Scand J Med Sci Sports 2016: 26: 226–234
doi: 10.1111/sms.12424

SCANDINAVIAN JOURNAL OF
MEDICINE & SCIENCE
IN SPORTS

Risk factors for lower extremity injuries among half marathon and marathon runners of the Lage Landen Marathon Eindhoven 2012: A prospective cohort study in the Netherlands

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Accepted for publication 9 January 2015

To determine risk factors for running injuries during the Lage Landen Marathon Eindhoven 2012. Prospective cohort study. Population-based study. This study included 943 runners. Running injuries after the Lage Landen Marathon. Sociodemographic and training-related factors as well as lifestyle factors were considered as potential risk factors and assessed in a questionnaire 1 month before the running event. The association between potential risk factors and injuries was determined, per running distance separately, using univariate and multivariate logistic regression analysis. In total, 154 respondents sustained a running injury. Among the marathon runners, in the univariate model, body mass index ≥ 26 kg/m^2, ≤ 5 years of running experience, and often performing interval training, were significantly associated with running injuries, whereas in the multivariate model only ≤ 5 years of running experience and not performing interval training on a regular basis were significantly associated with running injuries. Among marathon runners, no multivariate model could be created because of the low number of injuries and participants. This study indicates that interval training on a regular basis may be recommended to marathon runners to reduce the risk of injury.

Long-distance running is very popular among participants of recreational sports (Van Gent et al., 2007; Van Middelkoop et al., 2008a; Van Poppel et al., 2014). In 2008, about 11.5% of the population in the United States ran and, of this group, 3.4% ran on average two times a week or more (Messier et al., 2008). In Europe, it is estimated that 36% of the population aged 15–65 years are recreational runners (http://www.everythingaboutrunning.asics.eu/). In the Netherlands, in 2012, about 1 900 000 people performed running activities and about 610 000 running injuries occurred (Van Hespen et al., 2012). However, in this study, it remains unclear how running injuries were defined.

Most running-related injuries occur in the lower extremities (Taunton et al., 2002; Van Gent et al., 2007; Chang et al., 2012; Lopes et al., 2012; Van Hespen et al., 2012; Van Poppel et al., 2014). A systematic review showed that the incidence of lower extremity running injuries ranged from 19.4–79.3% (Van Gent et al., 2007). running injuries ranged from 19.4 to 79.3% (Van Gent et al., 2007). The most common anatomical site of running injuries is the knee (Van Middelkoop et al., 2008a, b; Van Poppel et al., 2014).

Risk factors for running injuries have been well investigated (Sattertwhaite et al., 1999; Yeung & Yeung, 2001; Taunton et al., 2002, 2003; Ferber et al., 2003; Van Middelkoop et al., 2008b; Buist et al., 2010a, b; Harrast & Colonno, 2010; Chang et al., 2012; Rasmussen et al., 2013). However, because of the heterogeneity of the studies (e.g., definition of injury, recreational or elite runners, and short- or long-distance runners), no clear overview is available regarding the most important risk factors for running injuries.

Increased training volume per week in male runners, and a history of previous injuries for runners, are known significant risk factors for running injuries (Van Gent et al., 2007). However, there is conflicting evidence for other risk factors, such as age and sex (Macera et al., 1989; Sattertwhaite et al., 1999; Taunton et al., 2002; Buist et al., 2010a, b), training distance (Sattertwhaite et al., 1999; Van Middelkoop et al., 2008b; Chang et al., 2012; Lopes et al., 2012), running experience (Wen, 2007), body mass index (BMI; Buist et al., 2010b), and use of orthotics (Lopes et al., 2012; Beck et al., 2014).

This study was approved by the Medical Ethical Committee of Erasmus University Medical Centre.

Despite the common belief that factors like running terrain, type of shoe, and training characteristics (duration, frequency of running, running speed, warm-up, and exercise habits before running) might be associated with running injuries, there is no evidence for such an association (Hreljac et al., 2000; Yeung & Yeung, 2001; Ferber et al., 2003; Taunton et al., 2003). This lack of evidence could be related to the differences between the groups investigated in the various studies.

In previous systematic reviews, potential risk factors for running injuries were assessed in one heterogeneous group ranging from running distances of 5 km to marathon distances (42.195 km; Van Gent et al., 2007; Ristolainen et al., 2010). Differences in training characteristics (e.g., mileage, duration, frequency, and intensity of training) between these running distances are expected. For example, one study showed that marathon runners had fewer years of experience ($P < 0.05$), completed fewer weekly training kilometers ($P < 0.001$), and fewer weekly running hours ($P < 0.01$) compared with marathoners (Zillmann et al., 2013). If such factors differ between marathon and marathon runners and are potential risk factors for injuries, we hypothesize that that the incidence and risk factors for running injuries will differ between marathon and marathon runners. To our knowledge, no studies have prospectively evaluated the incidence of running injuries and risk factors for these injuries, in recreational male and female runners in a marathon (21.095 km) and marathon (42.195 km) during one event, both distances analyzed separately.

Therefore, this study aims to assess the incidence of running injuries in half marathon and marathon runners, as well as risk factors for running injuries in the lower extremities, of runners in the half marathon and marathon.

Methods

Study participants

Participants in the Lage Landen Marathon Eindhoven (October 14, 2012), an annual national running event, were invited to join this study. The runners participated in various distances: marathon (42.195 km), marathon (21.095 km), relay marathon (10.5 km), city run (5 km), or mini-marathon (2.5 km). During this event, the Dutch national championship marathon was also held.

Participants were included if they were recreational runners and ran the marathon or marathon. Exclusion criteria were registration ≤ 4 weeks prior to the start of the event, no email address available, competition runners, company runners, or missing baseline information. Based on low numbers of participants we also excluded the runners on the relay marathon from this study.

This study was approved by the Medical Ethical Committee of the Erasmus Medical Centre Rotterdam.

Data collection

Of the 14 155 participants, 5304 (37.5%) received an invitation by email to participate in this study. They received a link to an online baseline questionnaire 1 month before the Lage Landen Marathon Eindhoven (T0). These questionnaires were previously used in the Singelloop Breda study (Van Poppel et al., 2014) and the Rotterdam Marathon study Van Middelkoop et al. (2007, 2008a, b). All participants who returned the baseline questionnaire were included and received a follow-up questionnaire 1 week after the marathon event (the questionnaire is available from the authors on request). Nonresponders were sent a reminder by email within one week after the marathon.

At baseline, runners were asked to complete questions about demographic characteristics (age, sex, height, weight), training variables (weekly training frequency, weekly running distance, running speed during training, type of training, running terrain, warming up routine and type of running shoes), years of running experience, lifestyle (other sports, smoking, alcohol, nutritional, and overall health) and previous running injuries during the previous 12 months (location of injuries and current injury).

The follow-up questionnaire (T1) collected information on the running event (running distance and performance), new running injuries during the Lage Landen Marathon Eindhoven, location of injuries, and pain intensity measured on an 11-point Numeric Rating Scale (NRS; Gallasch & Alexandre, 2007; Mintken et al., 2009).

Risk factors

Risk factors of interest were training characteristics, i.e., weekly kilometers of running 8 weeks before the event, weekly frequency of running, type of running terrain, and type of training. Training distance, frequency of running and running experience were categorized into three groups (Chang et al., 2012).

Running terrain (hard, not hard, tartan track), training type (long-distance training and interval training), warming-up, cooling down and stretching activities had the following answer options: "always, often, sometimes, rarely, or never." "Always" and "often" were categorized as "often." Similar to another study, "sometimes, rarely and never" were categorized as "sometimes" (Van Middelkoop et al., 2008b).

Other factors of interest were sociodemographic variables such as age, gender, and BMI. BMI was categorized into three groups (≤ 20, 20–26, > 26; Taunton et al., 2003). Information on injuries incurred in the 12 months prior to the event was asked in a "yes" or "no" format.

Outcome

The outcome of interest was the presence of new running injuries during the Lage Landen Marathon Eindhoven as reported at follow-up (T1). Running injuries are defined as self-reported complaints of muscles, joints, tendons, or bones in the lower extremity (hip, groin, thigh, knee, lower leg, ankle, foot, and toe) caused by running activities. These complaints have to reduce the running intensity or frequency, or need medical consultation (Macera et al., 1989; Van Middelkoop et al., 2008b; Van Poppel et al., 2014).

Statistical analysis

Runners were categorized into two groups based on their running distance during the event: marathon (42.195 km) and marathon (21.095 km). Descriptive statistics were calculated for baseline characteristics, including frequencies for categorical variables and means and standard deviations (SD). In case the data did not show a normal distribution, medians and interquartile ranges (IQR) were calculated for continuous variables. Incidence rates were calculated according to the consensus statement of Timpka et al. (2014): (a) in-competition injuries as number of injuries per 1000 athletes, and (b) overall incidence as number of injuries per exposure hours during competition.

To evaluate possible risk factors, all determinants were first independently analyzed for their association with an injury using univariate logistic regression analysis for the participants on the half marathon and marathon separately. Correlations between all potential factors were calculated by Spearman's rho test. If a correlation between two factors was ≥ 0.8, only one of the risk factors was selected for the multivariate analyses. Factors with a *P*-value ≤ 0.20 in the univariate models were entered in the multivariate logistic regression model. Forward stepwise entering was used and $P \leq 0.10$ was applied as a cut-off level for acceptance. In the analysis, no more than one single variable was chosen for every 10 injuries (Peduzzi et al., 1996). Data were analyzed using the Statistical Package for Social Sciences, version 22 (SPSS, Chicago, Illinois, USA).

Results

Participants

In total, 943 runners (17.8%) returned the baseline questionnaire of which 39 missed baseline information and were therefore excluded. Of these, there were 40 relay marathon runners, which were also excluded. Of the remaining 864 runners, 614 runners (71.1%) responded to the follow-up questionnaire and were included in the analysis (Fig. 1); 464 participants (75.6%) ran the marathon and 150 (24.4%) participants ran the marathon.

Of all included participants, 570 participants (92.9%) started and finished their run, eight (1.3%) participants started but did not finish, and 36 (5.9%) persons did not start because of sickness or injuries.

At follow-up, 142 runners (23.1%) reported a total of 209 new injuries. Runners in the full marathon group had the lowest incidence rate of in-competition injuries with 226 injuries per 1000 athletes, followed by the marathon group with 237 injuries per 1000 athletes. Most of the injuries occurred in the knee (18.7%).

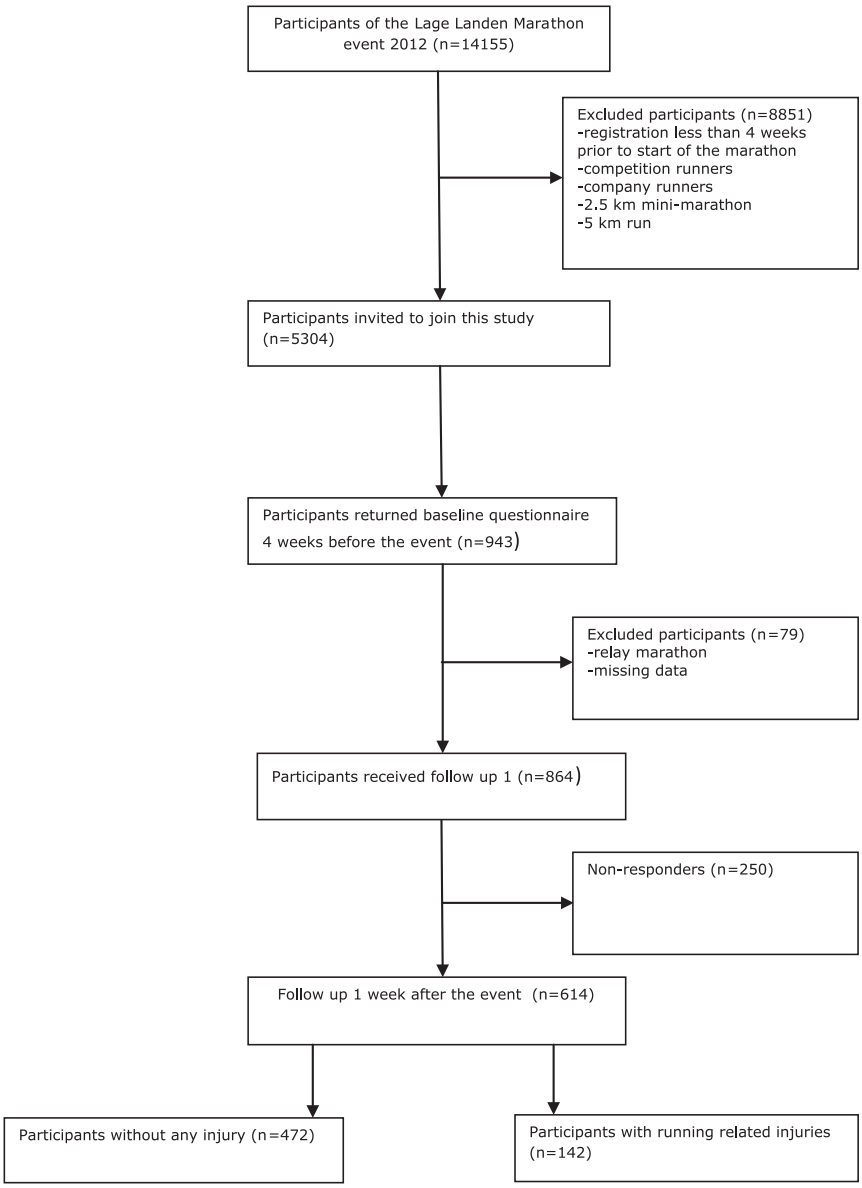

Fig. 1. Flowchart the Lage Landen Marathon Eindhoven 2012.

Table 1. Baseline characteristics of the participants of the Lage Landen Marathon Eindhoven

	Half marathon *n* = 464	Marathon *n* = 150	Total *n* = 614
	Number (%)	Number (%)	Number (%)
Gender males	311 (67.0%)	103 (68.7%)	414 (67.4%)
Age (years), mean (SD)	43.6 (11.4)	44.0 (11.1)	43.8 (11.2)
<20	46 (9.9%)	16 (10.7%)	62 (10.0%)
20–26	362 (77.7%)	118 (78.6%)	480 (78.2%)
>26	58 (12.4%)	16 (10.7%)	74 (12.1%)
Previous injury 12 months (% yes)	285 (61.2%)	82 (54.7%)	367 (59.8%)
0–4	221 (47.4%)	59 (39.3%)	298 (45.6%)
5–10	112 (24.0%)	49 (32.7%)	161 (26.2%)
>10	133 (28.5%)	42 (28.0%)	175 (28.5%)
Trainings distance (km/week)			
<20	119 (25.5%)	39 (26.0%)	158 (25.7%)
20–40	226 (48.5%)	65 (43.3%)	291 (47.4%)
>40	121 (26.0)	46 (30.7%)	167 (27.2%)
Training frequency (times/week)			
0–2	19 (4.1%)	1 (0.7%)	20 (3.3%)
2–5	434 (93.1%)	144 (96.0%)	578 (94.1%)
>5	13 (2.8%)	5 (3.3%)	18 (2.7%)
Running speed (km/h), median (IQR)	11.0 (2.0)	11.0 (2.0)	11.0 (2.0)
Hard training underground (% often)	406 (87.1%)	130 (86.7%)	536 (87.3%)
No hard training underground (% often)	127 (27.3%)	40 (26.7%)	167 (27.2%)
Tartan training underground (% often)	48 (10.3%)	18 (12.0%)	66 (10.7%)
Long-distance training (% often)	433 (92.9%)	140 (93.3%)	573 (93.3%)
Interval training (% often)	213 (45.7%)	61 (40.7%)	274 (44.6%)
Warming up before training (% often)	215 (46.1%)	71 (47.3%)	286 (46.6%)
Stretching before training (% often)	237 (50.9%)	67 (44.7%)	304 (49.5%)
Cooling down after training (% often)	194 (41.6%)	65 (43.3%)	2595 (42.2%)
Stretching after training (% often)	299 (64.2%)	82 (54.7%)	381 (62.1%)
Organized running in groups (% yes)	210 (45.1%)	62 (41.3%)	272 (44.3%)
Shoe advice (% yes)	406 (87.1%)	131 (87.3%)	537 (87.5%)
Participation other sports (% yes)	290 (62.2%)	89 (59.3%)	379 (61.7%)
Daily smoking (% yes)	17 (3.6%)	6 (4.0%)	28 (3.7%)
Alcohol use (glasses/week), median (IQR)	4.0 (6.0)	4.0 (6.0)	4.0 (6.0)
Special feeding supplements (% yes)	136 (29.2%)	51 (34.0%)	187 (30.5%)
Running injuries (% yes)	110 (23.6%)	34 (22.7%)	144 (23.5%)

BMI, body mass index; IQR, interquartile range; SD, standard deviation.

Baseline characteristics

The mean age of the runners was 43.7 (SD 11.2) years; 67.1% was male and the average BMI was 23.1 (SD 2.5) kg/m^2. Table 1 presents the demographic characteristics, training-related characteristics, lifestyle, and running injuries. No differences were found between responders and non-responders ($P < 0.05$). About 60% of the runners suffered one or more running injuries during the 12 months preceding the baseline questionnaire. Almost 55% of the runners had ≥ 5 years of running experience. Training-related characteristics were similar between marathon and marathon runners. The majority of runners (87.0%) ran mostly on hard underground, whereas 27.0% also reported to run mostly on soft underground. Long-distance training is the most frequently used training in all groups (93.1%); 44.1% of the runners also used interval training. The incidence per 1000 h running was 107 injuries. Categorizing runners by running distance, the incidence was 131 injuries per 1000 h of running among marathon runners and 66 injuries per 1000 h of running among marathon runners.

Risk factors

Univariate analysis

Among half marathon runners, five risk factors were independently associated with running injuries ($P < 0.20$; Table 2), i.e., gender (OR 1.44; CI 0.90–2.32), BMI ≥ 26 kg/m^2 (OR 3.00; CI 1.08–8.34), ≤ 5 years of running experience (OR 1.77; CI 1.07–2.92), not performing regular interval training (OR 0.55; CI 0.35–0.85), and a weekly training frequency of one time per week (OR 0.25; CI 0.04–1.45). Three of these factors were significant risk factors in the univariate analysis ($P < 0.05$), i.e., BMI (> 26), running experience (0–4 years) and not (often) performing interval training.

Among marathon runners, eight risk factors were associated with running injuries ($P < 0.20$) (Table 2): BMI ≥ 26 kg/m^2 (OR 0.24; CI 0.40–1.43), weekly training distance ≤ 20 km/week (OR 0.47; CI 0.17–1.32), weekly training frequency ≥ five times per week (OR 5.70; CI 0.91–35.67), tartan surfaces (OR 2.48; CI 0.88–6.99), regularly performing interval training (OR 1.91;

Table 2. Univariate odds ratios (ORs) for running injuries vs no injuries in runners of the half marathon and marathon group

Variables	Half marathon (n = 466)			Marathon (n = 150)		
	OR	95% CI	P-value	OR	95% CI	P-value
Age (years)	0.99	0.97–1.01	0.22	0.99	0.96–1.03	0.47
Gender (male)	1.44	0.90–2.32	0.13*	0.26	0.56–2.83	0.57
BMI (kg/m^2)						
<20	1.44	0.79–2.65	0.24	0.51	0.11–2.37	0.39
20–26	1		0.11*	1		0.24
>26	3.00	1.08–8.34	**0.04***	0.24	0.40–1.43	0.12*
Previous injury (yes)	0.83	0.53–1.29	0.41	0.91	0.43–1.97	0.82
Running experience (years)						
0–4	1.77	1.07–2.92	**0.03***	1.390	0.55–3.54	0.49
4–10	1.19	0.68–2.09	0.55	1.226	0.47–3.21	0.68
>10	1		0.07*	1		0.79
Training distance (km/week)						
<20	0.93	0.51–1.71	0.82	0.47	0.17–1.32	0.15*
20–40	1		0.91	0.77	0.30–2.01	0.59
>40	0.89	0.53–1.51	0.67	1		0.33
Training frequency (times/week)						
0–2	0.25	0.04–1.45	0.12*	0.00	0.00	1.00
2–5	1		0.14*	1		0.18*
>5	0.61	0.13–2.79	0.52	5.70	0.91–35.67	0.06*
Hard underground (often)	0.68	0.38–1.25	0.21	0.86	0.29–2.57	0.79
No hard underground (often)	1.20	0.75–1.91	0.46	0.70	0.30–1.60	0.40
Tartan underground (often)	0.84	0.40–1.74	0.63	2.48	0.88–6.99	0.09*
Long-distance training (often)	1.42	0.57–3.54	0.45	0.66	0.16–2.72	0.57
Interval training (often)	0.55	0.35–0.85	**0.01***	1.91	0.88–4.13	0.10*
Warming up before training (often)	0.84	0.54–1.29	0.41	1.34	0.62–2.88	0.46
Stretching before training (often)	1.10	0.72–1.69	0.65	0.97	0.45–2.10	0.94
Cooling down after training (often)	0.83	0.54–1.29	0.40	1.93	0.89–4.17	0.10*
Stretching after training (often)	1.08	0.69–1.69	0.75	1.71	0.78–3.78	0.18*
Organized running in groups (yes)	1.19	0.77–1.83	0.43	0.54	0.25–1.17	0.12*
Shoe advice (yes)	0.79	0.40–1.54	0.48	1.11	0.34–3.61	0.86
Participation other sports (yes)	0.97	0.63–1.51	0.90	1.03	0.47–2.24	0.95
Daily smoking (yes)	0.88	0.61–1.28	0.51	0.99	0.51–1.92	0.96
Alcohol use (glasses/week)	1.22	0.69–2.17	0.50	1.02	0.93–1.10	0.73
Special feeding supplements (yes)	1.36	0.83–2.21	0.22	0.93	0.42–2.07	0.86

OR > 1.00 is a risk factor; OR < 1.00 is a protective factor.

*Entering multivariate model $P < 0.20$; bold: significance $P < 0.05$.

CI, confidence interval.

CI 0.88–4.13), regularly performing cooling down (OR 1.93; CI 0.89–4.17), stretching afterwards (OR 1.71; CI 0.78–3.78), and organized running in groups (OR 0.54; CI 0.25–1.17). None of them were significant risk factors by univariate analysis ($P < 0.05$).

Multivariate analysis

In the marathon group, all five univariately associated factors were entered in the multivariate logistic regression analysis to develop a risk model (Table 3). Running experience for ≤ 5 years, and not performing interval training, were included in the final risk model.

Because the injury rate in the marathon group was low, it was not possible to create a multivariate logistic regression model to assess the combined effect of the eight factors found on the univariate analysis.

Table 3. Multivariate regression model (forward stepwise) for running injuries vs no injuries in runners of the half marathon (n = 466)

Variables	OR	95% CI	P-value
Running experience			
<5 years	1.87	1.13–3.11	0.02
5–10 years	1.14	0.64–2.01	0.66
>10 years (reference)	1		0.04
Interval training (always vs sometimes)	0.67	0.33–0.81	<0.01
Nagelkerke R^2			0.045

Only entered variables shown; OR, odds ratio; CI, confidence interval.

Discussion

This study assessed the incidence of running injuries and the risk factors for running injuries in the lower extremities of marathon and marathon runners. In the total study sample, the incidence rate was 23.1%. Also, in the half marathon group, ≤ 5 years of running experience and not often performing interval training were significantly associated with running injuries of the lower extremity. In the short-distance group and the marathon group, it was not possible to calculate a risk model because of the relatively small numbers of participants and injuries in these specific distances.

Comparison with other studies

In the present study, the incidence of lower extremity injuries in the half marathon group was 23.6%, compared with 42.4% among half marathon runners in another study (Chang et al., 2012). An explanation for the difference could be the training distance per week, i.e., in our study 74.5% of the runners ran ≥ 20 km/week and 52.5% had ≥ 5 years running experience, compared with 35.5% and 35.4%, respectively, in the earlier study (Chang et al., 2012). Our runners may have developed some musculo-skeletal adaptation to running due to a higher weekly training distance and more years of running experience, thereby being less predisposed to develop injuries during long-distance running (Van Middelkoop et al., 2008b; Rasmussen et al., 2013).

Our marathon runners show a rate of running injuries of 22.7%; this lies within the range of 18.2–23.8% reported by others for marathon runners (Sattertwhaite et al., 1999; Van Middelkoop et al., 2008a). However, due to lack of information about training-related characteristics, comparison between our study and others is limited (Sattertwhaite et al., 1999).

In marathon runners, Van Middelkoop et al. (2008b) reported an average weekly training distance of 50.2 (SD 18.3) km and 21.3% ran ≥ 60 km/week, whereas in the present study, 30.7% of marathon runners ran ≥ 40 km/week. Other training-related variables were similar to those in the present study. Therefore, it is possible that the lower rate of running-related injuries reported by Van Middelkoop et al. (2008b) was due to a higher weekly training distance. Compared with males, female gender is also a risk factor for running injuries (Newman et al., 2013; Rauh, 2014). This could explain why the incidence rates in our study were higher than those of van Middelkoop et al., as the present study also included females (31.3%). Another explanation could be that most of our runners ran ≤ 30 km/week. The incidence of running injuries is reported to be lower when runners run ≥ 30 km/week (Rasmussen et al., 2013).

A higher amount of training is reported to be a risk factor for injuries in endurance athletes (Ristolainen et al., 2014). Exposure time in a marathon is over twice as long as in the marathon (world record for the marathon is 2:02:75 in Berlin 2014, and for the marathon 58:23 in Lisbon 2010), and running characteristics differed between marathon and marathon runners in terms of experience, weekly training kilometers and weekly running hours (Zillmann et al., 2013). marathon runners had fewer years of experience, completed fewer weekly training kilometers, and fewer weekly running hours compared with marathoners.

We hypothesized that the percentage of running injuries would be higher in the marathon group than in the half marathon group and that training-related characteristics would differ between the two groups. Therefore, a higher mileage per week (44.7 km/week) and a higher weekly training frequency (3.7 training units a week) and speed (11.1. km/h) were expected among marathon runners (Hamstra-Wright et al., 2013; Hispanol et al., 2013; Zillmann et al., 2013). However, both our groups showed little differences in training-related characteristics. An explanation for the similar rate of running injuries in both groups could be that runners switched their running distance, i.e., participants who registered for the marathon in fact ran half a marathon. Also, half marathon runners in this event could be training for a marathon later that same year.

Weekly running frequency was also similar between half marathon and marathon runners and was not significantly associated with running injuries. This study reveals that in the half marathon group, 2.8% and in the marathon group, 3.3% ran ≥ five times/week, whereas another study reported 23.9% and 50.4%, respectively, for the running frequency ≥ five times/week (Chang et al., 2012). In the present study, it remains unclear why only 3.3% of the marathon runners trained ≥ 5 times a week. An explanation could be that we excluded competition runners, who are more likely to train more frequently than recreational runners.

In the study population of Chang et al., 87.4% of the participants were males compared with 67.4% in our study; however, this does not explain the differences in training frequency. An explanation could be that, in our study, half marathon and marathon runners seem to run less frequently, but a longer distance, than the runners in the study of Chang et al., who ran more frequently but a shorter distance. In our study, only 2.7% of the runners ran ≥ 5 times/week compared with 31.1% in the study of Chang et al.; 15.4% of the runners in the latter study ran ≥ 40 km/week (Chang et al., 2012), whereas in our study, 27.2% ran at least 40 km/week. Although the results in the present study differ from those reported by Chang et al. (2012), we also found no significant association between weekly frequency and running injuries in our two groups. An explanation could be the categorizing of weekly running frequency into three groups: the majority of runners (93.9%) reported a weekly frequency of 2–5 times/week. Therefore, we hypothesize that categorizing weekly frequency into a smaller range would make a difference.

Running on a hard surface (e.g., concrete or asphalt roads) was found to be a risk factor for running injuries (Macera et al., 1989; Chang et al., 2012), whereas others found no association between lower extremity injuries and type of running terrain (Macera et al., 1989; Taunton et al., 2003). It is suggested that, compared to hard surfaces, softer surfaces (e.g., grass, forest or tartan surface) provide more shock absorption and may reduce the possibility of getting running injuries and that, therefore, the running terrain had a great impact on lower extremity kinematics (Sattertwhaite et al., 1999). In the present study, despite that 87% of the participants ran on hard surfaces, no association was found with running injuries

in either group, and other surfaces were not associated with running injuries, as reported by others (Van Gent et al., 2007; Van Middelkoop et al., 2008b; Chang et al., 2012). A possible explanation for the lack of association with running terrain is provided in a study showing that use of soft shoe insoles, or insoles with a medical arch, can protect runners from knee or hip pain. This might improve kinematics and reduce shock absorption, possibly explaining why hard surfaces are not associated with injuries. On the other hand, a randomized-controlled trial showed that routine use of orthotic insoles did not prevent physical stress-related lower limb injuries in healthy young male adults (Matilla et al., 2011). Another study reported that the use of orthotic insoles was more prevalent in patients with tibial stress injury than in controls (25% vs 5.6%, respectively; $P < 0.02$; Beck et al., 2014).

The present study revealed a protective association for interval training in both groups, besides long-distance training among half marathon runners. This result is in line with a similar study (Van Middelkoop et al., 2008b); the latter authors reported a lack of interval training as a significant risk factor for the occurrence of knee injuries in marathon runners (Van Middelkoop et al., 2008b). This might be a focus for the future to reduce the incidence of running injuries in the lower extremities.

Another risk factor for running injuries emerging from this study was ≤ 5 years running experience. Other studies also identified running experience as a risk factor for running injuries of hamstrings, knee, or foot (Macera et al., 1989; Taunton et al., 2003; Van Gent et al., 2007; Van Middelkoop et al., 2008b), whereas one study showed conflicting evidence between running experience and running injuries (Sattertwhaite et al., 1999). If experienced runners have developed musculo-skeletal adaptation to running compared with novice runners, they may be less predisposed to injuries. Additionally, they may be better able to interpret their body's signals and hence train more appropriately before running injuries occur (Van Middelkoop et al., 2008b; Rasmussen et al., 2013).

Strengths and limitations

This study has several limitations. First, the response rate is lower than in similar studies (Van Middelkoop et al., 2008b; Chang et al., 2012; Rasmussen et al., 2013; Van Poppel et al., 2014). However, response rates for email surveys are known to be lower than paper and pencil surveys (Cook et al., 2000), which might explain the lower response rates in our study. Selection bias cannot be ruled out because people with injuries may be more highly motivated to participate in the study. Moreover, recall bias might be present; however, this seems unlikely in the follow-up questionnaires because participants were asked for information about their injuries relatively quickly after the event. With regard to the baseline questionnaire, recall bias could be present because information about the prevalence of injuries was collected up to 1 year before the running event. Following the rules of statistical analysis, not more than one single parameter was chosen for every 10 injuries (Peduzzi et al., 1996); the study sample was too small to perform multivariate analysis in marathon runners.

Thirdly, according to the definition of injuries, an injury is evident as self-reported complaints of muscles, joints, tendons, or bones in the lower extremity (hip, groin, thigh, knee, lower leg, ankle, foot, and toe) because of running activities. These complaints have to reduce the running intensity or frequency, or need medical consultation. This definition has been used previously (Van Middelkoop et al., 2007, 2008a, b; Van Poppel et al., 2014) but is slightly different from a recent international consensus on defining an injury reported by Timpka et al. (2014). Hereby, an injury is defined as: "A physical complaint or observable damage to body tissue produced by the transfer of energy experienced or sustained by an athlete during participation in Athletics training or competition, regardless of whether it received medical attention or its consequences with respect to impairments in connection with competition or training." This difference may have led to an underestimation of the running injuries in the present study.

The exact diagnosis of injuries remains unknown. Although no systematic physical investigation was made to objectify injuries, we had a good insight into the self-reported pain and discomfort of running injuries reported by the runners themselves. However, participants may apply the criteria for answering the questions differently. For example, this could, have led to an overestimation of running-related injuries, while complaints of post-exercise muscle soreness are interpreted as an injury according to our definition. Conversely, there could also be an underestimation if participants did not report any injuries because of the absence of impairments in training or competition and/or medical consultation with regard to the definition from the recent consensus (Timpka et al., 2014). In view of these limitations, our results should be interpreted with caution.

The incidence rate of running injuries could also be biased by a self-selection process of runners, who may have switched their running distance before the start of the race. Overestimating or underestimating their physical capacity, e.g., because of training or occurrence of pain preceding the race, could bias incurring injuries. This might also explain why only a minor difference in training-related characteristics was found between marathon and marathon runners, while greater differences were expected. Also, because all outcomes (including running injuries) and determinants were obtained based on self-reported questionnaires, the validity of the information is debatable. Self-report studies are biased by the person's feelings at the time they filled in the questionnaire (Schwarz, 1999). Thirdly, the final model is weak.

It is possible that we missed other potential risk factors, such as psychosocial or other physical factors.

Despite these limitations, the results of this study may contribute to the growing body of knowledge that describes the need for examining, separately, the risks and risk factors for injury among half marathon and marathon runners.

Results cannot be generalized to competition runners.

Perspectives

The present results do not support the hypothesis that the incidence of running injuries differs between different distances of a running event. Also, risk factors did not differ between marathon and half marathon runners. This study shows that interval training on a regular basis before running a half marathon had a protective effect against running injuries. Also in marathon runners, ≤ 5 years of running experience compared with ≥ 10 years of running experience is shown to be a risk factor.

Medical professionals and coaches could use the present findings to advise potential runners and inexperienced runners planning to run a half marathon, how to potentially reduce the risk of running injuries. It seems useful to perform interval training on a regular basis. However, caution is required when interpreting these results because of a possible biased rate of running injuries and possible information bias because of self-reported questionnaires.

Future studies with larger populations will enable to categorize more groups and determinants to discriminate between risk factors related to different running distances.

Key words: Running-related injuries, risk factors, running.

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