is in contrast with the results from a recent systematic review article on risk factors for RRI in long-distance runners, in which the only statistically significant association for overall lower extremity running injuries showed a positive relation with the female sex. 13

Age and BMI

In the current study, younger age in male participants was positively associated with the risk of sustaining an RRI. This finding is supported by other studies that conclude that increasing age was significantly related with lower incidences of RRI. 7,21 A reason for this phenomenon could be "the healthy runner effect", whereby only those runners who stay injury-free continue to run. 7 On the other hand, only 25% of the participants in our study population were already engaged in regular running. Other studies conclude that increasing age is a statistically significant risk factor for sustaining an RRI. 18 Higher BMI is associated with sustaining an RRI in female participants. Heavier persons may have a higher risk of RRI because of the added physical stress of extra weight. 21 Different associations between BMI and RRI are found in the literature: Marti 7 found that lower BMI (< 19.5) and higher BMI (> 27) were risk factors for development of RRI.

Previous sports activities

Only women who where participating in sports activities without axial loading at baseline (eg, cycling and swimming) were 1.8 times at higher risk (95% CI 1.1 to 3.2) than women participating in sports activities with axial load at baseline, that is, sports involving running and jumping. Other studies found no clear links between participation in other sports activities and development of RRI. 7,8 The difference between our results and results from other studies could be caused by the fact that we categorised "previous sports activities" into axial loading and non-axial loading.

Running experience

Lack of running experience was the most important risk factor for male and female participants in this study (HR 2.6 in men and 2.1 in women). In another study on RRI, participants who were running less than 3 years were 2.2 times at a higher risk compared to the more experienced ones. 7 Review articles of van Mechelen 7 and Hoeberigs 24 also state that running inexperience is a major risk factor for sustaining an RRI. Although they arrive at the same conclusion, caution is advised when making a comparison with our study, since in those studies, running experience was assessed as the number of years engaged in running, and the study populations were different compared to our study, that is, participants had more running experience.

Previous injury of the lower extremity

No association was found between previous injury of the lower extremity and RRI. Hootman et al 6 stated that "previous lower extremity injuries that were completely healed should not increase the risk for a subsequent lower extremity injury". According to Taunton et al 6 of those with a previous injury, 42% indicated not being completely rehabilitated before starting with the training programme. It is not clear whether a high rate of re-injury suggests incomplete healing of the original injury, a personal susceptibility for re-injury, or an uncorrected biomechanical problem. A recent systematic review on incidence and determinants of lower extremity running injuries in long-distance runners showed strong evidence that a history of previous injuries was a risk factor for RRI. Again, most of the studies that were included consisted of participants engaged in long-distance running. Also, in most of the studies on risk factors for RRI, it is not clear whether previous injuries are about "running-related" injuries of the lower extremity. If that is the case, a personal propensity for an uncorrected biomechanical problem could be the explanation. 7

Conclusion

The incidence of RRI found in this study was 30.1 per 1000 h of running exposure. Of all runners at risk, 25.9% sustained an RRI during the 8-week period, and of those who sustained injury, 39% did not restart running.

Male and female participants have different risk profiles. The study showed that for male recreational runners, younger age and lack of running experience were significant risk factors for RRI. In female participants, higher BMI, type of previous sports activities (non-axial loading) and lack of running experience were all significant risk factors for sustaining an RRI during the 8-week follow-up. Male participants were more prone to sustain an RRI after correcting for age, BMI, previous sports activity and running experience. The highest drop-out rate was seen in novice runners after sustaining an RRI. Care should be taken

Table 2 Number and percentage of participants sustaining RRP and RRLs, total running exposure time, and incidence of RRI per 1000 h of running exposure during the 8-week follow-up

<table>
<thead>
<tr>
<th></th>
<th>Pain-free and injury-free</th>
<th>RRP</th>
<th>RRI</th>
<th>Exposure (h)</th>
<th>Incidence (n/1000 h) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Women (n = 422)</strong></td>
<td>166 (39.3%)</td>
<td>158 (37.4%)</td>
<td>98 (23.2%)</td>
<td>3565.4</td>
<td>27.5 (22.0 to 32.9)</td>
</tr>
<tr>
<td><strong>Men (n = 207)</strong></td>
<td>83 (40.1%)</td>
<td>59 (28.5%)</td>
<td>65 (31.4%)</td>
<td>1857.2</td>
<td>35.0 (26.5 to 43.5)</td>
</tr>
<tr>
<td><strong>Total (n = 629)</strong></td>
<td>249 (39.6%)</td>
<td>217 (34.5%)</td>
<td>163 (25.9%)</td>
<td>5422.6</td>
<td>30.1 (25.4 to 34.7)</td>
</tr>
</tbody>
</table>

RRI, running-related injury causing a restriction of running for at least 1 day; RRP, running-related pain without restriction of running.

Figure 3 Anatomical distribution of RRIs in male and female participants.
When interpreting this result as the study period was relatively short. Also, the sex-specific risk models for RRI showed that among both male and female participants, novice runners were the most at risk. These findings suggest that novice runners are the ones who may benefit most from preventive interventions for RRI.

### What is already known on this topic

Incidences of RRI in recreational runners is high.

### What this study adds

Accurate data collection of RRI and exposure resulted in more precise information on incidence of RRI in recreational runners and potential risk factors. This information gives health care providers the possibility to reach those runners who are most vulnerable for developing an RRI, that is, novice runners.

### REFERENCES


### Competing interests

None.