Lower Extremity Complaints in Runners and Other Athletes

Marienke van Middelkoop

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Copromotor

Dr. S.M.A. Bierma-Zeinstra

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Chapter 1

General introduction

INTRODUCTION

Because of the expected positive health effects of physical exercise, more and more people are becoming stimulated to increase their physical activity. Running is one of the most accessible sports and, probably for this reason, is practiced by many persons all over the world. In the Netherlands, an estimated 3.9 million people practiced the running sport in 2005. Of these runners, 1.6 million people (10% of the entire population) practiced the running sport for at least once a week.[1] However, besides the positive health effects of running there are some concerns about the high incidence of running injuries, especially to the lower extremities. Various studies have reported annual rates of lower extremity injuries of runners[2-8] and a substantial number of these running injuries occur in preparation for or during a long-distance running event such as a marathon run.[3, 6, 9, 10] A review of literature from Van Mechelen[11] yielded incidence rates of running injuries ranging from 24% to 77%. This indicates the wide range found for the incidence of running injuries. However, after the publication of that review new studies have emerged. Therefore we performed an updated systematic review to provide an overview of the recent literature on the incidence on and risk factors for running injuries. In order to promote the prevention of running injuries it is also of interest to enlarge knowledge concerning potential risk factors, especially modifiable risk factors. Furthermore, the course of running injuries is currently unknown, because no study until now has included follow-up measurements of the injured runners. Consequently, the possible prognostic factors for persistent complaints of these injuries are also unknown. The identification of prognostic factors for injured runners at risk for developing persistent complaints may assist the selection of patients who will most likely benefit from early interventions to prevent persistent complaints. Therefore, the Rotterdam marathon study was set up in 2005 to investigate these factors and will be presented in this thesis.

It is known that about 40% of all sport injuries involve the knee.[12] In the Netherlands, a large percentage of athletes with knee complaints will visit their general practitioner (GP) for primary health care. Therefore, it is of interest to investigate if there are any substantial differences in type of knee complaints presented to the GP between athletes and non-athletes. Further, it might be possible that the policy-making of the GP is influenced by the physical activity level of persons presenting themselves to the GP. For example, there might be a difference in medical consumption because of the gatekeeper function of the GP in the Netherlands.

An open population study among the Dutch general population revealed a one-year prevalence of 21.9% of knee pain.[13] As mentioned above, musculoskeletal complaints are often associated with physical activity. However, the relationship between physical activity and musculoskeletal complaints is complex: participation in sport activities can be a threat to musculoskeletal pain due to injuries, but sport and physical activity can also be protective towards musculoskeletal complaints. Because of this complex relationship it is meaningful to investigate the possible differences in prevalence and incidence of musculoskeletal pain between athletes and non-athletes.

STUDY AIMS AND OUTLINE OF THIS THESIS

The aim of **chapter 2** is to present an overview of the current literature addressing the incidence of and risk factors for injuries among long-distance runners. **Chapter 3** describes the prevalence and incidence of lower extremity injuries occurring before and during the Rotterdam marathon, and evaluates the impact of the injuries. **Chapter 4** examines the relationship between possible risk factors and lower extremity injuries occurring shortly before or during a marathon run. **Chapter 5** investigates the 3-month course of running injuries occurring shortly before or during the Rotterdam marathon, and evaluates possible prognostic factors for persistent complaints among recreational marathon runners. The aim of **chapter 6** is to investigate differences in knee complaints between athletes and non-athletes presenting in general practice with respect to: a) type of knee complaints, b) initial policy of the GP, c) medical consumption, and d) prognosis. **Chapter 7** investigates the pattern of musculoskeletal pain among athletes and non-athletes in a general population with respect to: a) type, location, severity and cause of complaints, b) type and intensity of sports activity, and c) the medical consumption. Finally, **chapter 8** addresses the most important results of the studies, as well as the study limitations and their implications.

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Chapter 2

Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review

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ABSTRACT

The purpose of this study was to present a systematic overview of published reports on the incidence and associated potential risk factors of lower extremity running injuries in long distance runners. An electronic database search was conducted using the PubMed–Medline database. Two observers independently assessed the quality of the studies and a best evidence synthesis was used to summarise the results. The incidence of lower extremity running injuries ranged from 19.4% to 79.3%. The predominant site of these injuries was the knee. Strong evidence was found for an increased risk of running injuries in the case of a long training distance per week in male runners, and for a history of previous injuries. Strong evidence was also found for a protective effect for knee injuries of an increase in training distance per week.

INTRODUCTION

Sports activities and exercises are known to have a positive influence on a person's physical fitness, as well as to reduce the incidence of obesity, cardiovascular disease, and many other chronic health problems.[1-4] Because of its easy accessibility, long distance running is practised by many people and along with the growing interest in disease prevention it continues to increase in popularity. However, running may also cause injuries, especially to the lower extremities. Various studies have reported on the prevalence and incidence of running injuries occurring in long distance runners during training or races.[2, 4, 5] Risk factors contributing to these injuries have also been reported.[2, 5, 6]
To help prevent such injuries it is necessary to summarise knowledge about potential risk factors. Thus the primary purpose of this study was to present an overview of published reports describing the incidence of various running injuries of the lower extremities in long distance runners. Our second aim was to identify risk factors associated with these running injuries.

METHODS

Search

The PubMed–Medline database, available through the NCBI (National Center for Biotechnology Information), was consulted up to May 2006 using search items concerning running injuries combined with the anatomical sites at which these injuries occur, and search items excluding specific publication types in which we were not interested. The search strategy is specified in the appendix. Additionally, all references in the articles included were screened according to the criteria described below.

Study criteria

Abstracts

The search in PubMed–Medline produced a group of abstracts which were screened using the following criteria:

- The subject of the study was running injuries to the lower extremities occurring in long distance runners. We included only studies where subjects ran ≥5 km per training or race, or both.
- The runners were recreational or competitive runners, but not belonged to the elite group (which presumably can rely on a better medical support).
- The study described epidemiology (prevalence, incidence) or aetiology (determinants) of lower extremity running injuries, or both.

- The study included a study population of at least 10 individuals (cross sectional studies, prospective cohort studies, retrospective cohort studies, case-control studies, case series and clinical trials).
- The study was written in English, Dutch, German, French, Spanish, Italian, Danish, Norwegian, Swedish, Icelandic or Indonesian.

Full text articles

Based on this first screening a selection of articles was made, which was further narrowed down using the following criteria after reading the full text of the articles.
Inclusion criteria: prospective cohort studies, cross sectional studies, retrospective cohort studies with a follow up period of maximum one month, and randomised clinical trials.
Exclusion criteria: studies in which the participants were predominantly exposed to types of sporting activity other than running (such as triathlon, military training programmes, and so on), and studies describing populations, which only take part in cross country running.

Quality scoring

To analyse the quality of the selected studies we used the following list of questions: (1) a clear definition of inclusion criteria; (2) description of demographic characteristics; (3) use of a prospective study design; (4) follow up of at least 80% of the included subjects; (5) information of withdrawals describing their demographic characteristics.
To examine risk factors appropriately we sought: (6) measurement of determinants at baseline or independently from injuries (blinding); (7) presentation of data and statistical significance (percentages, odds ratios (ORs), relative risks (RRs), p values); (8) the use of multivariate analysis to adjust for other risk factors and confounding variables.
The quality score was calculated for each study, based on the sum of the eight items specified above and scored as positive. It could therefore range from 0 to 8. Articles were judged as high quality studies when they had a quality score of 4 or more (≥50% of the maximum attainable score). Two observers (RNvG and DS) obtained the quality scores of the studies independently, so that K-values could be calculated to describe the interobserver agreement. The K-values both for the interobserver agreement in studies describing the incidence or prevalence of lower extremity running injuries (in this calculation questions 6, 7, and 8 were left out of consideration) and for the interobserver agreement in studies describing determinants for these injuries (in this calculation all eight questions were included) were calculated separately. A K-value of >0.7 indicates a high level of agreement between assessors, a value between 0.5 and 0.7 a moderate level of agreement, and a value <0.5 a poor level of agreement.[7] In case of disagreement, a final decision was made by a third observer (SMAB-Z).

Analysis

SPSS 10.1 was used to calculate K-values of the quality score. For the determinants of injuries, we calculated some ORs that were not given in the reports but could be obtained from the raw data. To summarise ORs and RRs, a best evidence synthesis was used, because clinical and statistical homogeneity across the studies was absent. The level of evidence was ranked based on the guidelines of Van Tulder et al.[8] and was divided in the following levels:

- *Strong evidence*: consistent findings (in ≥75% of the studies) among multiple (≥2) high quality studies.
- *Moderate evidence*: consistent findings (in ≥75% of the studies) among one high quality study and multiple low quality studies.
- *Limited evidence*: consistent findings (in ≥75% of the studies) among multiple low quality studies or one high quality study.
- *Conflicting evidence*: provided by conflicting findings (fewer than 75% of the studies reported consistent findings).
- Only statistically significant associations were considered as associated factors.

RESULTS

After examining the 1113 titles and abstracts, 172 articles were identified as potentially relevant. The full texts of 166 of these articles were retrieved (this was not possible for six), and were subsequently evaluated by both observers. Review of the complete texts excluded 155 articles, because they did not meet our criteria; thus 11 articles were selected in our study. In addition to this selection, we included six more articles after searching through the references of these 11 selected articles. Therefore our final selection comprised 17 articles (1.5%). Most of these were published in English, but there were two foreign language publications (one German and one Norwegian).

Description of the studies

Thirteen prospective cohort studies[9-21] and four retrospective cohort studies[22-25] were included. The study characteristics of the selected studies were described to obtain insight into the homogeneity of the study populations (table 1).

The follow up period in the studies ranged from 1 day to 18 months. The studies contained runners participating in specific training programmes or races from 4 km to a full marathon. Two studies included runners who were followed during one season of training and race participation.[9, 13] In one of the studies, runners wished to be notified of upcoming road races, but their exact training programme or race attendance was unknown.[14] The proportions of subjects analysed ranged from 41.8% to 100%. Both the population characteristics and

Table 1 Study characteristics

Author, year of publication	Study design (follow-up period)	Running type	Number included/ analysed (%)	Description of population	Injury definition	Quality score of study
Taunton et al. 2003[19]	Prospective cohort (12-13 weeks)	Recreational runners, registered in training clinics, interested in either completing a 10 km race or improving their existing race time	1020 / 844 (82.7%)	24.4% ♂: 75.6% ♀ ♂, age(y): 12.3% <30, 51.5% 31-49, 19.1% 50-55, 17.2% >56 ♂, BMI: 1.0% <19, 55.1% 20-26, 41.0% >26 ♀, age(y): 18.6% <30, 63.6% 31-49, 11.5% 50-55, 6.3% >56 ♀, BMI: 4.3% <19, 69.8%, 20-26, 16.7% > 26	Experiencing pain only after exercise (grade 1); pain during exercise (grade 2); pain during exercise and restricting distance or speed (grade 3); pain preventing all running (grade 4).	6
Lun et al. 2004[12]	Prospective cohort (6 months)	Recreational runners, running more than 20 km/ week	153 / 87 (56.8%)	50.6% ♂: 49.4% ♀ 38.0 y	Any musculoskeletal symptom of the lower limb that required a reduction or stoppage of a runners' normal training.	6
Steinacker et al. 2001[18]	Prospective cohort (6 months)	58 runners in training for a marathon, of which 42 did participate in a marathon	58 / 58 (100%) of which 42 ran a marathon	62.1% ♂: 37.9% ♀ ♂: 43.6 y, 76.3 kg, BMI 23.1 ♀: 45.5 y, 61.7 kg, BMI 23.3	Injuries and having had to skip training	3
Satterthwaite et al. 1999[17]	Prospective cohort (1 week)	Runners participating in a marathon	1054 / 875* (83.0%)	Age (y): 5.7 % <25, 12.5% 25-29, 17.4% 30-34, 21.3% 35-39, 43.2% ≥40	1) Injuries and other health problems sustained by runners attending the medical aid posts.	6
Satterthwaite et al. 1996[16]			1054 / 916 (86.9%)#	80.3% ♂: 19.7% ♀ ‡ 38.6 ± 9.8 y (range 19-74 y)	2) Specific health problems using a matrix of 13 body sites and 11 problem types sustained both during or immediately after the marathon and in the seven days following the marathon	7

Author, year of publication	Study design (follow-up period)	Running type	Number included/ analysed (%)	Description of population	Injury definition	Quality score of study
Wen et al. 1998[21]	Prospective cohort (32 weeks)	Runners participating in a training program for a marathon	355 / 255 (71.8%)	42.0% ♂: 58.0% ♀ 41.8 ± 10.8 y ♂: 176.8 ± 6.3 cm, 79.3 ± 11.7 kg ♀: 164.3 ± 7.3 cm, 64.1 ± 12.3 kg	Answering yes to having had "injury or pain" to an anatomic part; answering yes to having had to stop training, slow pace, stop intervals, or otherwise having had to modify training; and a "gradual" versus "immediate" onset of the injury or a self-reported diagnosis that is generally considered an overuse injury.	6
Bennell et al. 1996[9]	Prospective cohort (12 months)	Track and field athletes during one season	111 / 95 (85.6%) of whom 21 were long-distance runners	52.3% ♂: 47.7% ♀ ‡ ♂: 20.3 ± 2.0 y, 179.3 ± 6.1 cm, 70.3 ± 7.8 kg ♀: 20.5 ± 2.2 y, 167.4 ± 6.1 cm, 59.0 ± 5.6 kg	1) Stress fracture (diagnosis on a bone or CT scan was made using a blinded protocol) 2) An injury was defined as any musculoskeletal pain or injury that resulted from athletic training and caused alteration of normal training in mode, duration, intensity, or frequency for one week or more.	6
Macera et al. 1989[14]	Prospective cohort (12 months)	Runners wishing to be notified of road races	966 / 583 (60.4%)	83.2% ♂: 16.8% ♀ ♂:41.6 ± 9.5 y (range 13-75 y), 178.6 ± 6.5 cm (range 154.9-195.6 cm), 73.6 ± 8.7 kg (range 39.6-104.6 kg), BMI 23.0 ± 2.2 (range BMI 16.5-31.0) ♀: 36.1 ± 8.2 y (range 22-64 y), 164.3 ± 6.0 cm (range 149.9-180.3 cm), 54.5 ± 6.1 kg (range 40.9-76.4 kg), BMI 25.8 ± 2.4 (range BMI 20.2-34.6)	A self-reported "muscle, joint or bone problem/injury" of the lower extremities (foot, ankle, Achilles tendon, calf, shin, knee, thigh or hip) that the participant attributed to running. The problem had to be severe enough to cause a reduction in weekly distance, a visit to a health professional, or the use of medication.	6

Table 1 continued

Author, year of publication	Study design (follow-up period)	Running type	Number included/ analysed (%)	Description of population	Injury definition	Quality score of study
Walter et al. 1989[20]	Prospective cohort (12 months)	Runners participating in a 4, 5.6, 16 or 22.4 km race and all adult members of the organizing clubs	1680 / 1288 (76.6%)	76.5% ♂: 23.5% ♀ ♂, age(y): 9.8% 14-19, 19.0% 20-29, 38.7% 30-39, 24.4% 40-49, 8.1% ≥50 ♀, age(y): 16.2% 14-19, 28.4% 20-29, 41.3% 30-39, 10.2% 40-49, 4.0% ≥50	Injuries, defined as "severe enough to reduce the number of miles run, take medicine, or see a health professional"	7
Bovens et al. 1989[10]	Prospective cohort (18 months)	Runners participating in a training program for a marathon with 3 phases (finished with a 15, 25 and 42 km race respectively)	115 / 73 (63.5%)	79.5% ♂: 20.5% ♀ ♂: 35.2 ± 7.9 y, 178.1 ± 5.7 cm, 71.9 ± 6.4 kg ♀: 33.5 ± 6.7 y, 165.6 ± 5.1 cm, 57.5 ± 5.0 kg	Any physical complaint developed in relation with running activities and causing restriction in running distance, speed, duration, or frequency was considered to be an injury.	7
Lysholm & Wiklander 1987[13]	Prospective cohort (12 months)	Competitive athletes of 2 track and field athletes during one season	60 / 60 (100%) of which 28 were long-distance runners	28 ♂ long-distance/marathon runners 34.5 ± 7.4 y	Any injuries that markedly hampered training or competition for at least one week.	5
Kretsch et al. 1984[11]	Prospective cohort (1 day)	Runners participating in a marathon	1098 / 459 (41.8%)	75.8% ♂: 24.2% ♀	1) Injuries occurring immediately before the race; medical problems experienced during the race; pains or "unusual" symptoms developing after the race. 2) A description of the principal symptoms and any other symptoms present at a first-aid station.	4

Author, year of publication	Study design (follow-up period)	Running type	Number included/ analysed (%)	Description of population	Injury definition	Quality score of study
Nicholl & Williams 1982[15]	Prospective cohort (1 day)	Runners participating in a marathon	3462 / 3429 (99.0%) of which 1140 ran a half marathon and 2289 ran a full marathon	93.8% ♂: 6.2% ♀ ╫	Clinical details of all contacts made by runners with any of the 12 first-aid posts.	6
Macera et al. 1991[23]	Retrospective cohort (1 month)	Runners participating in a 5 or 10 km race, or in a marathon	534 / 509 (95.3%) of whom 347 ran a 5 or 10 km race and 162 ran a marathon	77.0% ♂: 23.0% ♀ ♂ marathon (37.2%): 36 y, 69.0% <45 y ♂ 5 & 10 km (62.8%): 80.0% <45 y ♀ marathon (13.7%): 33 y, 94.0% <45 y ♀ 5 & 10 km (86.3%): 87.0% <45 y	Musculoskeletal problems: development of problems in foot, ankle, Achilles tendon, calf or shin, knee, thigh, or hip, regardless of cause, that required a consultation with a physician or reduction in usual running mileage. These problems may or may not be due to running.	4
Jakobsen et al. 1989[22]	Retrospective cohort (1 day)	Runners participating in a half or a full marathon	831 / 831 (100%)	88.0% ♂: 12.0% ♀ 34.6 ± 9.75 y	Injuries: ankle sprains; overuse/stress injuries of feet, ankle, lower leg, knee, or thigh; blisters. ⊥	3
Maughan & Miller 1983[24]	Retrospective cohort (1 week)	Runners participating in a marathon	497 / 449 (90.3%)	95.0% ♂: 5.0% ♀ 32 ± 8 y ‡	Injuries incurred during training and the race itself.	3
Nicholl & Williams 1982[25]	Retrospective cohort (10 days)	Runners participating in a half or a full marathon	614 / 557 (90.7%) of which 242 ran a half marathon and 312 ran a full marathon	83.2% ♂: 16.8% ♀ Half marathon: 73.6% ♂, 26.4% ♀, 74.4% <40 y, 25.6% ≥40 y Full marathon: 90.7% ♂, 9.3% ♀, 76.6% <40 y, 23.4% ≥40 y	Medical problems in the week after the race. ⊥	6

* This population was used to determine risk factors.
# This group is selected from the 1219 runners, which are known to have started the marathon.
‡ Description of population concerns all included subjects.
╫ Description of population concerns the 4559 entrants of the marathon, not the 3462 registered starters; significantly more over –40s (82%) were registered than younger entrants (75%) ($p < 0.05$).
⊥ The injury definition was extracted from the results section in the article, while this is normally obtained from the materials and methods section.
BMI = Body Mass Index (kg/m^2); ♂ = male, ♀ = female, y (years)

the injury definition differed between the various reports. The quality score of the studies ranged from 2 to 7 (table 2).

Four studies were judged as of low quality.[11, 18, 22, 24] The interobserver agreement in studies describing the incidence or prevalence, or both, of lower extremity running injuries was moderate, with a K-value of 0.60 (agreement in 83% of the questions), whereas in studies describing determinants for these injuries the K-value of 0.58 showed a moderate level of agreement (agreement in 82% of the questions). Disagreements were especially seen in items 2, 4, and 5, whereas in only two studies were more than two disagreements found.[10, 21]

Incidence of injuries

The overall incidence of lower extremity injuries found in the 17 studies varied from 19.4% to 79.3%.[9, 12, 14, 19, 21-24] In other studies in which non-lower-extremity injuries were also described and included in the overall incidence number, the reported incidence for injuries varied from 26.0% to 92.4%.[10, 11, 13, 17, 18, 20, 25] The predominant site of lower extremity injuries was the knee, for which the location specific incidence ranged from 7.2% to 50.0%. Injuries of the lower leg (shin, Achilles tendon, calf, and heel), foot (also toes), and upper leg (hamstring, thigh, and quadriceps) were common, ranging from 9.0% to 32.2%, 5.7% to 39.3%, and 3.4% to 38.1%, respectively. Less common sites of lower extremity injuries were the ankle and the hip/pelvis (also groin), ranging from 3.9% to 16.6% and 3.3% to 11.5%, respectively (table 3).[9, 10, 12-14, 16, 18-22, 24]

Only five studies described incidence figures for specific types of injuries (table 4).[11, 15, 16, 22, 25]

Two studies also reported the incidence numbers of injuries presented at medical aid posts during a race: 6.2%[16] and 17.9%[15] of runners participating in a marathon and 3.6% of runners participating in a half marathon.[15]

Determinants of injuries

We divided the determinants into four categories: systemic factors (table 5), running/training related factors (table 6), health factors (table 7), and lifestyle factors (table 8). Based on the large heterogeneity in the studies, pooling of the results was not possible, leaving us to present a best evidence synthesis.

Systemic factors

Greater age was reported to be a significant risk factor for incurring running injuries in four high quality studies.[15, 17, 19, 21] However, in two high quality studies greater age was reported to be a significant protective factor.[17, 25] Therefore there is conflicting evidence over whether greater age is a risk factor for overall lower extremity running injuries. There was, however,

Table 2 Quality score of articles

Articles	Questions								Outcome
	Definition	Demographics	Prospective design	80% follow-up	Withdrawals	Blinding	Data presentation	Multivariate analysis	
Taunton et al. 2003[19]	+	+	+	+	-	-	+	+	6
Lun et al. 2004 [12]	+	+	+	-	+	+	+	-	6
Satterthwaite et al. 1999[17]	+	+	+	+	-	-	+	+	6
Wen et al. 1998[21]	+	+	+	-	+	+	+	+	7
Bennell et al. 1996[9]	+	+	+	+	-	+	+	-	6
Macera et al. 1991[23]	+	+	-	+	-	-	+	+	5
Macera et al. 1989[14]	+	+	+	-	+	-	+	+	6
Walter et al. 1989[20]	+	+	+	-	+	+	+	-	6
Jakobsen et al. 1989[22]	+	+	-	-	-	-	+	-	3
Kretsch et al. 1984[11]	+	-	+	-	-	-	+	-	3
Nicholl & Williams 1982[15]	+	+	+	+	-	+	+	-	6
Nicholl & Williams 1982[25]	+	+	-	+	-	+	+	-	5
Steinacker et al. 2001[18]	-	+	+	-	-	na	na	na	2
Satterthwaite et al. 1996[16]	+	+	+	+	-	na	na	na	4
Bovens et al. 1989[10]	+	+	+	-	+	na	na	na	4
Lysholm & Wiklander 1987[13]	+	+	+	+	-	na	na	na	4
Maughan & Miller 1983[24]	+	+	-	-	-	na	na	na	2

Questions that could be answered with yes are"+", those answered with no or unknown are"-"; "+"scores 1 and "-" score 0.
na = not applicable

Table 3 Overall and location specific incidence of injuries

Author, year of publication	Incidence of injuries			Location specific incidence of injuries								
	Overall	Males	Females	Foot	Ankle	Lower leg	Knee	Upper leg	Hip/ pelvis	LEX, not stated	Other sites, not LEX	Other sites, not stated
Taunton et al. 2003[19]	28.0% (236 injuries by 236/840 runners)	26.3%	28.7%	14.0%	11.0%	26.7%	35.2%	3.4%	9.7%			
Steinacker et al. 2001[18]	46.6% (injuries by 27/58 runners)* during training	41.6%	54.5%			16.6%	50.0%		11.1%	11.1%	11.2%	
	43.9% (injuries by 18/41 runners)*during marathon	38.5%	53.3%	11.1%		16.7%	33.4%			16.6%	22.2%	
Lun et al. 2004[12]	79.3% (injuries by 69/87 runners)	79.5%	79.1%	15.0%	3.9%	9.0%	7.2%	9.0%	5.0%		3.9%	
Wen et al. 1998[21]	32.9% (84 injuries by 84/255 runners)			16.7%	10.7%	32.1%	31.0%	3.6%	5.9%			
Bennell et al. 1996[9]	31.6% (9 injuries by 6/19 runners)#	20.0%	44.4%							100%		
Satterthwaite et al. 1996[16]	92.4% (2671 injuries by 846/916 runners) during or immediately after marathon			22.6%		16.0%	8.8%	28.9%				23.7%
	78.9% (1905 injuries by 723/916 runners) in the 7 days following the marathon			14.8%		20.5%	12.7%	38.1%				13.9%
Macera et al. 1989[14]	51.5% (injuries by 300/583 runners)*	52.0%	49.0%	22.0%			24.0%			54.0%		
Walter et al. 1989[20]	48.4% (747 new + recurrent injuries by 620/1281 runners)	49.3%	45.5%	15.7%	15.0%	12.0%	26.6%	7.2%	8.8%		10.6%	4.0%
	26.0% (427 new injuries by 333/1281 runners)	26.8%	23.3%	18.5%	16.6%	14.8%	25.5%	8.2%	8.7%		5.4%	2.3%

Author, year of publication	Incidence of injuries			Location specific incidence of injuries								
	Overall	Males	Females	Foot	Ankle	Lower leg	Knee	Upper leg	Hip/ pelvis	LEX, not stated	Other sites, not LEX	Other sites, not stated
Bovens et al. 1989[10]	84.9% (174 injuries by 62/73 runners) 58.0% in 15 km phase 60.0% in 25 km phase 67.0% in 42 km phase			5.7%	12.1%	32.2%	24.7%	6.3%	11.5%		7.5%	
Lysholm & Wiklander 1987[13]	57.1% (18 injuries by 16/28 runners)			33.3%								66.6%
Kretsch et al. 1984[11]	92.0% (injuries by 422/459 runners)* of which 11% had injuries for more than 1 day after the marathon											
Macera et al. 1991[23]	21.6% (injuries by 75/347 runners)* in 5 & 10 km race	24.0%	15.8%									
	35.2% (injuries by 57/162 runners)* in the marathon	34.2%	43.8%									
	26.1% (injuries by 133/509 runners)* in both races	28.1%	19.7%									
Jakobsen et al. 1989[22]	19.4% (193 injuries by 161/831 runners)			6.9%	10.8%	16.6%	26.9%	11.4%		27.4%‡		
Maughan & Miller 1983[24]	27.2% (122 injuries by 122/449 runners)			39.3%	4.9%	13.1%	32.0%	7.4%	3.3%			
Nicholl & Williams 1982[25]	40.1% (injuries by 97/242 runners)* in half marathon	39.3%	42.2%									
	65.1% (injuries by 203/312 runners)* in marathon	65.7%	58.6%									

* total number of injuries is unknown.

\# Overall incidence number of stress fractures, obtained in this study; the injuries in this study are all stress fractures.

‡ These are all blisters; the exact location of the blisters was not given.

LEX = lower extremity

Table 4 Incidence of injury by specific injury type

Author, year of publication	Group characteristic	Types specific incidence of injuries									
		Skin lesions	Pain/ stiffness	Overuse/ stress injuries	Cramps	Haema-tomas	Ankle sprains	Joint problems	Tendonitis	Other, not running injuries	Other injuries, not stated
Satterthwaite et al. 1996[16]	At medical aid post*	14.5%			19.7%	14.5%			6.6%	21.1%	23.7%
	During or immediately after a marathon	14.9%	61.3%		8.7%			1.0%			14.1%
	In the 7 days following a marathon	7.6%	80.3%		2.5%			1.8%			7.8%
Kretsch et al. 1984[11]	After a marathon	7.9%	44.4%							14.5%	33.2%
Nicholl & Williams 1982[15]	During full marathon at first aid- station	15.6%	57.6%							25.3%	1.5%
Jakobsen et al. 1989[22]	During a half and a full marathon	27.4%		67.5%			5.1%				
Nicholl & Williams 1982[25]	During a half and a full marathon	10.5%	54.1%					22.4%		13.0%	

* Type specific distribution of injuries in the 1219 runners who are known to have started the marathon.

Table 5 Systemic factors for lower extremity injuries

Determinant	Author	Injury	Specification of determinant	Outcome (95% CI)
Age	Taunton et al. 2003[19]	Overall injuries *	♀ Age >50 y	RR = 1.92 (1.11 – 3.33) #
		New injuries *	♀ Age <31 y	RR = 0.58 (0.34 – 0.97) #
	Satterthwaite et al. 1999[17]	Stiffness and/or pain in front thigh	Age 25-29 y (ref. <25 y)	OR = 1.42 (0.79 – 2.53) #
		Stiffness and/or pain in front thigh	Age 30-34 y (ref. <25 y)	OR = 1.83 (1.04 – 3.22) #
		Stiffness and/or pain in front thigh	Age 35-39 y (ref. <25 y)	OR = 1.34 (0.77 – 2.31) #
		Stiffness and/or pain in front thigh	Age ≥40 y (ref. <25 y)	OR = 0.96 (0.56 – 1.63) #
		Stiffness and/or pain in calf	Age 25-29 y (ref. <25 y)	OR = 0.60 (0.32 – 1.13) #
		Stiffness and/or pain in calf	Age 30-34 y (ref. <25 y)	OR = 0.43 (0.23 – 0.78) #
		Stiffness and/or pain in calf	Age 35-39 y (ref. <25 y)	OR = 0.56 (0.31 – 1.01) #
		Stiffness and/or pain in calf	Age ≥40 y (ref. <25 y)	OR = 0.40 (0.23 – 0.73) #
	Wen et al. 1998[21]	Knee injuries	Higher age ‡	RR = 2.09 (0.95 – 4.58) #
			Higher age (miles) ╫	RR = 1.08 (0.99 – 1.17) #
		Overall injuries *	Lower age (miles) ╫	RR = 0.39 (0.15 – 0.97) #
	Macera et al. 1989[14]	Lower extremity injuries	♂ Higher age	OR = 1.0 (1.0 – 1.0) #
			♀ Higher age	OR = 1.0 (0.9 – 1.0) #
	Kretsch et al. 1984[11]	Overall injuries *	Age 14-20 y (ref. ≥41 y)	p <0.025
	Nicholl & Williams 1982[15]	Overall injuries *	Age 40+ y	p <0.05
	Macera et al. 1991[23]	Lower extremity musculoskeletal problems	♂ Higher age	OR = 1.0 (1.0 – 1.0) #
			♀ Higher age	OR = 1.0 (0.9 – 1.1) #
	Jakobsen et al. 1989[22]	Overall injuries	Lower age	p <0.01
	Nicholl & Williams 1982[25]	Overall injuries *	Age <40 y (half marathon)	OR = 2.12 (1.13 – 3.98)
			Age <40 y (marathon)	OR = 1.31 (0.76 – 2.25)

Table 5 continued

Determinant	Author	Injury	Specification of determinant	Outcome (95% CI)
Gender	Satterthwaite et al. 1999[17]	Stiffness and/or pain in hamstring	♂	OR = 1.60 (1.04 – 2.47) #
		Stiffness and/or pain in hip	♀	OR = 1.88 (1.15 – 3.06) #
		Stiffness and/or pain in calf	♂	OR = 1.86 (1.29 – 2.68) #
	Bennell et al. 1996[9]	Stress fractures	♀	OR = 3.20 (0.42 – 24.42)
	Macera et al. 1989[14]	Lower extremity injuries	♀	OR = 0.89 (0.58 – 1.37)
	Nicholl & Williams 1982[15]	Overall injuries *	♀	p <0.05
	Macera et al. 1991[23]	Lower extremity musculoskeletal problems	♀ (marathon)	OR = 1.49 (0.53 – 4.25)
			♀ (5 & 10 km)	OR = 0.60 (0.32 – 1.10)
	Jakobsen et al. 1989[22]	Overall injuries	♀	p >0.05
	Nicholl & Williams 1982[25]	Overall injuries*	♀ (half marathon)	OR = 1.13 (0.63 – 2.01)
			♀ (marathon)	OR = 0.74 (0.34 – 1.61)
Height	Walter et al. 1989[20]	New injuries*	♂ 170-179 cm (average) (ref. <170)	OR = 2.04 (1.15 – 3.46) #
			♂ ≥180 cm (tallest) (ref. <170)	OR = 2.30 (1.29 – 3.90) #
			♀ 160-169 cm (average) (ref. <160)	OR = 1.29 (0.65 – 2.48) #
			♀ ≥170 cm (tallest) (ref. <160)	OR = 0.78 (0.32 – 1.97) #
Weight	Wen et al. 1998[21]	Foot injuries	Higher weight ‡	RR = 0.94 (0.89 – 0.99) #
BMI	Taunton et al. 2003[19]	Overall injury*	♂ BMI >26	RR = 0.41 (0.21 – 0.79) #
	Macera et al. 1989[14]	Lower extremity injuries	♂ BMI (>74th percentile)	OR = 0.7 (0.5 – 1.2) #
			♂ BMI (<26th percentile)	OR = 1.2 (0.7 – 1.9) #
			♀ BMI (>74th percentile)	OR = 3.0 (0.5 – 18.8) #
			♀ BMI (<26th percentile)	OR = 2.0 (0.6 – 6.6) #

Determinant	Author	Injury	Specification of determinant	Outcome (95% CI)
Alignment	Lun et al. 2004[12]	Overall injuries	Left subtalar varus	CI = 0.2 - 4.2
	Wen et al. 1998[21]	Overall injuries *	Lower leg-length difference (hours) ╫	RR = 1.96 (1.07 – 3.58) #
			Higher arch index (hours) ╫	RR = 0 (0 – 0.37) #
		Knee injuries	Lower heel valgus (miles) ╫	RR = 0.08 (0.01 – 0.74) #
			Higher heel valgus (miles) ╫	RR = 0.09 (0.01 – 0.81) #
			Higher right arch index (hours) ╫	RR = 0.11 (0.01 – 0.90) #
			Lower right arch index (hours) ╫	RR = 0.25 (0.05 – 1.20) #
		Shin injuries	Higher left tubercle-sulcus angle (miles)╫	RR = 11.02 (2.00 – 60.86) #
			Higher knee varus (miles) ╫	RR = 1.09 (1.03 – 1.15) #
			Higher arch index (hours) ╫	RR = 0 (0 – 8.21) #
		Foot injuries	Higher heel valgus (miles) ╫	RR = 0.76 (0.58 – 0.98) #
			Higher heel valgus (hours) ╫	RR = 0.74 (0.58 – 0.94) #

* Not-running injuries and running, but not lower extremity, injuries were included to establish the outcome.

Represents adjusted OR or RR.

‡ RRs were calculated dividing the number of injured runners by the total number of runner-weeks accumulated (relative incidence ratio's).

╫ RRs were obtained from special subgroups in which information on distances run (miles) and time spent running (hours) was measured.

♂ = male, ♀ = female, ref. = referred to, BMI = Body Mass Index, y = years, CI = confidence interval, OR = odds ratio, RR = relative risk

Table 6 Running / training related factors for lower extremity injury

Determinant	Author	Injury	Specification of determinant	Outcome (95% CI)
Training frequency	Taunton et al. 2003[19]	Overall injuries*	♀ Running frequency 1 d/wk	RR = 3.68 (1.08 – 12.30) #
	Macera et al. 1989[14]	Lower extremity injuries	♂ Run 6 or 7 d/wk	OR = 1.4 (0.8 – 2.5) #
			♀ Run 6 or 7 d/wk	OR = 0.5 (0.1 – 2.1) #
	Walter et al. 1989[20]	New injuries*	♂ 3 d running/wk (ref. 0-2)	OR = 2.93 (1.27 – 6.20) #
			♂ 4 d running/wk (ref. 0-2)	OR = 2.49 (1.08 – 5.26) #
			♂ 5 d running/wk (ref. 0-2)	OR = 3.13 (1.38 – 6.46) #
			♂ 6 d running/wk (ref. 0-2)	OR = 3.66 (1.62 – 7.50) #
			♂ 7 d running/wk (ref. 0-2)	OR = 5.92 (2.49 – 12.75) #
			♀ 3 d running/wk (ref. 0-2)	OR = 0.59 (0.15 – 2.22) #
			♀ 4 d running/wk (ref. 0-2)	OR = 1.91 (0.56 – 5.65) #
			♀ 5 d running/wk (ref. 0-2)	OR = 1.25 (0.36 – 3.82) #
			♀ 6 d running/wk (ref. 0-2)	OR = 2.11 (0.62 – 6.12) #
			♀ 7 d running/wk (ref. 0-2)	OR = 5.50 (1.44 – 17.39) #
			♂ Running year round	OR = 1.64 (1.12 – 2.35) #
			♀ Running year round	OR = 2.00 (1.01 – 3.75) #
	Jakobsen et al. 1989[22]	Overall injuries	Less months training	p >0.05
			Less h/wk	p <0.05
Training alteration	Satterthwaite et al. 1999[17]	Stiffness and/or pain in front thigh	Increase in training of 1 d/wk	OR = 1.19 (1.05 – 1.34) #
		Stiffness and/or pain in hamstring	Increase in training of 10 km/wk	OR = 1.07 (1.02 – 1.13) #
		Stiffness and/or pain in knee	Decrease in training of 10 km/wk	OR = 1.13 (1.04 – 1.23) #
	Wen et al. 1998[21]	Overall injuries*	Increased hours/week (miles) ‡	RR = 0.57 (0.42 – 0.78) #
			Increased hours/week (hours) ‡	RR = 0.58 (0.45 – 0.73) #
		Knee injuries	Increased miles/week (miles) ‡	RR = 0.90 (0.82 – 0.99) #
			Increased hours/week (hours) ‡	RR = 0.49 (0.30 – 0.80) #
		Foot injuries	Increased hours/week (miles) ‡	RR = 0.31 (0.15 – 0.63) #
			Increased hours/week (hours) ‡	RR = 0.21 (0.10 – 0.44) #
	Macera et al. 1991[23]	Lower extremity musculoskeletal problems	♂ Increased mileage in month before the race	OR = 1.1 (0.7 – 1.8) #
			♀ Increased mileage in month before the race	OR = 1.6 (0.6 – 4.6) #

Determinant	Author	Injury	Specification of determinant	Outcome (95% CI)
Training distance	Macera et al. 1989[14]	Lower extremity injuries	♂ 16.0-31.8 km/wk for preceding 3 months	OR = 1.6 (0.8 – 3.0) #
			♂ 32.0-47.8 km/wk for preceding 3 months	OR = 1.6 (0.8 – 3.2) #
			♂ 48.0-63.8 km/wk for preceding 3 months	OR = 1.7 (0.8 – 3.6) #
			♂ 64.0+ km/wk for preceding 3 months	OR = 2.9 (1.1 – 7.5) #
			♀ 16.0-31.8 km/wk for preceding 3 months	OR = 2.1 (0.5 – 9.7) #
			♀ 32.0-47.8 km/wk for preceding 3 months	OR = 4.2 (0.8 – 21.7) #
			♀ 48.0-63.4 km/wk for preceding 3 months	OR = 7.4 (0.9 – 60.3) #
			♀ 64.0+ km/wk for preceding 3 months	OR = 3.0 (0.3 – 27.5) #
	Walter et al. 1989[20]	New injuries*	♂ Longest run each wk >8 km	OR = 2.49 (1.64 – 3.71) #
			♀ Longest run each wk >8 km	OR = 1.78 (0.99 – 3.13) #
			♂ 16 – 30.4 km/wk (ref. <16)	OR = 0.88 (0.40 – 1.58) #
			♂ 32 – 46.4 km/wk (ref. <16)	OR = 1.36 (0.77 – 2.35) #
			♂ 48 – 62.4 km/wk (ref. <16)	OR = 1.27 (0.70 – 2.27) #
			♂ ≥64 km/wk (ref. <16)	OR = 2.22 (1.30 – 3.68) #
			♀ 16 – 30.4 km/wk (ref. <16)	OR = 0.98 (0.43 – 2.21) #
			♀ 32 – 46.4 km/wk (ref. <16)	OR = 1.37 (0.58 – 3.23) #
			♀ 48 – 62.4 km/wk (ref. <16)	OR = 1.97 (0.97 – 4.80) #
			♀ ≥64 km/wk (ref. <16)	OR = 3.42 (1.42 – 7.85) #
	Kretsch et al. 1984[11]	Overall injuries*	<60 km/wk in 3 months before marathon	p <0.025
	Jakobsen et al. 1989[22]	Overall injuries	More km/wk	p <0.01
Race distance	Macera et al. 1991[23]	Lower extremity musculoskeletal problems	♂ Marathon	OR = 1.7 (1.0 – 2.8) #
			♀ Marathon	OR = 4.7 (1.2 – 17.4) #

Table 6 continued

Determinant	Author	Injury	Specification of determinant	Outcome (95% CI)
Experience	Satterthwaite et al. 1999[17]	Stiffness and/or pain in hamstring	Participation in marathon for first time	OR = 1.55 (1.08 – 2.22) #
		Stiffness and/or pain in knee	Participation in marathon for first time	OR = 1.66 (1.16 – 2.38) #
	Wen et al. 1998[21]	Overall injuries*	Higher experience ╫	RR = 1.88 (1.16 – 3.05) #
		Foot injuries	Higher experience ╫	RR = 1.09 (1.03 – 1.15) #
	Macera et al. 1989[14]	Lower extremity injuries	♂ 0-2 y running experience	OR = 2.2 (1.5 – 3.3) #
			♂ 10+ y running experience	OR = 1.2 (0.8 – 1.9) #
			♀ 0-2 y running experience	OR = 1.4 (0.3 – 6.4) #
			♀ 10+ y running experience	OR = 1.7 (0.5 – 6.1) #
			♂ run a marathon during preceding 12 months	OR = 1.3 (0.7 – 2.2) #
			♀ run a marathon during preceding 12 months	OR = 4.3 (0.7 – 27.0) #
	Nicholl & Williams 1982[15]	Overall injuries*	Any previous experience of running a half and/or a full marathon	p <0.05
	Jakobsen et al. 1989[22]	Overall injuries	<5 Years experience	p >0.05
	Nicholl & Williams 1982[25]	Overall injuries*	No previous experience of running a half and/or a full marathon (half marathon)	OR = 1.66 (0.99 – 2.80)
			No previous experience of running a half and/or a full marathon (marathon)	OR = 1.75 (1.10 – 2.81)

Determinant	Author	Injury	Specification of determinant	Outcome (95% CI)
Warm-up	Macera et al. 1989[14]	Lower extremity injuries	♂ Stretch before running	OR = 1.1 (0.8 – 5.9)
			♀ Stretch before running	OR = 1.6 (0.7 – 3.5)
	Walter et al. 1989[20]	New injuries*	♂ Usually using stretching (ref. always)	OR = 0.80 (0.55 – 1.17) #
			♂ Sometimes using stretching (ref. always)	OR = 1.56 (1.10 – 2.21) #
			♂ Never using stretching (ref. always)	OR = 0.87 (0.50 – 1.57) #
			♂ Usually using warm-up (ref. always)	OR = 1.03 (0.73 – 1.44) #
			♂ Sometimes using warm-up (ref. always)	OR = 1.30 (0.87 – 1.93) #
			♂ Never using warm-up (ref. always)	OR = 0.37 (0.19 – 0.81) #
			♀ Usually using stretching (ref. always)	OR = 0.95 (0.48 – 1.96) #
			♀ Sometimes using stretching (ref. always)	OR = 1.78 (0.91 – 3.53) #
			♀ Never using stretching (ref. always)	OR = 0.85 (0.27 – 3.22) #
			♀ Usually using warm-up (ref. always)	OR = 0.82 (0.42 – 1.60) #
			♀ Sometimes using warm-up (ref. always)	OR = 0.95 (0.47 – 1.96) #
			♀ Never using warm-up (ref. always)	OR = 0.55 (0.22 – 1.51) #
Circumstances of training	Macera et al. 1989[14]	Lower extremity injuries	♂ Hilly terrain	OR = 1.1 (0.7 – 1.6)
			♂ Asphalt surface	OR = 1.2 (0.8 – 1.7)
			♂ Run in dark	OR = 0.9 (0.6 – 1.3)
			♂ Run in morning	OR = 1.1 (0.7 – 1.7)
			♀ Hilly terrain	OR = 1.0 (0.4 – 2.5)
			♀ Asphalt surface	OR = 1.8 (0.8 – 4.2)
			♀ Run in dark	OR = 1.0 (0.4 – 2.7)
			♀ Run in morning	OR = 1.4 (0.6 – 3.2)
			♂ Concrete surface	OR = 1.4 (0.8 – 2.5) #
			♀ Concrete surface	OR = 5.6 (1.1 – 29.3) #
Type of runner	Walter et al. 1989[20]	New injuries*	♂ Recreational runner (ref. fitness runner)	OR = 1.18 (0.84 – 1.66) #
			♂ Competitive runner (ref. fitness runner)	OR = 1.73 (1.21 – 2.49) #
			♀ Recreational runner (ref. fitness runner)	OR = 0.71 (0.37 – 1.40) #
			♀ Competitive runner (ref. fitness runner)	OR = 1.93 (0.97 – 3.89) #

Table 6 continued

Determinant	Author	Injury	Specification of determinant	Outcome (95% CI)
Shoe use	Taunton et al. 2003[19]	Overall injuries*	♂ Running shoe age 4-6 months	RR = 0.36 (0.15 – 0.83) #
			♀ Running shoe age 4-6 months	RR = 1.74 (1.10 – 2.98) #
		New injuries	♀ Running shoe age 1-3 months	RR = 0.61 (0.38 – 0.99) #
	Wen et al. 1998[21]	Shin injuries	Higher number of shoes (hours) ‡	RR = 6.91 (1.36 – 35.15) #
Pace	Wen et al. 1998[21]	Shin injuries	More intervals ╫	RR = 14.89 (0.50 – 147.33)#
	Jakobsen et al. 1989[22]	Overall injuries	Lower pace	p = 0.06

* Not-running injuries and running, but not lower extremity, injuries were included to establish the outcome.
# Represents adjusted OR or RR.
‡ RR's were obtained from special subgroups in which information on distances run (miles) and time spent running (hours) was measured.
╫ RR's were calculated dividing the number of injured runners by the total number of runner-weeks accumulated (relative incidence ratio's).
♀ = female, ♂ = male, wk = week, d = days, OR = odds ratio, RR = relative risk, CI = confidence interval, ref. = referred to

Table 7 Health factors for lower extremity injury

Determinant	Author	Injury	Specification of determinant	Outcome (95% CI)
History of previous injuries	Wen et al. 1998[21]	Overall injuries* Shin injuries	History of previous injuries # History of old shin injuries #	RR = 2.02 (1.27 – 3.21) ‡ RR = 7.24 (2.40 – 21.82) ‡
	Macera et al. 1989[14]	Lower extremity injuries	♂ New lower extremity injury during the previous 12 months ♀ New lower extremity injury during the previous 12 months	OR = 2.7 (2.6 – 2.7) ‡ OR = 1.9 (0.7 – 4.9) ‡
	Walter et al. 1989[20]	New injuries*	♂ Injured in previous year ♀ Injured in previous year	OR = 1.69 (1.27 – 2.25) ‡ OR = 2.35 (1.33 – 4.07) ‡
	Kretsch et al. 1984[11]	Overall injuries*	Number of medical or physical problems experienced during training	p >0.05
	Macera et al. 1991[23]	Lower extremity musculoskeletal problems	♂ Previous musculoskeletal problems in the past year ♀ Previous musculoskeletal problems in the past year	OR = 6.3 (3.7 – 10.8) ‡ OR = 7.6 (2.0 – 28.4) ‡
Medical history	Satterthwaite et al. 1999[17]	Stiffness and/or pain in knee	Current medication use Being unwell in last 2 weeks before marathon	OR = 1.56 (1.02 – 2.32) ‡ OR = 1.42 (1.03 – 1.95) ‡
	Kretsch et al. 1984[11]	Overall injuries*	Positive medical history	p <0.025

* Not-running injuries and running, but not lower extremity, injuries were included to establish the outcome.
# RR's were calculated dividing the number of injured runners by the total number of runner-weeks accumulated (relative incidence ratio's).
‡ Represents adjusted OR or RR.
♂ = male, ♀ = female, CI = confidence interval, RR = relative risk, OR = odds ratio

limited evidence that greater age was positively associated with front thigh injuries but protective against calf injuries.[17]

The only significant association for overall lower extremity running injuries showed a positive relation with female sex.[15] There was also limited evidence that female runners were more prone to incur hip injuries, and limited evidence that male runners were at greater risk of getting hamstring or calf injuries.[17]

There was limited evidence that a lower leg length difference was associated with overall lower extremity running injuries, and that a higher left tubercle–sulcus angle or a greater knee varus were risk factors for shin injuries.[21] Additionally, there was limited evidence that a higher heel valgus was protective against knee and foot injuries, while a lower heel valgus and a higher right arch index were protective factors only for knee injuries.[21] There was limited evidence that static biomechanical lower limb alignment was not related to lower limb injuries.[12]

Table 8 Lifestyle factors

Determinant	Author	Injury	Specification of determinant	Outcome (95% CI)
Drinking alcohol	Satterthwaite et al. 1999[17]	Blisters	Drinking alcohol ≥1/m	OR = 1.44 (1.01 – 2.05)*
		Stiffness and/or pain in front thigh	Drinking alcohol ≥1/m	OR = 1.38 (1.01 – 1.88)*
Smoking	Satterthwaite et al. 1999[17]	Blisters	Smoking	OR = 0.39 (0.17 – 0.88)*
Participation in other sports	Satterthwaite et al. 1999[17]	Stiffness and/or pain in front thigh	Cycling	OR = 1.53 (1.13 – 2.06)*
		Stiffness and/or pain in hamstring	Aerobics	OR = 1.74 (1.05 – 2.89)*

* Represents adjusted OR or RR.
CI = confidence interval, m = months, OR = odds ratio

Male runners whose height was 1.70 metres or more were reported to be at a significantly greater risk of suffering new injuries.[20] Thus there was limited evidence for the positive association between male runners of greater height and lower extremity running injuries.
There was limited evidence that greater weight was protective against foot injuries,[21] and there was also limited evidence that a body mass index of >26 kg/m^2 protected male runners from overall lower extremity running injuries.[19]

Running/training related factors

Only one high quality study reported that male runners were at statistically significant greater risk when running more than two days a week[20], whereas conflicting evidence was found for female runners for this association.[19, 20] Running a whole year through without a break from training was reported to be a significant risk factor for incurring a lower extremity running injury. As there was only one study that reported this association, there was limited evidence for the association.[20] There was conflicting evidence for an association between an increase of training and overall lower extremity running injuries.[17, 21] An increase of training distance per week was reported as a significant protective factor against knee injuries in two high quality studies, which means there is strong evidence for this association.[17, 21] There was limited evidence that an increase in days of training per week was a risk factor for incurring front thigh injuries[17], that an increase of training distance per week was a risk factor for hamstring injuries[17], and that an increase of hours training per week was a protective factor for knee as well as foot injuries.[21]
Two high quality studies reported training for more than 64 km/week as a significant risk factor for male runners incurring lower extremity running injuries,[14, 20] while in female runners this association was only reported in one high quality study.[20] Thus there was stronger evidence for an association between higher training distance for male runners than for female runners. There was no evidence for an association between training less than 60 km in the last

three months before a marathon and overall lower extremity running injuries, because this association was only significant in one low quality study.[11]

Lower extremity injuries in one high quality study were associated with longer race distances (marathon races compared with 5 and 10 km races).[23] Thus there was limited evidence that participating in races of greater distance was a risk factor for incurring these injuries.

There was conflicting evidence for an association between inexperience in running and overall lower extremity injuries.[14, 15, 17, 21, 25] An association between hamstring or knee injuries and participation in a marathon for the first time was reported in one high quality study,[17] while foot injuries were associated with more experienced runners in another high quality study.[21] Thus there was limited evidence for inexperience as a risk factor for hamstring or knee injuries or as a risk factor for foot injuries.

Two high quality studies reported no significant associations between the use of a warm up and lower extremity injuries, implying that there is no such association.[14, 20]

There was limited evidence for an association between female runners running on concrete surfaces and lower extremity injuries.[14] There was no significant association between male runners running on a specific surface and lower extremity injuries and between training on hilly terrain, or running in the dark or in the morning and these injuries, implying that there is no association between these determinants and lower extremity running injuries.[14]

For an association between competitive running and lower extremity running injuries there was limited evidence for male runners only.[20]

There was limited evidence for an association between shin injuries and the use of a greater number of shoes for running.[21] There was limited evidence that a shoe age of four to six months was a protective factor for lower extremity running injuries in male runners, but was a risk factor in female runners.[19]

No significant association between pace and lower extremity running injuries was reported, implying that there is no association.[21, 22]

Health factors

A history of previous injuries was reported to be a significant risk factor for injuries in multiple high quality studies.[14, 20, 21, 23] Thus there was strong evidence for an association between a history of previous injuries and lower extremity running injuries. For an association between a positive medical history and these injuries there was only limited evidence.[17]

Lifestyle factors

There was limited evidence that drinking alcohol was a risk factor for incurring blisters or front thigh injuries and that participation in cycling and aerobics were risk factors for, respectively, front thigh and hamstring injuries.[17] There was, however, some evidence that smoking was a protective factor against blisters.[17]

DISCUSSION

Three reviews on running injuries were published more than a decade ago.[25-27] New studies are performed on running injuries the last decade and have been incorporated into this systematic review. Further, in contrast to the methods used in those reviews, we undertook a systematic search strategy. We also evaluated the quality of the studies included and carried out a best evidence synthesis for determinants of lower extremity running injuries. Thus our review is a rigorous update of earlier reviews and provides evidence of risk factors for these injuries.

Incidence of injuries

The reported overall incidence of lower extremity running injuries showed a large range (19.4% to 79.3%). An increase in the incidence range is mainly seen in studies that also included non-lower-extremity injuries in their incidence numbers (19.4% to 92.4%), although higher incidences may partly reflect higher rate of lower extremity injury. Previous reviews reported ranges of 24% to 83%[26], 33% to 85%[27], and 24% to 77%.[28]

The most common site of lower extremity injuries was the knee (7.2% to 50.0%), followed by the lower leg (9.0% to 32.2%), the foot (5.7% to 39.3%), and the upper leg (3.4% to 38.1%). Less common sites of lower extremity injuries were the ankle (3.9% to 16.6%) and the hip/pelvis (3.3% to 11.5%). Our results supports Van Mechelen's conclusion that most of running injuries are located in the knee.[28]

Determinants of injuries

Only limited evidence was found for some of the systemic, lifestyle, and health factors as risk factors for running injuries. These included greater age (a clear cut off point for greater age could not be observed), sex, lower leg length difference, greater left tubercle–sulcus angle and greater knee varus, greater height in male runners, drinking alcohol, participation in cycling and aerobics, and a positive medical history. We found strong evidence for a greater training distance per week in male runners and a history of previous injuries as a risk factor for both male and female runners. There was also strong evidence that increased training distance per week was a protective factor, although only for knee injuries. It remains unclear why increasing weekly distance is protective for knee injuries. However, the relation between distance and injury may not be simple and there may be a fine balance between overuse and under conditioning among long distance runners. For several other training/running related factors we only found limited evidence that they were risk factors (greater training frequency in male runners, running the whole year through, greater training distance in female runners, participation in races of greater distance, women running on concrete surfaces, competitive male runners, increase in days of training per week, increase in training distance per week, level of experience in running, use of more shoes for running, and shoe age).

Although limited evidence was found that greater weight and a body mass index of >26 kg/m^2 were protective factors, this association may be caused by the fact that in these groups of runners less training activity is being undertaken.

Limitations

Because of the specific search definition and because the language restriction we used to identify studies in the PubMed–Medline database, we may have found fewer studies on running related injuries than are available. In the studies identified there was a lack of standard definition of injury. In some studies running injuries were defined as running related injuries to the lower extremities, but other studies also included non-lower-extremity injuries and even problems such as headache, dehydration, fatigue, and others. Further, different study designs, differing data collection methods, and differing methods of determining the denominator might have affected the incidence rates of the studies. Also, the type of runners selected for each study varied- usually a specific selection of runners was made (for example, male runners, recreational runners, runners in training programmes, race participants). All these factors may have influenced the final incidence rates of injuries and the odds ratios and relative risks for the determinants.

We decided only to include studies that investigated long distance runners. The studies of Bennell et al.[9] and Lysholm and Wiklander[13] both described a group of track and field athletes; however, they also described a separate group of long distance/marathon runners. Both these studies were included in our review because they described the results of the long distance runners separately from the whole track and field athletes group; thus only the results for the long distance runners were included in this study.

The results could also be biased by a self selection process of healthy runners participating in running events or training programmes in the studies included, or by injured runners not responding to questionnaires or over-reporting of injuries because of the self reporting nature of some studies.

For some subgroups reported here, there was low power. This might have influenced our conclusions, based on the best evidence synthesis. For example, associations were found for male but not female runners, while the estimate of the association in both sexes was the same. This probably reflects a reduced statistical power in the female subgroup.

Fortunately, 12 studies reported the sites where the lower extremity running injuries occurred. Specific diagnoses, however, were discussed in only three studies and not even for all injured runners.[10, 11, 20] Also the impact of these running injuries was rarely reported. Very little information was provided on the duration and severity of these injuries, and there was a lack of information about health care visits (for example, to general practitioner, physiotherapist, orthopaedic specialist) or the treatment used (drugs, rest, operation, other).

Implications

The presence of associations between determinants and running injuries suggests that advice and education may still be necessary. An unmodifiable risk factor is a history of previous injuries. Runners with this risk factor should pay extra attention to signs of injuries, avoid other determinants of injuries, and take time to recover fully from their injuries. The training distance per week is a modifiable risk factor and therefore runners should preferably not exceed 64 km/week.

Further investigation is necessary, because the incidence of running injuries in long distance runners is not clear and knowledge of the specific determinants of these injuries is still unsatisfactory. Future studies should clearly define the type of runners included (sprinters, middle distance, or long distance runners) and also specifically report information about training characteristics and race participation, so that the results can be applied on the correct group of runners. Also investigators should try to use a universal definition of running injury, so that results can easily be compared.

Likewise the length of observation period needs to be equal in different studies and the incidence numbers need to be expressed in comparable units.

Finally, to obtain information on the clinical consequences of running injuries, details on the duration and severity of these injuries, as well as information on the use of professional medical advice and the chosen treatment, is required.

Conclusions

The reported incidence of running injuries to the lower extremities in long distance runners varied from 19.4% to 92.4%. The most common site of lower extremity running injuries was the knee. There is strong evidence that a greater training distance per week in male runners and a history of previous injuries are risk factors for lower extremity running injuries. We recommend further well-designed studies on risk factors for running injuries for male and female runners.

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APPENDIX

Specification of the search strategy used in the PubMed-Medline database

(runn*) AND (injur* OR syndrome* OR tend* OR fract* OR pain* OR fasciitis OR bursitis OR splint* OR tear* OR sprain* OR strain* OR entrapment* OR ostei* OR osteop* OR osteom* OR osteoc* OR osteoa* OR rupture* OR arthro* OR arthri* OR lipoma OR sciatica OR lumbago OR laceration* OR split* OR tenosynovitis OR blister* OR cramp* OR corn OR callus* OR edema* OR sesamoiditis OR ganglion* OR rhabdomyolisis OR hernia* OR muscle soreness OR delayed onset muscle soreness OR hemorrh* OR ischi* OR neurom* OR abrasion OR wart* OR mold* OR dislocation* OR damage OR trauma OR displacement OR periostitis) AND (patell* OR knee* OR tibial* OR fibular* OR spinal OR lumbar OR plantar OR calcaneal OR achilles* OR hamstring* OR ligament* OR ankle* OR foot* OR infrapatellar OR hip OR back OR adductor* OR tigh* OR pubi* OR menisc* OR toe* OR lower extremity OR shin OR calve* OR neck OR shoulder OR groin OR ischia* OR sacral OR metatars* OR tars*) NOT ("addresses"[Publication Type] OR "bibliography"[Publication Type] OR "biography"[Publication Type] OR "case reports"[Publication Type] OR "clinical conference"[Publication Type] OR "comment"[Publication Type] OR "congresses"[Publication Type] OR "dictionary"[Publication Type] OR "directory"[Publication Type] OR "editorial"[Publication Type] OR "festschrift"[Publication Type] OR "government publications"[Publication Type] OR "interview"[Publication Type] OR "lectures"[Publication Type] OR "legal cases"[Publication Type] OR "legislation"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "newspaper article"[Publication Type] OR "retracted publication"[Publication Type] OR "retraction of publication"[Publication Type] OR "review"[Publication Type] OR "review literature"[Publication Type] OR "review of reported cases"[Publication Type] OR "review, academic"[Publication Type] OR "review, multicase"[Publication Type] OR "review, tutorial"[Publication Type] OR "scientific integrity review"[Publication Type] OR "technical report"[Publication Type] OR "twin study"[Publication Type] OR "validation studies"[Publication Type]). Limits: Human.

Chapter 3

Prevalence and incidence of lower extremity injuries in male marathon runners

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ABSTRACT

The aim of this study is to describe the prevalence and incidence of lower extremity injuries occurring before and during the Rotterdam marathon, and to evaluate the impact of the injuries. A cohort study was compiled of recreational male participants in the 2005 Rotterdam marathon. Demographic data and information on previous injuries were obtained from participants using a baseline questionnaire. Information on injuries sustained shortly before or during the marathon was obtained from a post-race questionnaire. A total of 725 (48.3%) participants returned the baseline questionnaire. The one-year prevalence of running injuries was 54.8%. In the post-race questionnaire, 15.6% of all respondents reported at least one new lower extremity injury in the month preceding the Rotterdam marathon. The incidence of lower extremity injuries occurring during the marathon was 18.2%; most of these injuries occurred in the calf, knee and thigh. Immediately after the marathon the median score of pain intensity at rest was 2 points vs 4.5 points during physical exercise. Hence, we can conclude that running injuries are very common among recreational male marathon runners. However, the pain severity and consequences for work and daily activities seem to be relatively low one week after the marathon.

INTRODUCTION

The health benefits of regular exercise have been documented extensively.[1-4] Long-distance running is a popular form of physical exercise that is practiced by many persons. More and more people are taking part in major international running events such as the city marathons in New York, Los Angeles, Rotterdam, or London.[5] Besides the positive health effects of running, and especially marathon running, running may also cause injuries, especially to the lower extremities.[6-9] Various studies have reported annual rates of lower extremity injuries for runners ranging from 19% to 75%.[8, 10-15] The most predominant site of lower extremity injuries is the knee, of which the reported location-specific incidence ranges from 9% to 50%.[9, 16]
It is probable that injuries affecting the lower extremities are caused not only by participation in the event but also by the necessarily long training sessions.[8, 17] Previous marathon studies have reported the high incidence of injuries during or shortly after running the marathon.[6, 8, 9, 18-20] However, there is no agreement in these studies regarding the incidence of running injuries of marathon runners. Most of these studies used different definitions of injuries and some, for example, also included blisters as a running injury.
Only a few studies have investigated the number of injuries associated with training before a marathon event, reporting prevalence rates of 29%–58%.[6, 8, 13, 18] Moreover, they have methodological shortcomings, e.g. there is no clear definition of a running injury, demographic characteristics were not reported, and/or a retrospective study design was used. Thus, few data are available on the prevalence and incidence of injuries associated with training for a marathon, or during a marathon. Therefore, the aim of this prospective study was to describe the prevalence and incidence of lower extremity injuries occurring before and during the Rotterdam marathon, and to evaluate the impact of the injuries.

METHODS

Study participants

The Rotterdam marathon is a run over a standard-length course (42.2 km) through the city of Rotterdam. The Rotterdam marathon 2005 began at 11:00 hours on Sunday, April 10. Out of the 6000 recreational male athletes who signed in for the Rotterdam marathon, a random sample of 1500 athletes was made. One month before the start of the Rotterdam marathon a baseline questionnaire was sent by a mail order firm to the 1500 randomly selected participants. These were asked to return the questionnaire by post before the marathon took place. Runners were included in the study if they met the following criteria: (1) they had to be a male resident of the Netherlands; (2) they were recreational/amateur runners; and (3) they returned the baseline questionnaire before running the 2005 Rotterdam marathon. Immediately after the Rotterdam marathon, a post-race questionnaire was posted to all included male runners. Those not returning the second questionnaire were posted a reminder and residual non-responders were later contacted by telephone and requested to return the completed questionnaire.

Recreational runners were runners who signed in for the Rotterdam marathon and were not competitive with the professional runners in the Rotterdam marathon race.

Questionnaires

Information about lower extremity injuries in the previous 12 months and information about injuries at the moment of completing the questionnaire was obtained from the baseline questionnaire. Participants were also asked to indicate the site of the injury. Running activity was measured in terms of the number of kilometers run per week (average from preceding 3-month total), number of hours run per week (average from preceding 3-month total), frequency (average from preceding 3-month total), total running kilometers in the previous 12 months and years of running experience.

The second, post-race questionnaire, obtained information regarding new injuries occurred during the month before the Rotterdam marathon and any injuries incurred during the marathon. These injuries were distinct from the injuries reported in the first questionnaire. An 11-point numerical rating scale (score range 0–10) measured the pain intensity of the lower extremity injuries.

The questionnaire was developed by the investigators and it was pilot tested on a group of runners during the half marathon, 6 months before the start of the marathon. The main outcome measure for this study was a self-reported running injury. The injury definition was elaborated on the injury definition of Macera et al.[13] A running injury was defined as "An injury to muscles, joints, tendons, and/or bones of the lower extremities (hip, groin, thigh, knee, lower leg, ankle, foot, toe) that the participant attributed to running." The problem had to be severe enough to cause a reduction in distance, speed, duration, or frequency of running.

Statistical analysis

Descriptive statistics were used for baseline characteristics. The chi-squared test was used to compare baseline characteristics, the proportions of injured runners who started or did not start the race and to compare the proportion of injured runners who finished or did not finish the race. SPSS (version 11) was used for the analyses.

RESULTS

Baseline characteristics

Of the 1500 selected runners, 726 replied to the baseline questionnaire. One female runner returned the questionnaire because she bought the start package, including the start num-

Table 1 Characteristics of participants (n=725) at baseline

Characteristic	Mean (SD)
Age (yr)	43.7 (±9.6)
Height (cm)	182.1 (±6.7)
Weight (kg)	78.2 (±8.9)
BMI (kg/m^2)	23.6 (±2.1)
Running experience (years)	10.7 (±8.9)
Running patterns for preceding 3 months	
Weekly distance in km	50.2 (±18.4)
Weekly training in hours	5.6 (±2.9)
Frequency, times per week	3.6 (±1.1)
Yearly kilometres	1845.1 (±981.7)

ber and questionnaire, from a registered male and was for this reason excluded. The baseline characteristics of the 725 males are represented in Table 1.

The average age of the runners was 43.7 (SD 9.6) years, which was representative for the entire male event population (42.8 ± 9.3 years). The average weekly running distance in the 3-month period preceding the baseline questionnaire was 50.2 (±18.4) kilometres. On average, respondents ran 1845km/year. More than half (54.8%) of the runners suffered at least one running injury during the year preceding the baseline questionnaire. Most of these lower extremity injuries occurred during training sessions (79.6%). The number of injuries per 1000h of running was 3.2; the location of these injuries are given in Table 2.

The most common site of lower extremity injury was the knee (30.7% of the total injuries) followed by the calf (23.2%) and the foot (14.6%). At the time of the baseline measurement, 195 (26.9%) runners reported one or more current lower extremity injury.

Table 2 Localisation of running injuries

Location	Previous year	Complaints at baseline
Total	397 (100%)	195 (100%)
Hip	39 (9.8%)	13 (6.1%)
Groin	32 (8.1%)	14 (6.6%)
Thigh	49 (12.3%)	27 (13.8%)
Knee	122 (30.7%)	52 (26.7%)
Shin	50 (12.6%)	23 (11.8%)
Calf	92 (23.2%)	28 (14.4%)
Achilles' tendon	54 (13.6%)	15 (7.7%)
Ankle	33 (8.3%)	14 (7.2%)
Foot	58 (14.6%)	32 (16.4%)
Toes	21 (5.3%)	10 (5.1%)

Table 3 Incidence of running injuries sustained before or during the Rotterdam marathon (n=694)

Location	One month before marathon	Sustained in the marathon
Total	108 (100%)	118 (100%)
Hip	4 (3.7%)	8 (6.8%)
Groin	6 (5.6%)	1 (0.8%)
Thigh	11 (10.2%)	21 (17.8%)
Knee	32 (29.6%)	32 (27.1%)
Shin	3 (2.8%)	2 (1.7%)
Calf	22 (20.4%)	40 (33.9%)
Achilles' tendon	8 (7.4%)	9 (7.6%)
Ankle	10 (9.3%)	5 (4.2%)
Foot	15 (13.9%)	16 (13.6%)
Toes	1 (0.9%)	16 (13.6%)

Incidence of injuries

Of the 725 male runners who returned the baseline questionnaire, 694 runners (95.7%) returned the post-race questionnaire. A comparison of age, BMI, running experience, weekly training distance, weekly training hours, and previous injuries of the runners who completed both questionnaires, compared with who did not, showed no significant differences (p>0.05).

Of the 694 runners, 46 (6.6%) did not start, and the outcome of one runner is unknown because this runner did not completely fill in the post-race questionnaire. Of those who did not start, 30 (65.2%) did not because of an injury. Of the 647 runners who started the race, 612 (94.6%) finished, and 35 (5.4%) did not finish. Of the 35 unfinished runners, 18 (51.4%) had an injury, seven (20%) were sick, and 10 (28.6%) had other reasons for not finishing.

Of the 397 runners who reported a running injury in the previous 12 months, 8.6% did not start while of the 328 runners who did not report a running injury 3.7% did not start (p=0.06). In the post-race questionnaire, 15.6% (n=108) of all respondents reported at least one new lower extremity injury in the month preceding the Rotterdam marathon. Of those runners who reported a new injury in the month preceding the marathon, 15 (13.9%) did not start, and seven (6.5%) started the marathon but did not finish. Runners who were injured in the month before the start were not at higher risk for not starting the race (p=0.82) and not finishing the race (p=0.47). Of the runners who had a running injury during the marathon race, 12.7% did not finish the race. This was significantly higher (p<0.001) than those who were not injured (3.8%). The sites of new lower extremity injuries are given in Table 3. The most frequent injured site shortly before the marathon was the knee (29.6%), followed by the calf (20.4%), and the foot (13.9%).

The incidence of lower extremity injuries in all started runners occurring during the Rotterdam marathon was 18.2% (n=118). The most frequent site was the calf (33.9%), followed by the knee (27.1%), and the thigh (17.8%). In total, 197 (28.4%) runners incurred at least one running injury in preparation for or during the Rotterdam marathon.

Of all started runners, 13.6% (n=88) had physical health problems other than in the lower extremities during the marathon. Most common cited problems were stomach–intestinal tract 33 (34.0%), locomotor apparatus (arms, neck, shoulder and back) 30 (30.9%) and the skin 10 (10.3%).

Impact of injuries

The pain intensity of injured runners in rest immediately after the marathon ranged from 0 to 9 on an 11-point scale. The median score was 2 and the interquartile range (IQR) was 3. For pain intensity during physical exercise the median score was 4.5 (range 0–10; IQR 4).

Of all injured runners (n=118) in the Rotterdam marathon, 86.4% were able to perform all their work tasks within 1 week after the marathon. Also 88.1% of all injured runners were able to carry out their usual activities of daily living (ADL) within 1 week. Sports and leisure activities could be carried out within 1 week by 53.4% of the injured runners.

DISCUSSION

The health benefits of running are well known. Running is widely perceived to be beneficial to the cardiovascular system[2] and to reduce the risk of mortality.[21] In addition, running has a positive effect on self-experienced physical fitness.[22] In our study, 54.8% of the participants in a popular running event had sustained one or more running injuries during the year preceding the race. At the moment of filling in the first questionnaire, still 26.9% of the runners experienced a running injury. During or immediately after the marathon, 18.2% of the started runners reported at least one new running-related injury to the lower extremities.

During the 12 months preceding the Rotterdam marathon, 54.8% of the respondents sustained at least one running injury to the lower extremities that was severe enough to reduce distance, speed, duration or frequency of running. This result is in line with the study of Maughan and Miller[8] who found a prevalence rate of running injuries of 58% preceding the marathon. However, Kretsch et al.[6] found that only 29% of the subjects reported some medical or physical symptoms, which occurred as a result of their training. This low prevalence may be partly due to methodological differences between the studies. Kretsch et al.[6] asked patients to record serious medical and physical problems, whereas our study reported lower extremity injuries, which had to be severe enough to cause a reduction in distance, speed, duration or frequency of running.

The incidence of injuries during the Rotterdam marathon was 18.2%. This percentage is somewhat lower than that found in other studies.[8, 11, 19] However, because these studies did not define their outcome it is difficult to compare with these data. The variation in the incidence of running-related injuries in the literature may in part be due to variations in the methodology. Also, the definition of a running injury may have caused differences between the studies.

The injury incidence expressed in exposure time was 3.2 injuries per 1000 running hours. It must be noted that our incidence rate expressed in exposure time could also include prevalent cases that were already present before the 12 months before the Rotterdam marathon. However, our result is supported by Lysholm and Wiklander[7] and Van Galen and Diederiks[23] who found incidence rates of, respectively, 3.6 and 2.5–5.8 per 1000 hours of running exposure.

In this study, the most common site of lower extremity injuries when preparing for the Rotterdam marathon was the knee (30.7%). Other studies also found the knee to be the most common injured site of the body during running.[8, 11, 13, 14, 16, 24] At our baseline measurement, the knee (26.7%) was the most common site of lower extremity injury, whereas during the marathon the calf (33.9%) was the most common injured site of the body. Satterthwaite et al.[25] also found a high incidence of stiffness and pain in the calf in 45.3% of the subjects during or immediately after the race. Other marathon studies predominantly found the knee and the foot to be the most injured site of the body during a marathon.[8, 9, 11, 16] The high incidence of foot injuries reported in other studies can be explained by the fact that most of these studies also considered blisters as injuries.

Limitations

The response rate of the baseline questionnaire was 48.4%, which is somewhat lower than what we had expected. Other athletics-based studies also had a relative high and comparable non-response.[26-28] For the baseline questionnaire, it was impossible to post reminders and to telephone the non-responders because of the anonymous mailing by a mail-order firm. Hence, unfortunately we do not have any information about the non-responders of the baseline questionnaire. Nevertheless, the response rate of the post-race questionnaire was very high; i.e. 95%. The one-year prevalence of running injuries found in the present study might have been influenced by selection bias. Subjects who were already injured or recently had a running injury might have been more willing to participate, in which case the prevalence rates could have been overestimated. Furthermore, the one-year prevalence of the injuries was obtained in a retrospective design from the first questionnaire. However, the incidence of running injuries shortly before and during the race was obtained with a prospective study design. Subjects were first included in the study and next they were prospectively observed for possible new injuries.

A further limitation of this study was that all information, including the information on injuries, was obtained by a self-administered questionnaire. For this reason, we do not have any meaningful information about the exact diagnosis of the injuries. Finally, the intention of this cohort study was to draw a random sample out of 10 000 male and female athletes.

However, through a communication problem with the mail-order firm, the random sample was only performed within the male runners group. As a consequence, this study is about male recreational runners only.

Perspectives

This study has shown that running injuries are very common in male marathon runners. However, the pain intensity in rest of all injured runners was relatively low and most of the injured runners were able to carry out their work and ADL tasks within one week after the marathon. There was no systematic physical examination in this study, so the exact diagnosis of the injuries is unknown. However, we have good insight into the self-reported pain and discomfort of the running injuries reported by the runners themselves.

For future research it would be interesting to look at the different preparation strategies and explore possible risk factors for developing an injury during the marathon. This may enable development of strategies to prevent the occurrence of running injuries. Because the positive health effects are evident, prevention of running injuries should have high priority.

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Chapter 4

Risk factors for lower extremity injuries among male marathon runners

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ABSTRACT

The aim of this study is to identify risk factors for lower extremity injuries in male marathon runners. A random sample of 1500 recreational male marathon runners was drawn. Possible risk factors were obtained from a baseline questionnaire one month before the start of the marathon. Information on injuries sustained shortly before or during the marathon was obtained using a post-race questionnaire. Of the 694 male runners who responded to the baseline and post-race questionnaire, 28% suffered a self-reported running injury on the lower extremities in the month before or during the marathon run. The following factors were associated with the occurrence of lower extremity injuries: participating more than six times in a race in the previous 12 months (OR 1.66; CI 1.08 – 2.56), a history of running injuries (OR 2.62; CI 1.82 – 3.78), high education level (OR 0.73; CI 0.51 – 1.04) and daily smoking (OR 0.23; CI 0.05 – 1.01). Among the modifiable risk factors studied, a training distance less than 40 kilometres a week is a strong protective factor of future calf injuries, and regular interval training is a strong protective factor for knee injuries. Other training characteristics appear to have little or no effect on future injuries.

INTRODUCTION

Running is a popular form of recreational exercise all over the world. Besides the positive health effects of this form of exercise, analysis of previous studies of recreational and competitive runners reveals a yearly incidence of injuries in runners of 26% to 92.4%.[1-7] There particularly is a high incidence of lower extremity injuries for those taking part in marathon runs.[2, 4, 7-9] Several studies have suggested a number of factors that may increase the risk of injuries for runners. A review from Macera et al.[10] concluded that among the modifiable risk factors studied, weekly running distance is the strongest predictor for future injuries. Most studies showed an increasing injury rate with increasing weekly running distance beyond approximately 32 km per week.[1, 7, 11-13] Previous running injuries are also reported to be a strong predictor for future injuries in several studies.[2, 7, 13-15] However, few studies investigated lower extremity injuries and their risk factors in long distance runners. As frequently seen in studies in the eighties, the methodological quality of these studies is quite low, especially with respect to the statistical analysis. Only one more recent study of Wen et al.[15], which studied the possibility of alignment as being a risk factor for running injuries, determined the possible risk factors independently from the injury and additionally applied a multivariate analysis. In order to enhance the prevention of running injuries it is of interest to enlarge the knowledge concerning potential risk factors, especially modifiable risk factors. Therefore, the aim of this study was to examine prospectively the relationship between possible risk factors and lower extremity injuries occurring shortly before or during a marathon run.

METHODS

Study participants

The Rotterdam marathon was held on the 10th of April 2005 over a standard-length course (42.2 km) through Rotterdam. The daily mean temperature in Rotterdam was 7.6°C (range 4.3 - 11.0°C) and the daily mean relative atmospheric humidity was 86%. Of the approximately 6000 recreational male runners who signed in for the Rotterdam marathon, a random sample of 1500 recreational runners was drawn. The questionnaires were added to every fourth start package that were sort out on start number by the mail order firm. One month before the start of the marathon a baseline questionnaire was sent by a mail order firm to the 1500 randomly selected recreational runners. These were asked to return the questionnaire by mail before the 10th of April 2005. Immediately after the Rotterdam marathon a second questionnaire was sent to all included runners. Those not returning the post-race questionnaire were sent a reminder letter. Residual non-responders were then contacted by telephone and asked to return the completed questionnaire.

Athletes were included in this study if they met the following criteria: 1) they had to be a male resident of the Netherlands; 2) they were recreational or amateur runners, and 3) they returned both the baseline questionnaire before running the marathon and the post-race questionnaire after the marathon run. Recreational runners were runners who signed in for the Rotterdam marathon and were not competitive with the professional runners in the Rotterdam marathon race.

Questionnaires

From the baseline questionnaire, we obtained information about possible risk factors for running injuries categorised in demographic factors, training related factors, race event factors, lifestyle factors and previous running injuries. Demographic factors included age, sex, height, weight and education. In the training related section, participants were asked about training distance, frequency and duration (average from last 3 months' total), running experience, type of training underground, training type (long-distance, interval) and shoes. Race event factors included earlier race participations, warming-up, cooling-down and stretching activities. Lifestyle aspects included other sport participation, special nutrition, smoking, medication and alcohol usage.

From the second questionnaire we obtained information regarding injuries occurring during the marathon (location of injury, pain intensity and other complaints). We also asked participants to report their warming-up and cooling-down strategy, nutrition intake and brace use with respect to the marathon run.

The researchers developed the questionnaire and it was pilot-tested on a group of runners during the half marathon, 6 months prior to the investigated marathon race. Questions were mostly multiple-choice or yes/no format. Questions about training and race factors were generally in short answer format.

The outcome measure for this study was a self-reported running injury occurring one month before or during the marathon run. The injury definition was elaborated on the injury definition of Macera et al.[13] A running injury was defined as a self-reported "injury on muscles, joints, tendons and / or bones of the lower extremities (hip, groin, thigh, knee, lower leg, ankle, foot, and toe) that the participant attributed to running". The problem had to be severe enough to cause a reduction in distance, speed, duration or frequency of running.

Statistical analysis

Descriptive statistics were used for baseline characteristics. Continues variables such as age, height, weight, training duration, frequency and distance, running experience, years of race participation and race participations in the last year were categorised in tertiles.

Using running injuries as the dependent variable, univariate regression analyses were performed on demographic, training, race event, lifestyle and previous running injury factors for each factor independently. Factors with a p-value ≤0.20 on the Wald test in the univariate models were entered in a multivariable logistic regression model. Backward stepwise elimination was used for the multivariable logistic analysis of prediction of runners at risk for injuries, and p≤0.10 was used as a cut-off level for elimination of non-significant predictors from the prognostic model.

Subgroup analyses were planned for the most frequently occurring running injuries. For these analyses, factors with a univariate p-value ≤0.20 on the Wald test were entered into category-specific regression models because fewer cases were involved in the analysis. Secondly, factors with a p-value ≤0.20 in the categorical models were entered into the full multivariable model. For these subgroup location specific analyses also the factor 'other incident injury than that location' was included in the analysis.

Calibration of the logistic model was assessed using the Hosmer-Lemeshow goodness-of-fit test[16] and discrimination was assessed using the area un the receiver operation characteristic (ROC) curve to evaluate how well the model distinguished patients who were injured from those who were not injured.[17, 18]

Odds ratios (ORs) are presented with 95% confidence intervals (CI). Possible risk factors were those with p≤0.1 on bivariate analyses. All statistical analyses were performed using SPSS for Windows, version 11.0, 2001.

RESULTS

A total of 726 runners responded to the baseline questionnaire. One female runner returned the questionnaire because she bought the start package, including the questionnaire, from a registered male and was excluded for this reason. The final study population consisted of 694 (95.7%) male runners who also responded to the second questionnaire. The baseline characteristics of the study population are represented in Table 1. The mean age of the study population was 44 years with a standard deviation of 9.6 years, which was representative for the entire male marathon population (42.8 ± 9.3 years). Almost half of the runners ran less than 4 times a week in the 3 months preceding the marathon. However, 21.3% of the respondents ran more than 60 km a week in the 3 months preceding the marathon. More than half of the runners had suffered a running injury during the 12 months preceding the baseline questionnaire.

Of the 694 respondents of the post-race questionnaire, 648 started the race, 46 did not start and the remaining of one respondent is unknown. Of those who started, 35 did not finish. Of the runners who did not start, 30 did not because of a running injury. A comparison of age, BMI, running experience, weekly running distance, frequency and previous running injuries of the runners who completed both questionnaires compared with those who did not, showed no significant differences (p>0.05).

Table 1 Baseline characteristics (n=694)

	Mean (SD)	n	%
Demographic characteristics			
Age (yrs),	43.8 (9.6)		
Height (cm)	182.1 (6.7)		
Weight (kg)	78.1 (8.8)		
BMI (kg/m^2)	23.5 (2.1)		
BMI >25		105	15.1
Education level (high)		324	46.7
Training-related factors			
Weekly distance (km)	50.2 (18.3)		
Weekly distance (km) >60		148	21.3
Weekly hours	5.7 (2.9)		
Weekly frequency	3.6 (1.1)		
Running experience (yrs)	10.8 (8.9)		
Weekly distance per weekly hours (km/hrs)	9.4 (2.6)		
Weekly distance per weekly frequency	14.0 (4.3)		
Special training program (yes)		454	65.4
Athletics association (yes)		318	45.8
Hard training underground (always)		669	96.4
Tartan training underground (always)		85	12.2
Gravel training underground (always)		10	1.4
No hard training underground (always)		156	22.5
Long-distance training (always)		682	98.3
Interval training (always)		301	43.4
Warming-up (always)		344	49.6
Stretching before training (always)		359	51.7
Cooling-down (always)		300	43.2
Stretching after training (always)		434	62.5
Knee brace use (yes)		10	1.4
Ankle brace use (yes)		6	0.9
Use of several shoes (yes)		600	86.5
Alternately wearing shoes (yes)		397	57.2
Shoe advice (yes)		616	88.8
Race events			
Earlier races (yes)		667	96.1
History of race participation (yrs)	9.0 (8.0)		
Times of race participation last year	6.5 (7.6)		
Participation race within framework of the marathon (yes)		325	46.8
Races 0-5 km (yes)		13	1.9

Table 1 continued

	Mean (SD)	n	%
Races 6-10 km (yes)		169	24.4
Races 11-22 km (yes)		608	87.6
Races 22-42 km (yes)		295	42.5
Warming-up before race (always)		429	61.8
Stretching before race (always)		405	58.4
Cooling-down after race (always)		240	34.6
Stretching after race (always)		355	51.2
Use of same shoes race and training (yes)		618	89.0
Knee brace use race (yes)		9	1.3
Ankle brace use race (yes)		6	0.9
Lifestyle factors			
Participation other sports (yes)		416	59.9
Daily smoking (yes)		22	3.2
Alcohol use (≥10 glasses / week)		185	26.7
Special feeding supplements (yes)		585	84.3
Non-musculoskeletal co-morbidities (yes)		124	17.9
Medication use (yes)		70	10.1
Running injuries			
Injury previous 12 months (yes)		376	54.2

A total of 195 runners (28.1%) reported a new running injury occurring in the month before or during the Rotterdam marathon. Of these injuries, 15.6% (n=108) occurred in the month before the marathon and 17.0% (n=118) of the runners suffered a new running injury during the marathon. Most of the incident injuries occurred in the knee (28.7%), calf (27.2%) and thigh (15.9%).

The median pain intensity of the 195 injured runners in rest directly after the marathon run was 2 (Interquartile Range (IQR) =3) and the median pain intensity during exercise was 4 (IQR=5), both on a pain scale from 0-10, with higher scores indicating more pain.

Non-musculoskeletal co-morbidities during the marathon were seen in 97 (14%) marathon participants. Most reported complaints were gastrointestinal tract (n=33), locomotor apparatus (arms, neck, shoulder and back) other than lower extremities (n=30) and the skin (n=10). Of all participants, 10.2% used pain medication shortly before or during the marathon run while 6.5% used pain medication after the marathon run.

Warming-up exercises before the start of the marathon were performed by 46% of the runners and more than 50% of the runners carried out some stretching exercises before the start. Directly after the marathon, 20% carried out some running exercises while almost 40% performed stretching exercises after the run.

Risk factors

Ten of the possible 48 potential risk factors (Table 2) were univariately associated with lower extremity injuries (p<0.20). A multiple logistic regression model was used to assess the combined effect of these risk factors on the occurrence of lower extremity injuries. The final multivariable logistic model after backward elimination is represented in Table 2. More than six times race participation in the last year (OR 1.66; CI 1.08 – 2.56) and previous running injuries (OR 2.62; CI 1.82 – 3.78) were associated with the occurrence of lower extremity injuries. High education level (OR 0.73; CI 0.51 – 1.04) and daily smoking (OR 0.23; CI 0.05 – 1.01) were protective factors for the occurrence of running injuries. The Hosmer-Lemeshow goodness-of-fit (p=0.87) showed no lack of fit of the final model to the data (a large p value indicating that there is not a large discrepancy between observed and expected injuries). The index of predictive discrimination for this model, namely the area under the receiver operating characteristic curve, was 0.65, reflecting moderate ability of the model to discriminate between patients who do and do not have a running injury.

Knee injuries

The occurrence of knee injuries was univariately associated with 11 of the potential 49 risk factors. The final multivariable logistic model is represented in Table 3. A previous running injury in the last 12 months (OR 3.67; CI 1.79 – 7.49) and a running experience of more than 15 years (OR 2.56; CI 1.22 – 5.34) were risk factors for the occurrence of knee injuries shortly before or during the marathon. Always performing interval training (OR 0.49; CI 0.26 – 0.93) was a protective factor for the occurrence of knee injuries. The accuracy of the model was moderate with an AUC of 0.72 and the Hosmer-Lemeshow goodness-of-fit (p=0.60) showed no lack of fit of the final model to the data.

Calf injuries

In the subgroup analysis, the occurrence of calf injuries was univariately associated with 7 of the 49 potential risk factors. Table 4 represents the final multiple logistic regression model for calf injuries. Having an incident injury at another localisation was a risk factor for incident calf injuries (OR 2.57; CI 1.42 – 4.67). A high education level (OR 0.60; CI 0.33 – 1.10), a training distance less than 40 kilometres a week (OR 0.36; CI 0.17 – 0.78) and membership of an athletics association (OR 0.58; CI 0.31 – 1.09) were all protective factors for calf injuries. The AUC was 0.69 reflecting a moderate accuracy of the model. The Hosmer-Lemeshow goodness-of-fit (p=0.44) showed no lack of fit of the final model to the data.

Table 2 Univariate Odds Ratios and multivariable risk model (backward elimination) for **incident injuries** versus no injury

Variables	Univariate analysis		Multivariable analysis	
	OR (95% CI)	p-value	OR (95% CI)	p-value
High education level	0.76 (0.55 - 1.07)	0.11	0.73 (0.51 - 1.04)	0.08
Long distance training				
always	0.32 (0.10 - 1.07)	0.06		
Interval training				
always	0.76 (0.54 - 1.07)	0.12		
Weekly distance per weekly frequency				
0-10	0.95 (0.64 - 1.42)	0.81		
11-15	Reference			
≥16	1.38 (0.86 - 2.22)	0.18		
History of race participation (yrs)				
0-3	1.21 (0.79 - 1.85)	0.39		
4-10	Reference			
≥11	1.47 (0.96 - 2.24)	0.08		
Times of race participation last year				
0-2	1.29 (0.84 - 1.97)	0.25	1.33 (0.86 - 2.06)	0.20
3-6	Reference		Reference	
≥7	1.55 (1.02 - 2.36)	0.04	1.66 (1.08 – 2.56)	0.02
Warming-up before race				
Always	0.79 (0.55 - 1.12)	0.18		
Daily smoking				
Yes	0.25 (0.06 - 1.07)	0.06	0.23 (0.05 - 1.01)	0.05
Non-musculoskeletal co-morbidities				
yes	1.45 (0.96 - 2.19)	0.08		
Injury previous 12 months				
yes	2.51 (1.76 - 3.56)	0.00	2.62 (1.82 - 3.78)	0.00

Only entered variables shown

DISCUSSION

This cohort study has identified several risk factors for the occurrence of marathon-related injuries on the lower extremities in male runners. More than six times race participation in the previous year and a history of running injuries were risk factors for the occurrence of running injuries. However, this study also revealed that a high education level and daily smoking are protective factors for marathon-related lower extremity injuries. We also found that a high education level, a training distance of less than 40 kilometres a week and membership of an athletics association were protective factors for the occurrence of calf injuries shortly before or during the marathon run. For knee injuries, runners with a history of running injuries and/or a running experience of more than 15 years were at higher risk.

Table 3 Multivariable risk model (backward elimination) for incident **knee** injuries versus no knee injury

	OR	95% CI	p-value
Interval training (always)	0.49	0.26 – 0.93	0.03
Injury previous 12 months	3.67	1.79 – 7.49	0.00
Running experience			0.03
0-4 yrs	1.43	0.63 – 3.26	0.40
15+	2.56	1.22 – 5.34	0.01

In this study, 28% of the runners suffered a running injury on the lower extremities in the month before or during the marathon run. The incidence rate found in this study is comparable with incidence rates found in other studies.[4, 19, 20] The knee and calf were found to be the most predominant sites of injuries, which have also been reported in several other studies.[1, 7, 9, 15, 20, 21]

Risk factors

In this study, a multivariable analysis of several modifiable risk factors was performed. Previous studies on running injuries were mostly retrospective and only represented a univariate analysis. However, several studies have reported numerous risk factors for injuries in long distance runners.

The rates of injuries among runners in this study do not increase with increasing age. Previous studies have reported higher age as a significant risk factor[5, 15, 21, 22] but higher age is also reported as a protective factor for the occurrence of running injuries.[2, 4, 5] However, in the majority of the literature age was not associated with running injuries and this is supported by the present study.

A history of running injuries was reported to be a significant risk factor for the occurrence of running injuries shortly before or during the marathon. This result was supported in other studies reporting relative risks of 1.7 to 2.7.[7, 13-15] This could suggest a possible role of unfavourable individual structural and biomechanical characteristics of injury sensitive runners, or an insufficient healing of the primary lesion, or both.[8] The increased risk of previous injuries may also been influenced by the severity of the primary injury, inadequate rehabilitation and/or premature return to sports activity.

A high educational level (vocational college / university) is shown to be a protective factor for running injuries. However, the association between running injuries and education level has not been investigated till this far. Nevertheless, a high education level is often seen as a protective factor for the occurrence of musculoskeletal complaints.[23] Runners with a high education level maybe more capable to deal with upcoming injuries and therefore do not develop the more serious injuries which are reported in the questionnaire.

Our present study indicates that daily smoking helps to prevent running injuries, but there is no evidence in the existing literature to support this finding. Though, Satterthwaite et al.[5] found a negative association between smoking and the occurrence of blisters. However, blisters were not included in this study so it remains difficult to explain these findings. We

Table 4 Multivariable risk model (backward elimination) for incident **calf** injuries versus no calf injury

	OR	95% CI	p-value
High education level	0.60	0.33 – 1.10	0.10
Training distance (km)			0.04
0-40	0.36	0.17 – 0.78	0.01
60+	0.57	0.27 – 1.19	0.14
Athletics association	0.58	0.31 – 1.09	0.09
Incident injury at another localisation	2.57	1.42 – 4.67	0.00

cannot give a possible physiological explanation for this finding. However, we think that daily smoking is a proxy variable for a non-measured variable in our study.

As mentioned in the introduction, weekly training distance is the most frequently cited risk factor for running injuries. However, we did not find an increased risk for injuries with increased weekly running distance. Following previous studies runners would be at greater risk when running more than 60 km a week.[7, 13] Nevertheless, Kretsch et al.[2] suggested that marathon entrants need to average at least 60 km/week in the two to three months before the race to minimize the risk requiring treatment on race day. In our study population, 27% of the runners with a weekly running distance more than 60 km a week were injured against 30.5% injured runners with a weekly running distance of 0-40 km a week. So the association between weekly running distance in the 3 months before the marathon and the occurrence of running injuries remains unclear.

A high education level, a training distance less than 40 kilometres a week and a membership of an athletics association are found to be protective factors for the occurrence of calf injuries. These last two factors are modifiable and indicate that the risk on calf injuries may be reduced. The factor membership of an athletics association may be covered by several other training factors, however these factors did not remain in the model.

The occurrence of knee injuries in this study was associated with previous running injuries and a running experience of more than 15 years and a lack of interval training. Several studies showed a previous injury to be a significant predictor for the occurrence of a new injury and this study indicates that this is true for knee injuries also. Satterthwaite et al.[5] already reported an association between knee injuries and participation in a marathon for the first time. Our findings suggest the opposite: more experienced runners who probably have more experience on marathon runs, are at greater risk for knee injuries. A relationship with higher age can be suggested, however the factor age does not survive in the multivariate model. Nevertheless, more than 40% of the experienced injured runners in our study are fifty years old or older versus 20% of the less experienced injured runners. This could suggest that these older runners might experience symptoms of early osteoarthritis. This should be in correspondence with the study of Lievense et al.[24] showing some evidence for the fact that long distance running predisposes for hip osteoarthritis. However for knee osteoarthritis no such evidence has been found yet.[25, 26]

Strength and limitations of the study

The strength of this study was its prospective study design. Injury information was obtained prospectively and extensive information was available concerning runners' characteristics, running experience and training patterns. One limitation of this study was that all outcomes and risk factors were self-reported and thus may not be completely reliable. Unfortunately, because we have no information from a physical examination, possible risk factors such as runners' strength, running pattern and alignment could not be taken into consideration. Running injuries were also self-registered. We chose not to mention the duration of an injury in our definition. However, it could have been useful to register the duration of a self-reported running injury as an index for injury severity. Further, we chose a significance level of 0.1. So we defined variables associated with running injuries of which the OR was not included in the 95% confidential interval. However, to our guidelines these variables are associated with running injuries.

The response rate of the baseline questionnaire was 48.4%, which is somewhat lower than we had expected. A comparable relative high non-response was found in other athletics-based studies as well.[27-29] For the baseline questionnaire it was impossible to post reminders and to telephone the non-responders because of the anonymous mailing by a mail-order firm. Nevertheless, the response rate of the post-race questionnaire was very high; i.e. 95%. The one-year prevalence of running injuries found in the present study might have been influenced by selection bias. Subjects who were already injured or recently had a running injury might have been more willing to participate, in which case the prevalence rates could have been overestimated.

The intention of this cohort study was to draw a random sample out of 10000 male and female athletes. However, through a communication problem with the mail order-firm the random sample was only performed within the male runners group. As a consequence, this study is about male recreational runners only.

Perspectives

Several risk factors were taken into account in this prospective cohort study. A high education level was found to be protective for running injuries and a history of running injuries in the previous 12 months is shown to be a risk factor. This result is also confirmed in several other studies so great care should be taken on subjects with a history of running injuries, especially in the 12 months prior to the marathon-event. Prior injuries should be sufficiently healed before participating in a marathon run. Among the modifiable risk factors studied, less than 40 training kilometres a week is a strong risk factor for future calf injuries and always performing interval training is a strong protective factor for knee injuries. Other training characteristics seem to have little or no effect on the injury rate.

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Chapter 5

Course and predicting factors of lower extremity injuries after running a marathon

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ABSTRACT

The objective of this study was to investigate in recreational runners the 3-months prognosis of and medical consumption due to running injuries occurring shortly before or during a marathon. Possible prognostic factors for persistent complaints were also evaluated. From the total cohort population (n=725), we extracted 165 recreational marathon runners who reported a new running injury in the month before or during the Rotterdam marathon 2005 and who were available for follow-up. By means of a baseline questionnaire, demographic, running (training distance, frequency and duration, experience etc.) lifestyle (other sports, smoking) and injury-related factors were collected. The main outcome measure was persistent complaints of running injuries occurring in the month before or during the Rotterdam marathon at three months follow-up. Potential prognostic factors for persistent complaints were analysed by multivariate logistic regression. At 3-months follow-up 25% of the 165 injured runners reported persistent complaints; they had little pain during exercise and almost no pain in rest. Of all 165 male runners, 27 (16.4%) visited a general practitioner (GP) because of their running injury and 40 (24.2%) visited a physiotherapist (218 times in total). Persistent complaints at 3-months follow-up were associated with non-musculoskeletal co-morbidities (OR 3.23; CI 1.24 to 8.43), and calf injuries (OR 0.37; CI 0.13 to 1.05). Thus, we can conclude that 25% of the injured runners had persistent complaints of their marathon-related running injury at 3-months follow-up. However, the clinical and social consequences of injuries seem to be relatively mild. Non-musculoskeletal co-morbidities at baseline are related to poor recovery, whereas recovery is also location specific.

INTRODUCTION

The positive effects of regular exercise and physical activity on health and well-being are described extensively.[1-3] A popular and challenging type of exercise is running. Especially long-distance running is currently one of the most popular fitness activities.[4] In spite of the health benefits, concerns have been raised about the high incidence of injuries, especially on the lower extremities.[5-8] Previous studies have reported incidence rates of lower-extremity injuries for runners ranging from 19-75%.[6,9-11] A substantial number of these running injuries occur in preparation for or during a large running event such as a marathon run.[6, 8, 12, 13] The clinical course of such running injuries is unknown. Most available studies on running injuries are descriptive and do not include follow-up measurements of the injured runners, and none has investigated the course of injured recreational marathon runners. Therefore, factors predicting the course of running injuries are also largely unknown. The identification of prognostic factors for injured runners at risk for developing persistent complaints may assist the selection of patients who will most likely benefit from early intervention to prevent persistent complaints.

Therefore, the aim of this study was to investigate the 3-months course of running injuries occurring shortly before or during the Rotterdam marathon, and to evaluate possible prognostic factors for persistent complaints in recreational marathon runners.

METHODS

The Rotterdam marathon was held on the 10th of April 2005 over a standard-length course (42.2 km) through Rotterdam. The daily mean temperature in Rotterdam was 7.6°C (minimum 4.3°C and maximum 11.0°C) and the daily mean relative atmospheric humidity was 86%. Of approximately 6000 recreational male runners who signed in for the Rotterdam marathon, a random sample of 1500 runners was made. One month before the start of the Rotterdam marathon 2005 a baseline questionnaire was sent by a mail order firm to these 1500 randomly selected participants. All runners were asked to return the questionnaire by mail before the marathon took place. Immediately after the Rotterdam marathon a second questionnaire (post-race) was sent to all 725 respondents (48.3%) of the first questionnaire. A third questionnaire was subsequently sent to all the runners who reported a running injury occurring in the month before or during the Rotterdam marathon. This third questionnaire was sent to these injured participants three months after the Rotterdam marathon (Fig. 1).

Runners were included in this study if they met the following criteria: 1) they had to be a resident of the Netherlands, 2) they were recreational/amateur runners, 3) they reported a new running injury in the month before or during the Rotterdam marathon 2005, 4) they started the marathon race, and 5) they returned the third questionnaire.

Subjects not returning the post-race or third questionnaire were sent another mailing. Residual non-responders were then contacted by telephone and asked to return the completed questionnaire.

Questionnaires

The baseline questionnaire sought information about the runners' age, height and weight (for calculation of body mass index; BMI), running experience and training patterns (including whether they regularly stretched and warmed-up before running), participation in other sports and other lifestyle factors.

From the second questionnaire we obtained information about running injuries in the month before the marathon and running injuries occurring during the marathon.

The third questionnaire inquired about possible persistent complaints of the new running injuries reported in the second questionnaire. Pain intensity was measured on an 11-point numerical rating scale (range 0-10, where 0 represents no pain and 10 unbearable pain). Runners were also asked about medical consumption such as visits to a physician and imaging, if any.

Data collection

The following prognostic factors were taken into consideration for all injured runners: demographic factors (age, BMI and education level), running factors (training distance, training time, training frequency, experience, special programme, etc), lifestyle factors (other sports, smoking, alcohol) and injury-related factors (previous injuries and localisation of injuries).

For injuries occurring during the marathon, factors from the second questionnaire (location of injury, pain, other complaints during the marathon, warming-up, cooling-down, stretching and special nutrition) were taken into consideration.

A running injury was defined as a self-reported "injury to muscles, joints, tendons and/or bones of the lower extremities (hip, groin, thigh, knee, lower leg, ankle, foot, toe) that the participant attributed to running". The problem had to be severe enough to cause a reduction in distance, speed, duration or frequency of running.

The main outcome measure for the present study was whether or not the injured recreational runners reported persistent complaints at 3-months follow-up.

Statistical analysis

Descriptive statistics were used to characterize the demographic information and to describe medical consumption and persistent complaints.

For categorisation of prognostic factors (age, BMI, weekly training distance, hours and frequency, running experience and race participation), the literature on risk factors of running injuries was taken into consideration. If no literature was available, prognostic factors were categorised with respect to a patient being above, between or below the respective overall 33rd and 66th percentile in injured runners in the present study.

Logistic regression models were constructed for the outcome persistent complaints at 3-months follow-up. A univariate logistic regression model was constructed for each of the

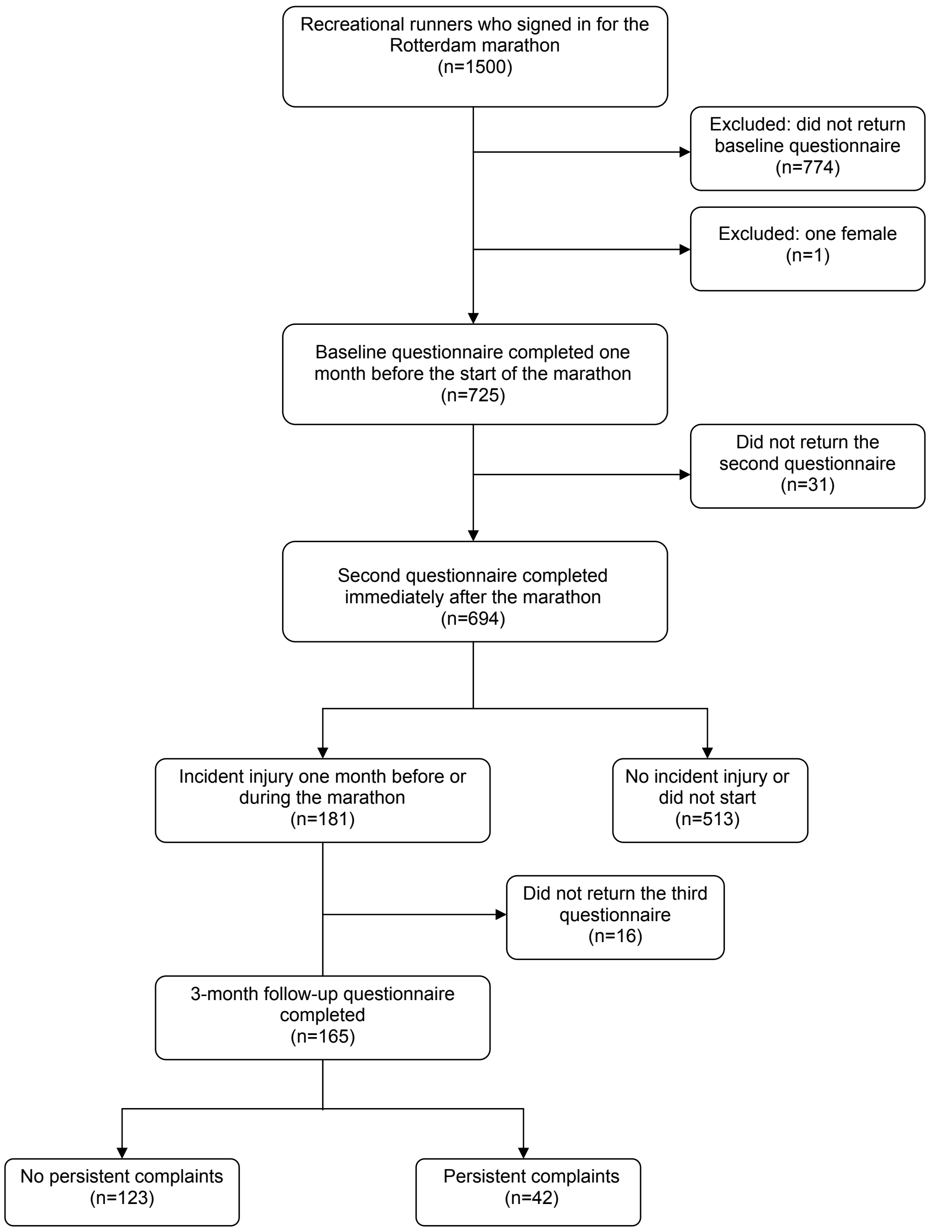

Figure 1. Flow chart

possible prognostic factors separately. Secondly, factors with a p-value ≤ 0.20 on the Wald test in univariate models were entered into a full multivariate logistic regression model [enter]. Subgroup analysis was performed only for the runners who were injured during the marathon, and for those with knee injuries and calf injuries separately.
The results are presented as odds ratios (ORs), with 95% confidence intervals (CI). All analyses were performed with the SPSS software package (version 11.0, 2001).

RESULTS

Baseline characteristics

A total of 726 runners responded to the baseline questionnaire. One female runner returned the questionnaire because she bought the start package, including the questionnaire, from a registered male and was for this reason excluded. Of the 725 included runners who responded to the baseline questionnaire, 694 (95.7%) returned the second questionnaire. Of these latter respondents, 181 received the third questionnaire because they reported a new running injury in the month before or during the Rotterdam marathon 2005 (Fig. 1). Of these, 165 (91.2%) replied to the third questionnaire. Table 1 represents the baseline characteristics and potential prognostic factors of these 165 runners. All these respondents were male and had a mean running experience of 9.5 years. A comparison of the age, BMI and education level of runners who completed the third questionnaire with all baseline respondents revealed no significant differences ($p>0.05$).
The mean follow-up time was 73.5 days (range 67-105 days). Of those completing the third questionnaire, 54.5% suffered a running injury in the month before the marathon and 63.6% had injuries that occurred during the marathon. Thus 30 runners suffered both a new injury in the month before as well as during the marathon. The most common site of lower extremity injury was the calf (30.3% of the total injuries) followed by the knee (29.1%) and the upper leg (13.9%). Only 17 (10.3%) of the 165 respondents did not finish the race.

Outcome at follow-up

Of all 165 respondents, 42 (25.5%) runners reported persistent complaints at 3-months follow-up. Of those 42 runners, 30 (71.4%) had no idea how long the complaints would continue, while 12 (28.6%) runners expected the persistent complaints to be over within a mean of 4.4 (±2.6) weeks. Of the 121 runners who reported no persistent complaints of their injury, 43 (35.5%) reported to be symptom-free within one week of occurrence. Only 24 (19.8%) of the 121 recovered runners had complaints lasting longer than one month but less than three months.
The median pain intensity of the running injuries of all 165 respondents in the preceding week before follow-up in rest was 0 and the interquartile range (IQR) was 1. For pain intensity

Table 1 Baseline characteristics and potential prognostic factors in runners with injuries (N=165)

	n	%
Demographic characteristics		
Age(yrs)		
(40-49)	64	38.8
(≥50)	45	27.3
BMI (>25)	27	16.4
Education (high)	98	59.4
Training-related factors		
Weekly distance in km (>=60)	50	30.3
Weekly hours		
(5-6)	50	30.3
(>6)	46	27.9
Weekly frequency		
(4)	51	30.9
(≥5)	31	18.8
Running experience		
(≤2)	40	24.2
(≥10)	61	37.0
Special training program (yes)	109	66.1
Athletics association (yes)	68	41.2
Hard training underground (always)	158	95.8
Tartan training underground (always)	16	9.7
Gravel training underground (always)	3	1.8
No hard training underground (always)	31	18.8
Long-distance training (always)	157	95.2
Interval training (always)	61	37.0
Warming-up (always)	81	49.1
Stretching before training (always)	93	56.4
Cooling-down (always)	67	40.6
Stretching after training (always)	106	64.2
Knee bandage use (yes)	6	3.6
Ankle bandage use (yes)	2	1.2
Use of several shoes (yes)	137	83.0
Alternately wearing shoes (yes)	45	27.3
Shoe advice (yes)	145	87.9
Race events		
Earlier races (yes)	157	95.2
Years race participation		
(4-8)	47	28.5
(≥9)	51	30.9
Yearly participation races		
(4-7)	38	23.0
(≥8)	52	31.5

Table 1 continued

	n	%
Race participation last year		
(3-6)	54	32.7
(≥7)	44	26.7
Participation race within framework of the marathon (yes)	80	48.5
Races 0-5 km (yes)	4	2.4
Races 6-10 km (yes)	38	23.0
Races 11-22 km (yes)	21	12.7
Races 22-42 km (yes)	68	41.2
Lifestyle factors		
Participation other sports (yes)	97	58.8
Daily smoking (yes)	2	1.2
Alcohol use (≥10 glasses / week)	40	24.2
Special feeding supplements (yes)	138	83.6
Non-musculoskeletal co-morbidities (yes)	21	12.7
Running injuries		
Injury previous year (yes)	111	67.3
Injury at baseline (yes)	48	29.1
Injury month before marathon (yes)	90	54.5
Injury during the marathon (yes)	105	63.6
Hip injury	11	6.7
Groin injury	6	3.6
Thigh injury	23	13.9
Knee injury	48	29.1
Shin injury	4	2.4
Calf injury	50	30.3
Achilles injury	14	8.5
Ankle injury	12	7.3
Foot injury	15	9.1
Toe injury	14	8.5

during physical exercise the median score was 1 (IQR 3). Of the 42 runners who reported persistent complaints the median pain intensity in rest was 1 (IQR 2.25) and the median pain intensity during exercise was 3.5 (IQR 4.25). Three runners (1.8%) were not able to work for up to 7 days due to their running injuries and, one runner was not able to work for 7 to 14 days as a result of his running injury. All 42 runners who reported persistent complaints were able to carry out their usual Activities of Daily Living within one week after the marathon run.

Shoe and/or training adaptations as a result of their running injury were made by 66 (40%) runners: 23 runners made shoe adaptations, 25 runners made adaptations in training duration, and 21 in training frequency.

Table 2 Multiple logistic regression (enter model) of prognostic factors associated with persistent complaints ($P_{in} < 0.20$) of incident injuries (n=165)

	Odds Ratio	CI 95%	p-value
Running experience (yrs)			
0-2	0.79	0.31 – 2.01	0.62
3-10	ref		
10+	0.40	0.12 – 1.30	0.13
Cooling down			
Never	ref		
Always	0.51	0.21 – 1.26	0.14
Yearly participation race			
0-3	ref		
4-7	0.97	0.23 – 4.05	0.97
8+	0.65	0.15 – 2.91	0.58
Participation last year			
0-2	ref		
3-6	0.63	0.13 – 3.10	0.57
7+	0.59	0.13 – 2.59	0.48
Races 0-5 km			
No	ref		
Yes	2.61	0.22 – 30.71	0.45
Non-musculoskeletal co-morbidities			
No	ref		
Yes	**3.23**	**1.24 – 8.43**	**0.02**
Injury previous 12 months			
No	ref		
Yes	1.41	0.48 – 4.09	0.53
Injury at baseline			
No	ref		
Yes	1.62	0.61 – 4.33	0.34
Injury by running the marathon			
No	ref		
Yes	1.93	0.73 – 5.07	0.19
Thigh injury			
No	ref		
Yes	0.38	0.09 – 1.69	0.21
Calf injury			
No	ref		
Yes	0.37	0.13 – 1.05	0.06
Ankle injury			
No	ref		
Yes	2.67	0.65 – 10.98	0.17
Toe injury			
No	ref		
Yes	2.54	0.60 – 10.67	0.20

Significant ORs are presented in bold.
ref = reference

Of all 165 runners, 27 (16.4%) visited a general practitioner as a result of their running injury. A total of 40 runners (24.2%) visited a physiotherapist, 218 times in total. X-rays were made in five injured runners; an echogram was made in two runners and in one runner MRI was performed.

In 20 (12.1%) runners a new lower-extremity injury occurred in the period between the onset of the injury before/during the marathon and 3-months follow-up.

Prognostic factors

In the univariate analysis, 13 of the possible 52 prognostic factors were associated with persistent complaints in the group with new injuries occurring one month before or during the marathon. In the multivariate logistic regression model, persistent complaints were associated with non-musculoskeletal co-morbidities (i.e. disorders of the nervous system, gastrointestinal tract/cardiac diseases) at baseline (OR 3.23, CI 1.24 – 8.43) whereas having a calf injury (OR 0.37, CI 0.13 – 1.05) was almost significant (p=0.06) (Table 2).

In the subgroup analysis, persistent complaints of injuries which occurred during the marathon were univariately associated with 8 of the 28 possible prognostic factors (Table 3). In the multivariate model, none of the eight factors was significant at the conventional 5%-level. However, having a calf injury (OR 0.39, CI 0.13 – 1.15) and taking special nutrition (OR 0.28, CI 0.07 – 1.12) were almost significant (p<0.10).

Persistent complaints in the subgroup with knee injuries (n=48) were univariately associated with 9 of the possible 52 prognostic factors. In the multivariate logistic model, only training on unimproved underground (OR 33.33, CI 2.11 – 526.36) was associated with persistent complaints.

In the univariate analysis in the subgroup with calf injuries (n=50), two (i.e. regularly running 22-42 km races, and shoe advise) of the possible 52 prognostic factors were associated with

Table 3 Multiple logistic regression (enter model) of prognostic factors associated with persistent complaints ($P_{in} < 0.20$) of incident injuries occurring during the Rotterdam marathon (n=105)

	Odds Ratio	CI 95%	p-value
Thigh injury	0.27	0.05 – 1.46	0.13
Calf injury	0.39	0.13 – 1.15	0.09
Ankle injury	2.01	0.27 – 16.14	0.48
Taken action to reduce complaints	2.94	0.55 – 15.81	0.21
Pain in rest	2.72	0.77 – 9.63	0.12
Warming-up before marathon	2.05	0.76 – 5.59	0.16
Cooling-down after marathon	1.65	0.44 – 6.17	0.46
Special feeding	0.28	0.07 – 1.12	0.07

no persistent complaints. However, these factors did not reach significance in the multivariate model ($0.05 < p \leq 0.20$).

DISCUSSION

In this cohort study, 25.5% of the injured recreational marathon runners reported persistent complaints at 3-months follow-up. During this period, in total, a physiotherapist was visited 218 times and a general practitioner 27 times. Non-musculoskeletal co-morbidities at baseline were related to poor recovery, while runners with a calf injury had a relatively good prognosis compared to injuries at other locations. The subgroup analysis showed that training on unimproved underground was associated with poor recovery of knee injuries.

Although a high percentage of injuries occurring in recreational long-distance runners has been reported, [6, 12, 14] the course of such running injuries has not yet been investigated. This is the first study to include a follow-up measurement of injured runners, and shows that 75% of the studied group of injured runners recover within three months after the marathon. The consequences of injuries occurring shortly before or during the marathon are relatively mild: the median pain intensity in rest at 3-months follow-up was zero while the median pain intensity during exercise was marginal (score of 1 on an 11-point scale). Runners experienced some discomfort due to their injury during exercise but are not limited in their work tasks and/or Activities of Daily Living. However, 27 of the 165 runners visited a general practitioner and 40 runners visited a physiotherapist, (i.e. almost 25% of the injured runners visit a physiotherapist due to their running injury).

Prognostic factors

In this study, the non-musculoskeletal co-morbidities at baseline are related to poor recovery, while injured runners with a calf injury have a relatively good prognosis compared to injuries at other locations. The percentage of calf injuries occurring shortly before or during the marathon was high (30.1% of all injuries). Most self-reported diagnoses of these injuries were cramps, strain and overload; this may partly explain why only 7 of the 49 runners with a calf injury reported persistent complaints at 3-months follow-up.

A positive trend was seen regarding running experience. Those with a running experience of more than 10 years were more likely to recover faster. This may represent a survival phenomenon, whereby those still running have 'survived' the injuries that cause many other runners to leave the sport. The reduction in the risk of persistent complaints may be explained by a similar survival mechanism: the fittest runners survive.[15] When the statistical multivariate method was repeated with a stepwise backward selection method, the final model included non-musculoskeletal co-morbidities and calf injuries but also having an injury at baseline

(OR 2.43, CI 1.13 – 5.24). Several studies have reported that a previous injury is a risk factor for future injuries. [11, 15-17] The present study also shows a positive trend of previous injuries being related to poor recovery after a new injury.

None of the prognostic factors associated with persistent complaints are modifiable, therefore persistent complaints cannot easily be prevented. However, injured runners with non-musculoskeletal co-morbidities should be particularly careful. Because persistent complaints of knee injuries were associated with training on unimproved underground, runners who often or always train on unimproved underground are more likely to have persistent complaints of their knee injury. Although there is no obvious explanation why these runners are at greater risk for persistent complaints, perhaps they are unaccustomed to running on a street surface.

Strength and limitations of the study

The strength of this study was its prospective design. Injury information was obtained prospectively and extensive information was available concerning runners' characteristics, running experience and training patterns. This study also has some limitations, which suggest the need for caution in interpreting the results. Data on both prognostic factors and outcome were self-reported and thus may not be completely reliable. Unfortunately, because we have no information on the specific type of injury (i.e., sprain, strain, stress fracture, etc.) we could not predict the prognosis of specific injuries common in runners but could only predict location-specific injuries. Further, we did not have any information from physical examinations and/or physical tests. Therefore, possible prognostic factors such as runner's strength, flexibility, running pattern and alignment are unknown.

The intention of this cohort study was to draw a random sample out of 10000 male and female athletes. However, through a communication problem with the mail order-firm the random sample was only performed within the male runners group. As a consequence, this study is about male recreational runners only.

Finally, we aimed for a follow-up period of 3 months. However, the mean time between the marathon run and filling in the third questionnaire was 73.5 days. The questionnaires were sent by mail and we had to anticipate on mailing time and time for filling in and returning the questionnaires. For this reason we decided to sent the third questionnaires at approximately 9.5 weeks follow-up. Afterwards we must conclude that the participants responded very quickly and the questionnaires were sent too early to the participants.

Conclusions

In this cohort study, one quarter of the runners had persistent complaints of their running injury at 3-months follow-up. However, the consequences of injuries occurring shortly before or during the marathon seem to be relatively mild. The pain intensity was marginal and there

were hardly any consequences for Activities of Daily Living and work tasks. However, almost 25% of the injured runners visited a physiotherapist due to their running injury.
Persistent complaints were related to non-musculoskeletal co-morbidities at baseline. Calf injuries predict relatively good outcome at 3-months compared to injuries at other locations.

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Chapter 6

Knee complaints seen in general practice: athletes versus non-athletes

Submitted

ABSTRACT

The aim of this study is to investigate the differences in type of knee complaints between athletes and non-athletes presenting in general practice. Further, differences in the initial policy of the GP, medical consumption, and outcome at one-year follow-up were also investigated. Patients consulting their GP for a new episode of knee complaints were invited to participate in the study. From the total HONEUR knee cohort population (n=1068) we extracted patients who were athletes (n=421) or non-athletes (n=388). The results showed that acute distortions of the knee were more often diagnosed in athletes than in non-athletes (p=0.04). More athletes were advised by their GP to 'go easy on the knee' than the non-athletes (p<0.01). Medical consumption was higher among athletes. No differences were found between the two groups for recovery at one-year follow-up. Therefore, we can conclude that there are hardly any differences in knee complaints between athletes and non-athletes presenting to the GP. Athletes are, however, advised more often to 'go easy on the knee' and to rest than the non-athletes. Further, there is a trend towards increased medical consumption among athletes while functional disability and pain are less severe compared to non-athletes. Despite the GP's advice and increased medical consumption, athletes do not have a better prognosis regarding their recovery at one-year follow-up.

INTRODUCTION

Complaints of the lower extremities are a serious problem because of their high prevalence and high impact on functional and work disability. A study among the Dutch general population showed a one-year prevalence of 21.9% for knee pain; about 33% of subjects reporting knee or hip complaints during the preceding year indicated that they had contacted their general practitioner (GP) for this complaint.[1] Among the Dutch population, knee problems are the most frequently presented complaints of the lower extremities: 21.4 per 1000 person-years for women and 22.8 per 1000 person-years for men.[2]

Since sport activities are strongly promoted, the risk of sport injuries is likely to increase. Knee complaints are very common among sport participants[3, 4] and it is reported that 39.8% of all sports injuries involve the knee.[3] Internal knee trauma, such as anterior cruciate ligament rupture, and distortion of the knee are the most common diagnoses of athletic knee injuries.[3] In addition, knee disorders such as the runner's knee, the patellofemoral pain syndrome, meniscus lesions and an anterior cruciate ligament rupture are often associated with sport participation.[5, 6]

In the Netherlands, almost everyone is registered in a general practice. At the time of conducting this study, all patients had first to visit their GP before being referred to a therapist or specialist in the Dutch health care system. Therefore, most care-seeking athletes with knee complaints in the Netherlands will visit their GP for primary care. Since knee complaints are common among athletes and are frequently presented in general practice, it is of interest to investigate the type of knee complaints represented in general practice of athletes in comparison with those of non-athletes. These differences could have implications for applied treatment strategies of these knee complaints, i.e. it might be beneficial to treat the athletes different than the non-athletes because of a different diagnosis. Further, it is of interest to explore differences between athletes and non-athletes regarding the GP's initial treatment, medical consumption and prognosis of the two groups. If the medical consumption appears to be the only difference between athletes and non-athletes we will need to reflect on the implications of such difference. Therefore, this study investigated differences in knee complaints between athletes and non-athletes presenting in general practice. The following questions were formulated: (1) Do athletes present with different knee complaints than non-athletes in general practice? (2) Is there a difference in initial policy of the GP between athletes and non-athletes? (3) Is there a difference in medical consumption between athletes and non-athletes during one-year follow-up? and (4) Do athletes have a better prognosis than non-athletes at one-year follow-up expressed in recovery, pain intensity and the WOMAC-score?

METHODS

Study design

A prospective, observational cohort study was set up, with a follow-up of one year. A total of 40 GP's from 5 municipalities in the southwest region of the Netherlands (all connected to the Erasmus Medical Centre GP Research Network HONEUR) participated in this study. Recruitment of patients started in October 2001 and finished in October 2003. Patients aged 12 years and older, consulting their GP for a new episode of knee complaints were invited to participate in the study. Complaints that were presented to the GP for the first time, and recurrent complaints for which the GP was not consulted during the preceding 3 months, were considered to be new complaints. During such a consultation, the GP briefly informed the patients of the existence of the study and handed over written information and a baseline questionnaire. Interested patients forwarded their contact details to the researchers. The researchers contacted the patients to give additional information about the study, and to make an appointment to sign informed consent, and to perform a comprehensive standardized physical examination of both knees. GPs noted the working diagnoses of the knee disorders according to the International Classification of Primary Care.

Patient characteristics, medical history, knee anamnesis, GP's initial policy and sport activities were recorded in the baseline questionnaire. Follow-up questionnaires were sent to all participants at 3, 6, 9 and 12 months. Patients underwent a standardized physical examination at baseline and at one-year follow-up.

The researchers did not interfere with usual care with respect to advice, diagnostics or treatment. The Ethics Committee of the Erasmus Medical Centre Rotterdam approved the study. A detailed description of recruitment and data collection are reported elsewhere.[7]

Study population

A total of 1068 patients were recruited from 40 GP's (Fig. 1). From this total cohort population we extracted patients who were athletes (n=421) or non-athletes (n=388). This selection was based on reported sport activities in the baseline questionnaire. Patients were first asked if they participated in any sport activity. Secondly, each patient could fill in his/her sport participation, to a maximum of three sports. For each sport activity, the type of sport, number of weeks of sport participation per year, and number of mean hours of sport participation per week were registered.

Athletes were defined as those who participated in sport for at least 30 weeks per year and minimally 2.5 hours a week for any one type of sport. Athletes who sport for minimally 20 weeks a year and at least 1.5 hours a week within one type of sport, and this for two or more sports, were also defined as athletes. The following activities reported on the questionnaires were not considered as being sport activities: bowls, billiards, darts, diving, golf, jeu de boules, go karting, 'slender you', shooting sports, fishing, and yoga. Non-athletes were defined as patients who reported no participation in sport activities at all. Because of the distinguishing power of this study, occasional athletes (n=259) were excluded from this study (Fig. 1).

Outcome measures

The four follow-up questionnaires reported on the medical consumption, pain, and functional disability of the knee of all participants. Pain was measured on a numerical rating scale (VAS) ranging from 0 (no pain) to 10 (unbearable pain). The WOMAC osteoarthritis index evaluates the functional disability of the knee with a score ranging from 0 (poor) to 100 points (excellent).[8,9] After one-year follow-up, satisfaction with the GP's given policy, treatment, discomfort during employment and daily activities, and experienced recovery were registered. Patients' satisfaction was measured on an 11-point numerical rating scale from 0 (completely unsatisfied) to 10 (completely satisfied). Discomfort during employment and daily activities was measured dichotomously ("yes" or "no"). Experienced recovery was measured on a 7-point Likert scale ranging from total recovery (=1) to worse than ever (=7). The categories 'total recovery' and 'major improvement' represent a clinically relevant improvement. All other categories represent persistent knee complaints.

Statistical analyses

Descriptive statistics were used to characterize demographic information, and chi-square and t-tests were applied to test the baseline differences for age, gender, BMI, WOMAC score and pain. Logistic regression analyses were used to test the association between athletic status and i) the type of knee complaint, ii) initial policy of the GP, iii) medical consumption, iv) patient satisfaction with treatment received, v) recovery at one-year follow-up, and, vi) discomfort during employment and daily activities.

All of these analyse were adjusted for age, gender and BMI. In addition, models ii, iii, iv, v and vi were adjusted for trauma and baseline severity (measured by the WOMAC). Model vi was also adjusted for the appropriate baseline discomfort score.

Linear regression was used to test the association between athletic status and pain and function, as measured by the WOMAC. These analyses were adjusted for the potential confounders age, gender, BMI, trauma and baseline severity (WOMAC). The analyses for pain and function (WOMAC) were also adjusted for appropriate baseline pain and function scores, respectively.

The results of the logistic regression analyses are presented as odds ratios (ORs), with 95% confidence intervals (CI). A p-value less than 0.05 was considered significant. All analyses were performed with the SPSS software package (version 11.0, 2001).

RESULTS

Study population

Comparison of baseline characteristics between dropouts (lost to follow-up at one year) and non-dropouts showed no significant differences with respect to gender, age and the WOMAC score. The pain score at baseline of the dropouts was significantly lower compared to the pain score of the non-dropouts (mean difference 0.69).

Table 1 presents baseline characteristics of the two groups. The mean age (SD) of the total study population (n=809) was 45.3(16.9) years. The mean age of the athletes was significantly lower than the non-athletes. The total study population consisted of 440 men (54.4%) and the mean BMI was 26.3(4.7); the BMI of the athletes was significantly lower (25.2(4.1)) than the non-athletes (27.6(4.9)). The functional disability score at baseline (WOMAC score) showed a significantly higher outcome, indicating better functioning, among the athletes.

Among the athletes, cycling was the most commonly practiced sport (54.2%), followed by walking (24.2%), fitness (17.1%), soccer (15.4%) and tennis (13.1%). At baseline, 177 (21.9%)

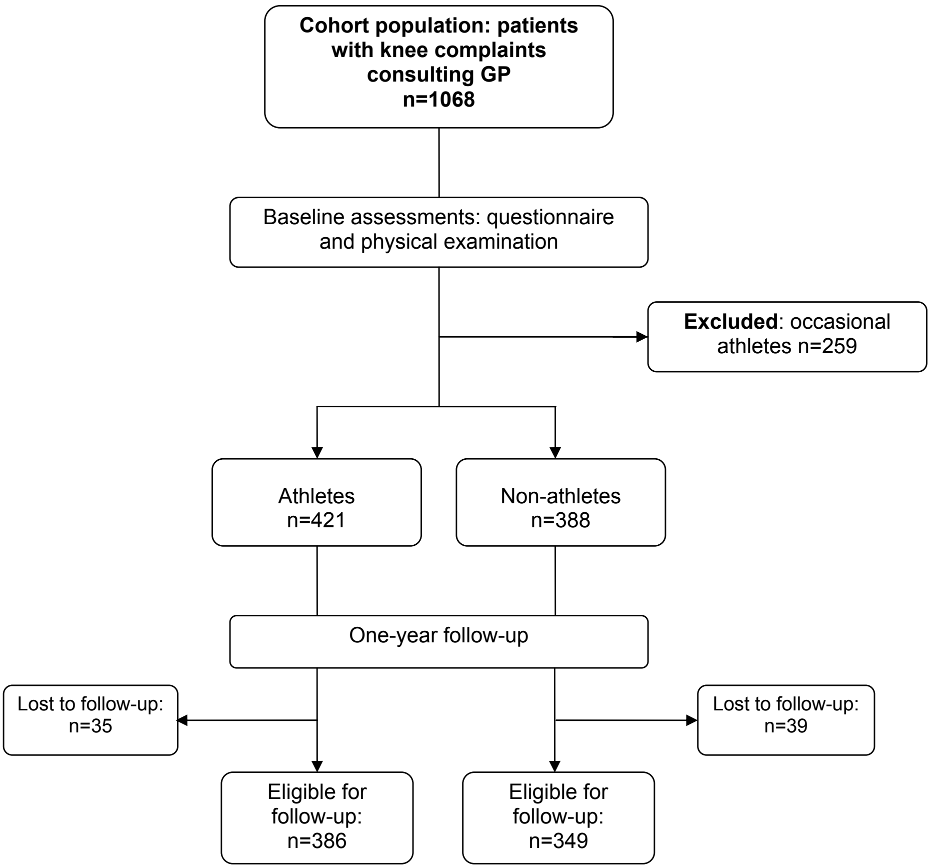

Figure 1. Flow chart

athletes practiced two types of sports, and 101 (12.5%) athletes practiced three types of sports.

Type of knee complaints

The different types of knee complaints among the study population are listed in Table 1. About 32% of all knee complaints in both groups were traumatic injuries. Almost 30% of the athletes sustained this injury during a sport activity. In total, 50% of the athletes reported an association between their knee complaint and their sport activity.

The most frequently presented knee complaints in general practice are designated as general knee complaints: 32.8% among athletes versus 35.6% among non-athletes. The patellofemoral pain syndrome (11%) is also a relatively often-diagnosed knee complaint. The proportion of acute distortions showed a significant difference: 5.2% of the non-athletes was labelled as 'acute distortion' compared with 8.8% of the athletes (p=0.04); however this difference is small. Osteoarthritis is also often diagnosed in general practice (8.7%). Osteoarthritis is more frequently seen among the non-athletes (12.6%) than among the athletes group (5.0%); however, there was no significant difference in frequency ratio in the adjusted analysis.

Table 1 Baseline characteristics of the study population

		Athletes (n=421)	Non-athletes (n=388)	p-value
Age (years)	Mean (SD)	41.0 (16.7)	50.0 (15.9)	**<0.001**
Gender (male)	N (%)	244 (58%)	196 (50.5%)	**0.034**
BMI (kg/m^2)	Mean (SD)	25.2 (4.1)	27.6 (4.9)	**<0.001**
WOMAC score	Mean (SD)	74.5 (19.5)	66.6 (21.1)	**<0.001**
Pain (VAS)	Mean (SD)	4.20 (2.15)	4.46 (2.19)	**<0.001**
*Type of knee complaints**				
Trauma	N (%)	147 (34.9%)	111 (28.6%)	0.26
Bilateral	N (%)	19 (4.5%)	13 (3.4%)	0.76
Recurrent complaints	N (%)	159 (37.8%)	165 (42.5%)	0.24
*Working diagnoses GP**				
General knee complaints	N (%)	138 (32.8%)	138 (35.6%)	0.62
Jumper's knee	N (%)	37 (8.8%)	38 (9.8%)	0.27
Acute distortion	N (%)	37 (8.8%)	20 (5.2%)	**0.04**
Osteoarthritis	N (%)	21 (5.0%)	49 (12.6%)	0.32
Osgood-Schlatter	N (%)	7 (1.7%)	1 (0.3%)	0.57
Acute meniscus / ligament rupture	N (%)	21 (5.0%)	17 (4.4%)	0.73
Chronic internal trauma	N (%)	45 (10.7%)	24 (6.2%)	0.07
Patellofemoral pain syndrome	N (%)	52 (12.4%)	37 (9.5%)	0.56
Chronic meniscus fracture	N (%)	5 (1.2%)	10 (2.6%)	0.29

* Analyses adjusted for gender, age and BMI. Significant differences are printed **bold**.

Table 2 Initial policy of the general practitioner at the first visit for knee complaints

Treatment by GP	Athletes	Non-athletes	OR (95% CI)	p-value
Passive strategy			1.64 (1.20 – 2.23)	**0.002**
Wait and see	24.5%	19.8%		
Rest	26.4%	21.1%		
Go easy on the knee	42.5%	30.9%		
Compresses	10.9%	9.3%		
Active strategy			1.20 (0.83 – 1.73)	0.33
Exercises	19.5%	13.9%		
Reduce body weight	3.1%	7.5%		
Medication			0.84 (0.59 – 1.20)	0.33
Medication	19.5%	28.1%		
Injection	-	1.0%		
Referrals for diagnostics	13.5%	19.8%	0.98 (0.64 – 1.48)	0.91
Referrals to care givers			1.09 (0.79 – 1.49)	0.61
Therapist	29.5%	23.5%		
Medical specialist	10.2%	12.4%		

Analyses adjusted for gender, age, BMI, trauma and baseline WOMAC-score.
Significant differences are printed **bold**.

GP's initial policy and medical consumption

The initial policy of the GP at baseline is shown in Table 2. Most patients were advised to 'go easy on the knee', to 'rest' and to 'wait and see'. More athletes were advised to 'go easy on the knee' (p=0.002). More than 25% of the patients were referred to a therapist and almost 25%

Table 3 Medical consumption at one-year follow-up

Medical consumption	Athletes	Non-athletes	OR (95%CI)	p-value
Revisit to general practitioner	36.8%	35.8%	1.43 (1.04-1.96)	**0.029**
Visit to therapist or specialist:	40.6%	38.7%	1.38 (1.01 – 1.88)	**0.045**
Physiotherapist	30.4%	29.6%		
Specialist	6.2%	4.4%		
Rheumatologist	0.0%	0.8%		
Orthopaedic surgeon	20.0%	18.0%		
Revalidation specialist	0.2%	0.0%		
Therapist Cesar / Mensendieck	0.7%	1.0%		

Analyses adjusted for gender, age, BMI, trauma and baseline WOMAC-score.
Significant differences are printed **bold**.

of all patients were prescribed medication. No statistical differences were found between the two groups regarding medication (p=0.33), and referrals for additional diagnostic testing (x-rays) (p=0.91) and to specialists/therapists (p=0.61).

Table 3 shows the medical consumption, expressed in numbers of patients visiting a specialist or paramedic. More than one third of the patients revisited the GP for their knee complaints; significantly (p=0.03) more athletes revisited the GP than non-athletes, but the difference is small. A therapist or specialist was visited by 40.6% of the athletes versus 38.7% of the non-athletes (p=0.045). However, when the analysis was adjusted for 'revisiting the GP', there was no longer a relationship between being an athlete and medical consumption (p=0.20). Most patients visited a physiotherapist (30%) or an orthopedic surgeon (19%). The mean number of visits to the physiotherapist was 10.3(7.5) among the athletes versus 11.1(8.7) among the non-athletes.

In general, patients were very satisfied with the GP's treatment of their knee complaints. Almost 43% of the patients scored an eight or higher on the numerical rating scale. The mean score on the 11-point numerical rating scale, among the athletes was 7.2(2.6) versus 7.6(2.5) among the non-athletes (p=0.90). Patients who were referred to a therapist (physiotherapist, manual therapist or occupational therapist) were generally very satisfied with their treatment: 62.1% of the athletes scored an eight or higher on the 11-point numerical scale versus 66.0% of the non-athletes (p=0.86).

Course and prognosis

Total recovery at one-year follow-up was reported by 59.8% of the athletes versus 50.7% of the non-athletes. However, self-reported recovery at one-year follow-up was not associated with being an athlete or not (p=0.40). Figure 2 shows the unadjusted mean pain and WOMAC

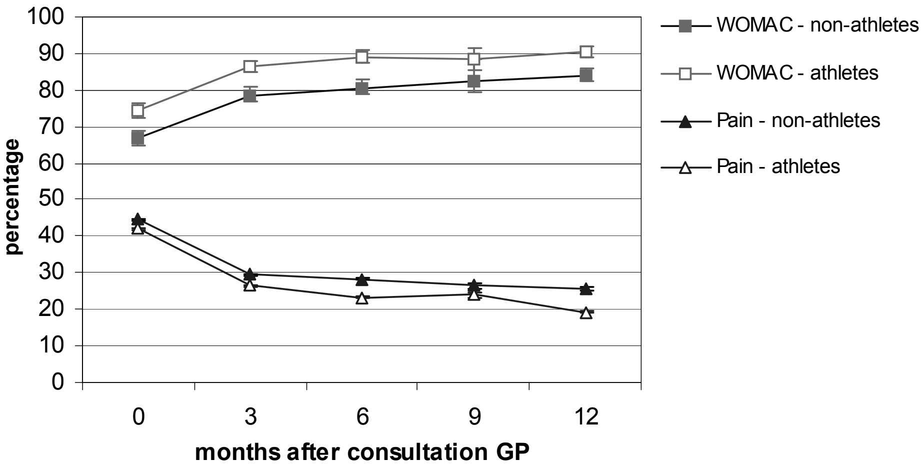

Figure 2. Course of knee complaints (mean scores and 95% CI)

scores at three-month intervals throughout one-year follow-up. The mean pain intensity scores of both groups decreased during follow-up. The mean pain score at one-year follow-up of the athletes was slightly lower than that of the non-athletes; however the difference was not significant (p=0.20). The WOMAC functional disability score was higher during the entire follow-up among the athletes compared with the non-athletes; however, there was no significant difference at one-year follow-up between the two groups (p=0.21).
About 10% of the athletes experienced discomfort during employment due to their knee complaints at one-year follow-up versus almost 15% of the non-athletes (p=0.054). The athletes also experienced less discomfort during any daily duties (17.6%)(employment, volunteer work, studies and housekeeping) compared to the non-athletes (29.6%) (p=0.003).

DISCUSSION

In this observational cohort study in general practice, most knee complaints were labelled as general knee complaints. Acute distortions were diagnosed significantly more often among athletes than non-athletes, but the difference was small. The GP advised more athletes to 'go easy on the knee' compared to non-athletes. Revisits to the GP occurred more frequently among athletes, and the athletes more frequently visited a therapist or specialist. At one-year follow-up the athletes experienced less discomfort during daily activities and employment due to their knee complaints than the non-athletes.

In the present study, traumatic injuries were seen in almost 35% of the athletes and almost 30% of the traumatic injuries of this group were sustained during a sport activity. In total, 50% of the athletes associated their knee complaint with their sport participation. In subgroup analyses, there were no differences in the type of knee complaints between the athletes who associated their complaint with their sport participation and those who did not. This implies that there is no specific knee complaint that can be associated with sport participation.
Most studies on knees and athletes focus on knee injuries, which are mostly traumatic, whereas in our study only 35% of the knee complaints in athletes, presented in primary care, were traumatic. Therefore, future research should not only focus on traumatic knee injuries in athletes, but also on non-traumatic injuries.
Osteoarthritis was more often presented among the non-athletes: 12.6% among the non-athletes versus 5.0% among the athletes; however, the adjusted OR shows no significant difference. The difference between the two groups can probably be attributed to the differences in age, gender and BMI rather than to sport participation itself. The non-athletes were significantly older, had a higher BMI and included more females than the group of athletes. These latter findings are supported by other studies showing that higher age, BMI and female gender are associated with knee osteoarthritis.[10-12]

Acute distortions were seen significantly more often in athletes (8.8%) than in non-athletes (5.2%), but the difference is small. Most of the distortions of the athletes occurred during soccer, cycling, fitness, tennis and walking.

There were few differences in the initial policy of the GP between the two groups. Athletes were more often advised to 'go easy on the knee' than the non-athletes; this is probable related to the physical activity level of the athletes or to the type of knee complaints. Patients with acute distortions were significantly more often advised to 'go easy on the knee', whereas patients with osteoarthritis and chronic meniscus fractures were significantly less often advised to do this. These findings might also be related to the fact that it is difficult for non-athletes to reduce their level of physical activities.

In the Dutch healthcare system patients generally have to visit their GP before being referred to a therapist or specialist. Consequently, we found a strong relationship between revisiting the GP and medical consumption ($p<0.001$). Therefore, we repeated the analysis for medical consumption (therapist or specialist) with adjustment for revisiting the GP. The adjusted analysis no longer showed a significant difference in medical consumption between the two groups ($p=0.20$). Thus, referral to therapists or specialists in this study is more dependent on the number of GP visits than on being an athlete or not. In the adjusted analysis we also found a significant difference in revisiting the GP between the two groups. However, the difference between both groups is very small: 36.8% versus 35.8%. Analyses showed that a revisit to the GP is more dependent on age and functional disability at baseline than on being an athlete or not. It is however noteworthy that there is a trend towards increased medical consumption among the athletes while the functional disability scores are higher and the pain scores lower than among the non-athletes. Besides, the athletes experienced less discomfort during their daily and work duties than the non-athletes, which might indicate that the athletes make greater demands on their body than the non-athletes. The role of the GP in this relationship remains unknown, i.e. it is unknown if the GP is aware of the physical activity level of the individual patient at consultation.

At one-year follow-up, almost 55% of the athletes indicated that they had recovered from their knee complaint versus 45% of the non-athletes. This difference is, however, not significant ($p=0.40$); the multivariate analysis showed that the recovery ratio is more dependent on age, gender and trauma than on physical activity level. Therefore, this study does not give any indications for the GP to inform athletes different than non-athletes regarding the prognosis of their knee complaints.

Finally, we did not find any substantial differences in the diagnosis and prognosis of the knee complaints between athletes and non-athletes but we did find a difference in medical consumption between the athletes and non-athletes. Apparently athletes do prefer a more active strategy compared to non-athletes. However, the exact reason for this higher medical consumption remains unknown.

Limitations

More than one third of the knee complaints are labelled by the GP as 'general knee complaints', indicating some difficulty in arriving a precise diagnosis of the knee complaints of their patients.

Although the group of athletes consisted of more males and younger people, because all analyses were adjusted for age, gender and BMI this difference should have no impact on our final conclusions. Further, the physical workload of the patients might have influenced the results of this study. The baseline questionnaire included some questions about work tasks; unfortunately, this information was not sufficient to analyze this potential confounder.

Conclusions

The results of this study indicate that there are no major differences in diagnosis and prognosis of knee complaints between athletes and non-athletes presented to the GP. This implies that there are no indications for different treatment strategies applied in both groups. Though, athletes are more often advised to 'go easy on the knee' and to rest than the non-athletes. However, this advice might be related to the physical activity level of the patients. Further, there is a trend towards increased medical consumption among athletes while the functional disability scores are higher and the pain scores are lower than among the non-athletes.

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Chapter 7

Musculoskeletal pain in relation to sport activity: athletes versus non-athletes

Submitted

ABSTRACT

This study focuses on the relationship between sport activity and musculoskeletal complaints. In order to provide better insight into this complex relationship we studied the pattern of musculoskeletal pain among athletes and non-athletes in a general population with respect to: 1) prevalence, incidence, severity and cause of complaints 2) type and intensity of sports activity, and 3) medical consumption as a consequence of musculoskeletal pain. The study population included a random sample of the Dutch population aged 25 years or older (baseline n=3664, follow-up after 6 months: n=2337). The baseline population consisted of 1162 athletes and 2502 non-athletes. Data collection included musculoskeletal pain (different sites), severity of complaints, sport activity, type of sport activity and medical consumption. At 6-months follow-up, non-athletes reported more upper extremity pain compared to the athletes ($p<0.01$). Half of the intensive athletes attributed their incident hip or knee complaint to sport activity while only 24.5% of the moderate athletes attributed their hip or knee complaints to sport activity ($p<0.05$). Among the subjects reporting pain, athletes report a higher medical consumption (physiotherapist) compared to the non-athletes. The results of this study showed that there are no large differences in the prevalence of musculoskeletal pain between athletes and non-athletes. However, there is some indication that engaging in sport activities is protective towards upper extremity complaints and, on the other hand, that sport activity contributes to lower extremity complaints, in both athletes and non-athletes. In addition, athletes seem to have a different pattern of health care utilization (i.e. using more physiotherapy) when they have pain.

INTRODUCTION

Participation in sport activities can be a threat towards musculoskeletal pain due to injury or overuse. On the other hand, sport and physical activities can also be protective towards musculoskeletal pain. This study aims to provide further insight into this complex relationship using population-based data on sports activity and musculoskeletal pain. Studying the – theoretically changeable - determinants of musculoskeletal pain is relevant because the public health burden of musculoskeletal pain is high. Previous studies revealed prevalence rates of musculoskeletal pain in Europe of 24% to 74% [1-3] and musculoskeletal pain has a high impact on disability, sickness absence and work disability.[4-7]

The positive effects of regular exercise and physical activity on health and well-being are broadly accepted and described extensively[8-10]; Therefore, physical activity is defined as an important component of healthy life. On the other hand, physical activity and sport impact is often associated with musculoskeletal complaints and injuries.[11-13] Numerous studies have reported on injuries in various types of sport activities. Especially complaints to the lower extremities are often associated with regular exercise.[14-16] In addition, musculoskeletal pain (regardless of its cause) can form an obstacle to engage in sport and therefore lead to inactivity. Furthermore, the way athletes cope with their musculoskeletal pain can differ from that of non-athletes. Therefore, it is of interest to explore possible differences in medical consumption between athletes and non-athletes.

To provide insight into the complex relationship between sport activity and musculoskeletal pain, this study investigated the pattern of musculoskeletal pain among athletes and non-athletes in the general population. This relationship is studied with respect to: 1) prevalence, incidence, severity and cause of musculoskeletal pain, 2) type and intensity of sports activity, and 3) medical consumption as a consequence of musculoskeletal pain.

METHODS

Design and data collection

For this study, baseline and follow-up data of the Dutch population-based Musculoskeletal Complaints and Consequences cohort study (DMC3-study) were analyzed. A random sample stratified by 10-year age group and by gender of 8000 persons aged 25 years and older was taken from the population register of 1998, identical to general surveys of Statistics Netherlands (Centraal Bureau voor de Statistiek, 1996). People who signed an informed consent for follow-up measurement were approached after six months. A detailed description of the study design and data collection is described elsewhere.[3]

A 28-page baseline questionnaire was sent to the 8000 randomly selected persons. The baseline questionnaire sought information about socio-demographics, physical activities, sport

activities, and having had pain during the last 12 months in five different anatomical areas: (1) neck, shoulder or higher part of the back, (2) elbow or wrist/hand, (3) lower part of the back, (4) hip or knee, and (5) ankle and foot. Socio-demographic data included age, gender, height, weight, marital status, educational level and self-reported health. Height and weight were used to calculate the Body Mass Index (BMI). Marital status was summarized in three groups: (Un)married without child(ren), married with child(ren) and one parent with child(ren). Educational level was divided into two groups: lower and higher educated (vocational colleges/ university). Self-reported general health was measured on a 5-point Likert scale, ranging from excellent to poor. General health was categorized in 'good' (excellent, very good and good) and 'poor' (moderate and poor). Persons were asked to report frequency (days/week) and duration (hours/day) for the following physical activities: walking, cycling, gardening and odd jobs. For these activities, mean days per week and mean hours per day were calculated.
For each anatomical area, the questionnaire started with the question: "Did you have pain in 'anatomical area' during the past 12 months?" Screen positives were asked to answer all the relevant questions about that anatomical area. Questions were focused on the anatomical site, whether or not the pain still exists (point prevalence), duration and severity of the pain (1-10 score), self-reported causes, and medical consumption such as contact with general practitioner (GP), physiotherapist and medical specialist. Medical consumption, as a result of pain, was reported for location-specific pain in the past 12 months. For each anatomical site, the one-year prevalence, point prevalence, and prevalence of chronic pain (i.e. current pain lasting more than 3 months) were calculated.
The follow-up questionnaire was a slightly shorter version of the baseline questionnaire and also asked about pain in the anatomical areas during the past 6 months.[17] The incidence of musculoskeletal pain at 6-months follow-up was calculated from the population at risk who did not report location-specific point-prevalent pain at baseline.

Sport activities

Subjects were asked to report their type of sport activities, by a maximum of two different types of sport. For each type of sport, mean days per week and mean hours per day of participation were registered. From these data, mean total hours of sports participation per week was calculated. Intensive athletes were defined as athletes who participated in sport activities for minimally 2.5 hours a week. Moderate athletes were defined as athletes who participated in sport activities for 1 to 2.5 hours a week. Persons performing less than 1 hour sport a week or no sport at all were defined as non-athletes.
All reported sport activities were coded with metabolic equivalent (MET) intensity levels.[18] All sport activities with a MET-value of 3.5 or higher were considered as being physical sport activities. One exception was made: surfing was included as being a sport activity with a MET-value of 3.0.

Statistical analyses

Descriptive statistics were used to characterize socio-demographics, pain prevalence and incidence, cause of complaints, and medical consumption.

Logistic regression analyses were used to examine associations between intensive, moderate and non-athletes of pain prevalence, point prevalence, chronic complaints, incidence, and medical consumption. Linear regression analysis was performed to compare the pain severity scores between athletes and non-athletes. All analyses were adjusted for age and gender. The results are presented as odds ratios (ORs), with 95% confidence intervals (CI). A p-value less than 0.05 was considered statistically significant. All analyses were performed with the SPSS software package (version 12.0.1, 2004).

RESULTS

Study population

The net response of the DMC3-study was 46.9% (n=3664). A total of 632 persons (17.2%) were considered to be intensive athletes and 530 (14.5%) were considered to be moderate

Table 1 Baseline characteristics

Characteristic		All	Athletes		Non-athletes
			Intensive	Moderate	
		(n=3664)	(n=632)	(n=530)	(n=2502)
Age*	Mean (SD)	54.6 (16.3)	47.6 (14.2)	48.4 (14.2)	57.61 (16.3)
Gender (male) *#	n (%)	1640 (44.8%)	329 (52.1%)	160 (30.2%)	1151 (46.0%)
BMI*	Mean (SD)	25.8 (12.9)	25.0 (9.5)	24.4 (3.5)	26.4 (14.8)
Educational level (high)*	n (%)	962 (26.3%)	241 (38.1%)	208 (39.2%)	513 (20.5%)
Self-experienced health*# Good/excellent	n (%)	2847 (77.7%)	571 (90.6%)	442 (83.9%)	1833 (74.4%)
Marital status	n(%)				
(Un)married without child(ren)		475 (13%)	125 (19.8%)	79 (14.9%)	271 (10.8%)
Married with child(ren)		2952 (80.6%)	467 (73.9%)	418 (78.9%)	2067 (82.6%)
One parent with child(ren)		237 (6.5%)	40 (6.3%)	33 (6.2%)	164 (6.6%)
Active daily activities: walking, cycling, gardening and 'odd jobs' *#					
> 3 hrs a week	n(%)	2000(54.6%)	402 (63.6%)	323 (60.9%)	1275 (51.0%)

* Statistical significant difference between athletes and non-athletes, $p < 0.05$.

Statistical significant difference between intensive and moderate athletes, $p < 0.05$.

Table 2 Musculoskeletal location specific pain of athletes and non-athletes[#](statistical significant differences presented in **bold**)

	Athletes	Non-athletes	OR_{crude}	p-value	OR_{ad}* (95%CI)	p-value*
Any prevalent	75.5%	72.9%	1.14	0.10	1.06 (0.90-1.25)	0.49
Any incident	45.3%	44.1%	0.87	0.12	0.92 (0.77-1.09)	0.32
Upper extremities						
One-year prevalence	50.9%	49.9%	1.04	0.58	0.97 (0.83-1.12)	0.63
Incident at follow-up	25.5%	29.0%	**0.70**	**<0.001**	**0.72 (0.59-0.87)**	**0.001**
Lower extremities						
One-year prevalence	35.0%	37.3%	0.91	0.18	1.03 (0.69-1.20)	0.69
Incident at follow-up	22.1%	20.1%	1.05	0.64	1.17 (0.95-1.44)	0.15
Neck						
One-year prevalence	32.0%	31.7%	1.02	0.85	0.96 (0.82-1.20)	0.57
Point prevalence	20.6%	22.1%	0.91	0.28	0.93 (0.78-1.11)	0.41
Chronic	13.9%	15.4%	0.87	0.18	0.91 (0.74-1.12)	0.36
Incident at follow-up	14.8%	18.7%	**0.75**	**0.03**	**0.74 (0.56-0.97)**	**0.03**
Shoulders						
One-year prevalence	29.3%	30.6%	0.94	0.44	0.89 (0.76-1.04)	0.15
Point prevalence	20.1%	21.8%	0.90	0.22	0.87 (0.73-1.04)	0.14
Chronic	14.1%	15.8%	0.87	0.16	0.86 (0.70-1.05)	0.14
Incident at follow-up	14.2%	17.1%	0.80	0.11	0.79 (0.60-1.05)	0.10
Upper back						
One-year prevalence	16.4%	20.2%	**0.77**	**0.006**	**0.76 (0.63-0.92)**	**0.005**
Point prevalence	8.3%	9.0%	0.91	0.44	0.84 (0.65-1.09)	0.20
Chronic	5.5%	6.4%	0.85	0.28	0.81 (0.59-1.10)	0.17
Incident at follow-up	8.8%	14.9%	**0.55**	**<0.001**	**0.62 (0.46-0.85)**	**0.002**
Elbow						
One-year prevalence	11.2%	11.8%	0.95	0.62	0.99 (0.78-1.24)	0.90
Point prevalence	8.1%	7.6%	1.08	0.57	1.14 (0.87-1.49)	0.35
Chronic	5.1%	5.7%	0.88	0.43	0.95 (0.68-1.31)	0.74
Incident at follow-up	5.1%	8.8%	**0.56**	**0.002**	**0.60 (0.41-0.88)**	**0.008**

Table 2 continued

	Athletes	**Non-athletes**	**OR_{crude}**	**p-value**	**OR_{ad}* (95%CI)**	**p-value***
Wrist/hand						
One-year prevalence	16.0%	19.0%	**0.81**	**0.03**	0.85 (0.70-1.03)	0.09
Point prevalence	11.7%	14.1%	**0.81**	**0.05**	0.89 (0.72-1.12)	0.32
Chronic	8.5%	10.6%	**0.78**	**0.046**	0.87 (0.68-1.12)	0.29
Incident at follow-up	10.3%	11.9%	0.85	0.27	0.88 (0.65-1.19)	0.40
Lower back						
One-year prevalence	44.1%	41.8%	1.10	0.20	0.99 (0.85-1.14)	0.84
Point prevalence	24.5%	28.0%	**0.84**	**0.03**	**0.83 (0.70-0.98)**	**0.025**
Chronic	18.2%	21.8%	**0.78**	**0.006**	**0.78 (0.65-0.93)**	**0.007**
Incident at follow-up	23.1%	22.2%	1.05	0.67	0.99 (0.78-1.27)	0.98
Hip						
One-year prevalence	11.9%	16.3%	**0.69**	**<0.001**	0.88 (0.71-1.09)	0.25
Point prevalence	9.1%	11.7%	**0.76**	**0.02**	1.01 (0.79-1.30)	0.91
Chronic	7.2%	9.4%	**0.74**	**0.02**	0.97 (0.74-1.28)	0.84
Incident at follow-up	6.9%	8.4%	0.82	0.24	1.01 (0.71-1.44)	0.96
Knee						
One-year prevalence	22.9%	23.5%	0.97	0.69	1.13 (0.95-1.34)	0.17
Point prevalence	15.5%	17.1%	0.89	0.22	1.08 (0.89-1.32)	0.45
Chronic	12.1%	12.9%	0.93	0.47	1.13 (0.90-1.41)	0.30
Incident at follow-up	13.4%	12.9%	1.04	0.76	1.18 (0.89-1.57)	0.26
Ankle						
One-year prevalence	9.7%	9.4%	1.03	0.78	1.13 (0.88-1.44)	0.35
Point prevalence	4.8%	5.8%	0.83	0.25	1.00 (0.72-1.40)	0.98
Chronic	3.4%	4.1%	0.82	0.29	0.97 (0.66-1.44)	0.90
Incident at follow-up	4.8%	6.4%	0.74	0.14	0.83 (0.55-1.24)	0.36
Foot						
One-year prevalence	7.8%	11.2%	**0.68**	**0.002**	0.79 (0.61-1.03)	0.08
Point prevalence	5.0%	8.4%	**0.58**	**<0.001**	**0.70 (0.51-0.95)**	**0.022**
Chronic	4.0%	6.6%	**0.58**	**0.001**	**0.70 (0.50-0.99)**	**0.045**
Incident at follow-up	7.0%	7.2%	0.98	0.90	1.16 (0.81-1.66)	0.42

* Analyses adjusted for age and gender.

[#] Percentage incident complaints at follow-up calculated from persons without location specific point-prevalent pain on baseline.

athletes. The remaining subjects were considered to be non-athletes (n=2502). Of the 2752 subjects who signed an informed consent for follow-up 2337 (84.9%) returned the follow-up questionnaire and could be adequately linked to the baseline data. Baseline characteristics are shown in Table 1. The athletes (n=1162) were on average younger, included more females, had a lower BMI and were higher educated than the non-athletes.

The most practiced sports of the athletes were tennis (14.3%), swimming (12.4%), fitness (12.1%), gymnastics (5.8%), cycling (5.5%), soccer (4.9%), running (4.6%) and volleyball (4.0%).

Musculoskeletal pain among athletes and non-athletes

The one-year prevalence of musculoskeletal pain in this population was 74.4% (n=2727). Chronic complaints were reported by 1683 persons (45.9%). Table 2 represents an overview of the differences in reported musculoskeletal pain between athletes and non-athletes.

The prevalence of upper back pain was lower among athletes than among non-athletes (absolute difference 3.8%). Further, the point prevalence and percentage of chronic lower back problems were significantly lower in the athletes group compared to the non-athletes group (absolute difference 3.5% and 3.6%, respectively). The same results were found for pain of the foot.

Subgroup analyses comparing intensive and moderate athletes showed no significant differences in prevalence, point prevalence and chronic complaints at any site between the two groups.

A total of 1600 subjects (68.5%) reported to have had musculoskeletal pain in one of the anatomical areas in the 6 months between the first and second questionnaire. Of these subjects reporting musculoskeletal pain in the follow-up questionnaire, 34.4% (n=423) reported new incident pain at one of the anatomical sites during follow-up. Non-athletes reported significantly more new upper extremity pain compared to the athletes (absolute difference 3.5%). No significant difference was found on any anatomical site when comparing the moderate athletes with the intensive athletes.

Pain severity of the athletes was significantly lower compared to the non-athletes for most pain locations, as shown by linear regression analyses of point-prevalent pain at baseline. The two exceptions were hip (β -0.10, $p=0.10$) and ankle pain (β -0.10, $p=0.26$). The mean pain severity of the athletes was 3.9±2.06 points compared to 4.7±2.17 points of the non-athletes on an 11-point VAS scale.

Musculoskeletal complaints attributed to sport activities

In the follow-up questionnaire, 144 (37.1%) of the 379 athletes with incident musculoskeletal pain at 6 months follow-up attributed their complaint(s) to sport participation compared to 10.0% of the non-athletes with incident musculoskeletal complaints. Significantly more athletes attributed their incident complaint to sport activity compared to the non-athletes on

Table 3 Incident complaints attributed to sport activities: moderate versus intensive athletes

	Moderate athletes	Intensive athletes	OR_{crude}	p-value	OR_{ad}#	p-value#
Neck, shoulders, upper back	11(14.5%)	24(27.3%)	2.22	0.049	2.09 (0.93-4.70)	0.08
Elbow, wrist/hand	6(16.7%)	20(31.7%)	2.33	0.11	2.18 (0.76-6.31)	0.15
Lower back	10(15.7%)	20(25.6%)	1.86	0.15	1.67 (0.69-3.99)	0.25
Hip, knee	13(24.5%)	37(50.7%)	3.16	0.004	2.49 (1.04-5.97)	0.04
Ankle, foot	5(17.2%)	27(52.9%)	5.40	0.003	4.48 (1.35-14.87)	0.01

Analyses adjusted for age and gender.

all five anatomical areas (data not shown). The ankle and foot were the areas most attributed to sport activities by the athletes (40%), and the hip and knee areas were the most attributed to sport activities by the non-athletes (14.5%). Table 3 presents the differences in incident complaints attributed to sport activities between the moderate and intensive athletes.
Significantly more regular athletes attributed their lower extremity complaints to sport activity compared to the moderate athletes. About 50% of the intensive athletes attributed their lower extremity complaints to sport activities compared to 17% (ankle, foot) and 24% (hip,

Table 4 Medical consumption due to musculoskeletal pain among athletes and non-athletes (statistical significant differences presented in **bold**)

	Athletes (n=1162)	Non-athletes (n=2502)	OR_{crude}	p-value	OR_{ad}#	p-value#
Prevalent complaints	881 (100%)	1866 (100%)				
GP	42.6%	47.5%	**0.82**	**0.02**	0.86 (0.72-1.01)	0.07
Physiotherapist	31.4%	31.0%	1.02	0.83	1.03 (0.86-1.23)	0.78
Medical specialist	28.5%	33.9%	**0.78**	**0.004**	0.88 (0.74-1.06)	0.18
Prevalent complaints of upper extremities	795 (100%)	1686 (100%)				
GP	17.7%	21.5%	**0.79**	**0.03**	0.90 (0.72-1.13)	0.38
Physiotherapist	30.3%	29.6%	1.04	0.72	1.03 (0.85-1.25)	0.74
Medical specialist	24.8%	30.2%	0.76	0.005	0.85 (0.70-1.04)	0.11
Prevalent complaints of lower extremities	409 (100%)	977 (100%)				
GP	35.2%	37.8%	0.90	0.37	1.01 (0.78-1.31)	0.93
Physiotherapist	22.7%	19.8%	1.20	0.21	1.30 (0.96-1.74)	0.09
Medical specialist	26.2%	28.8%	0.88	0.33	1.05 (0.80-1.38)	0.73
Chronic complaints	506 (100%)	1177 (100%)				
GP	50.6%	57.1%	**0.77**	**0.01**	**0.79 (0.64-0.99)**	**0.04**
Physiotherapist	38.1%	38.5%	0.99	0.89	0.98 (0.78-1.22)	0.83
Medical specialist	39.1%	41.3%	0.91	0.41	1.00 (0.80-1.24)	0.97
Incident complaints	379 (100%)	763 (100%)				
GP	39.8%	40.5%	0.97	0.83	1.07(0.82-1.39)	0.61
Physiotherapist	29.8%	26.0%	1.21	0.17	**1.37(1.03-1.83)**	**0.03**
Medical specialist	23.7%	24.5%	0.96	0.78	1.11(0.82-1.50)	0.50

Analyses adjusted for age and gender.

knee) of the moderate athletes. Further, no significant differences were found for the upper extremity and lower back complaints between the intensive and moderate athletes.
About one quarter (26.0%) of the athletes with incident upper extremity complaints attributed these to sport activities; the most practiced sports in this group were tennis (17.2%), fitness (13.8%) and volleyball (10.3%). Also, one quarter of the athletes (26.7%) with lower extremity complaints attributed these complaints to sport activities; the most practiced sports in this group of athletes were tennis (22.0%), soccer (16.0%) and fitness (12.0%).
Of the 1866 non-athletes with prevalent musculoskeletal complaints at baseline, 8.0% (n=150) was attributed to the practice of sports; most of these subjects suffered hip and knee complaints. Almost one third (32.6%) of the athletes reported that their prevalent complaint(s) was attributed to sport activity. Significantly more intensive athletes attributed their complaints to sport activities compared to the moderate athletes on all anatomical areas.

Pain-related medical consumption among athletes and non-athletes

A slightly higher percentage of the non-athletes visited the GP due to their musculoskeletal complaints compared to the athletes (table 4). Nevertheless this difference was not significant (p=0.07). The GP was visited significantly more often by the non-athletes with chronic musculoskeletal pain compared to the athletes. Further, the physiotherapist was more frequently visited by the athletes with lower extremity complaints compared to the non-athletes (p=0.09), and a significantly higher percentage of the athletes with incident complaints visited the physiotherapist than the non-athletes (p=0.03).
Subgroup analysis among athletes revealed that significantly more intensive athletes visited a medical specialist for their prevalent musculoskeletal complaints (p=0.008; OR 1.51, 95%CI 1.11-2.05) and for their chronic complaints (p=0.01; OR 1.63, 95%CI 1.12-2.36) compared to the moderate athletes.

DISCUSSION

This study shows that there are hardly any differences in (point) prevalence, percentage of chronic musculoskeletal pain or incident pain between athletes and non-athletes. Some significant differences were found but the absolute differences were small. Thus, the overall differences were minimal. Globally, this can imply that the advantages (healthy effects) of engaging in sport activity are outweighed by its disadvantages (sport-related injuries), but it can also imply that engaging in sport activity does not have an important effect (positive or negative) on musculoskeletal pain. Below, we discuss the findings of this study by site-specific pain.

Non-athletes reported more point-prevalent and chronic low back complaints than athletes; however, no difference in incidence of low back pain between athletes and non-athletes was found at six-months follow-up. This might indicate that sport activity may protect against a long duration of low back pain. Further, athletes reported significantly less incident upper extremity complaints than non-athletes. This might imply that people practicing sport activities (minimally 1 hour per week) are at less risk to develop upper extremity complaints than those who do not participate in sport activities.

No significant difference was found between the athletes and non-athletes in the prevalence and incidence of knee pain. However, the knee is the only site with a positive trend in both prevalence and incidence towards the athletes group. We expected to find a higher incidence and prevalence of knee pain in the athletes group because the knee is the most often reported injury in many types of sport.[11, 19-21] The reason for a lack of difference between the athletes and non-athletes in knee prevalence and incidence may be due to the types of sport reported in this study. For example, knee injuries are not often associated with swimming[22], but swimming was one of the most practiced sports in the present study. Nevertheless, about 30% of the swimmers in our study population reported one-year prevalent knee pain. Because swimming is frequently recommended to persons with lower extremity musculoskeletal complaints, they may practice swimming because of their musculoskeletal pain; this is supported by the finding that the highest prevalence and percentage of chronic complaints within the athletes group for the different sites is found for the swimmers (data not shown).

It is striking that many people with chronic complaints still perform some kind of sport activity: 30.1% of those with chronic complaints engage in sport activities versus 33.1% of those without chronic complaints. The most practiced sport of the athletes with chronic complaints is swimming, followed by tennis and fitness. This finding suggests that chronic musculoskeletal pain does not lead to physical inactivity in a large percentage of this population.

About 30% of the subjects with musculoskeletal pain in the athletes group attributed their prevalent complaint to sport activities compared to 8.0% of the non-athletes. About 10% of the non-athletes with incident complaints attributed their complaint to sport activities; these complaints may have occurred during a once-only sport activity when the risk on injuries may be relatively high. For lower extremity complaints a difference in attribution to sport activities was found between the intensive and moderate athletes. This suggests that intensive athletes are at higher risk to develop a sport-related lower extremity complaint than moderate athletes. Although the exposure time to sport activity is larger in the intensive athletes group, those with intensive sport activity could have a higher capacity and may therefore have a lower risk. The complaints most often attributed to sport activity were lower extremity complaints. Almost half of the intensive athletes with prevalent or incident hip or knee complaints attributed this complaint to sport activity. Majewski et al.[22] reported that soccer was the most important activity leading to knee injuries. Knee injuries also often occur among tennis players.[22, 23] These latter results are in correspondence with our data, showing that the most practiced sports within the intensive athletes with incident lower extremity pain were indeed tennis (22.0%) and soccer (16.0%).

Our population-based study also showed that athletes with lower extremity complaints or incident complaints are more likely to visit the physiotherapist compared to non-athletes, whereas the GP was more frequently visited by the non-athletes with prevalent and chronic complaints than the athletes. The frequent visits of the athletes to the physiotherapist might be related to the way athletes cope with their musculoskeletal complaints. Athletes might make higher demands on their physical health and therefore prefer a more active strategy for recovery; unfortunately, to our knowledge, no literature is available on this subject. Medical consumption is of course also dependent on pain severity. Noteworthy is that the point-prevalent pain severity of the athletes was significantly lower compared to the non-athletes.

Strengths and limitations

To our knowledge, this is the first population-based study comparing athletes and non-athletes regarding musculoskeletal pain. Although the study includes a large sample of subjects, only 47% responded to the baseline questionnaire. Nevertheless, based on the general characteristics of the population register, there were no important differences between responders and non-responders, nor did responders in the DMC3 study differ from responders in an interview survey.[24] The follow-up questionnaire was returned by 84.9% of the respondents which is quite high.

All results from this study were obtained by means of self-registered questionnaires; especially for pain assessment, self-reports are unavoidable.

Our decision to define sport as an activity with a MET-value of at least 3.5 was an arbitrary one. A MET-value of 3.5 and higher includes moderate (3-6 METs) to vigorous (>6 METs) intensity of activities. Although it is debatable whether walking should be considered as a sport activity, leisure activities such as walking and cycling were separate issues in the questionnaire and therefore it is plausible that only those subjects who considered their walking and cycling activities as a sport activity are included in the athletes group.

All the statistical analyses are adjusted for age and gender. Because the baseline analysis showed a significant difference in BMI and educational level between the two groups, we repeated the analysis for prevalence and incidence with adjustment for age, gender, BMI and educational level. The results of these analyses showed no notable differences compared with the data in table 2.

Conclusions and implications

The results of this study showed that there are no large differences in the prevalence of musculoskeletal pain between athletes and non-athletes. However, there is some indication that engaging in sport activities is protective towards upper extremity complaints, whereas sport activity may contribute to lower extremity complaints, both in athletes and non-athletes.

In addition, athletes seem to have a different health care utilization pattern i.e. using more physiotherapy when experiencing pain.
The results of this study highlight the complex relationship between sport activities and musculoskeletal complaints, which needs further research. For instance, more specific prognostic data are needed to investigate the possible causal relationship of the impact of sport on musculoskeletal complaints.

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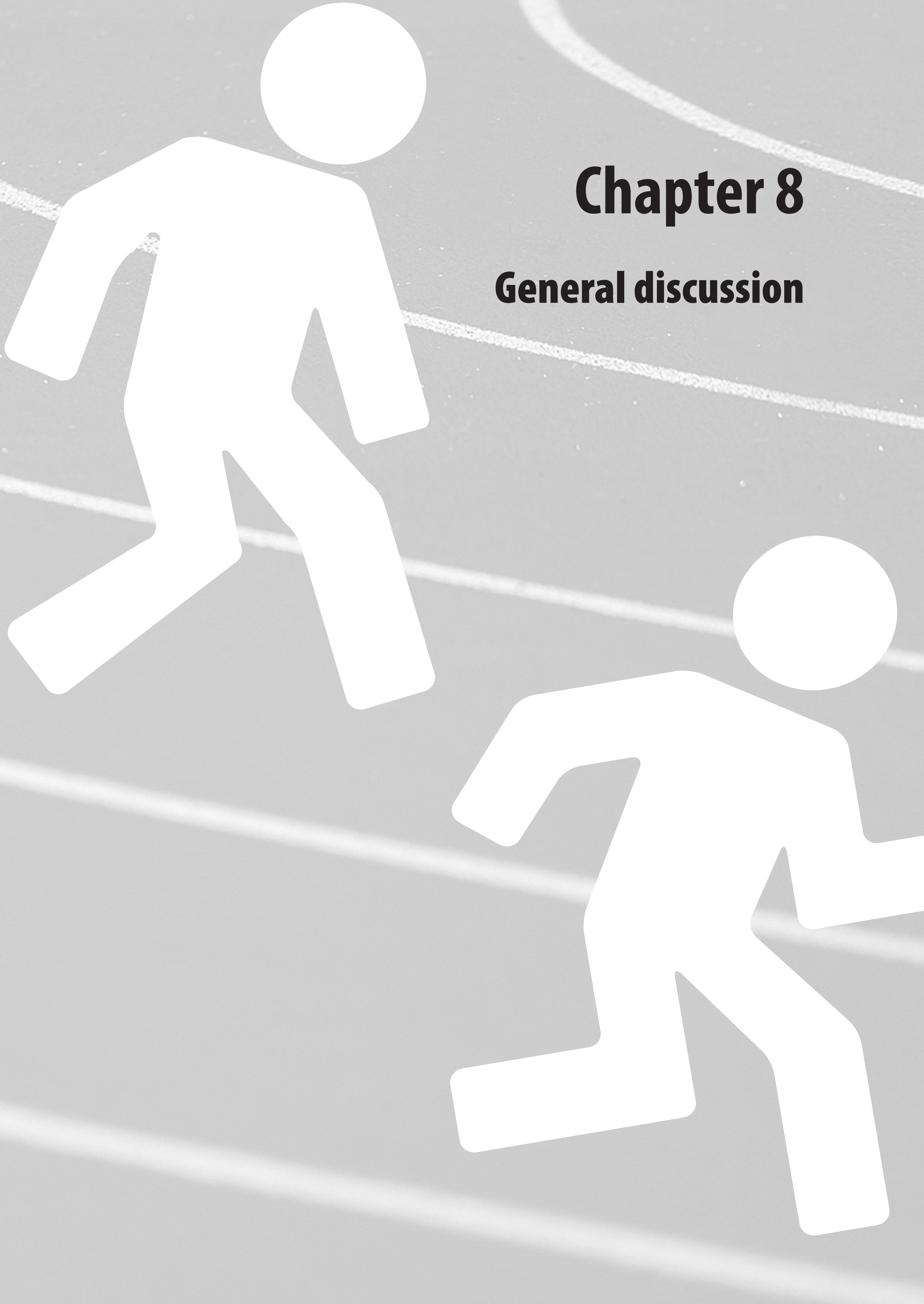

Chapter 8

General discussion

INTRODUCTION

Physical exercise is widely stimulated nowadays for a variety of reasons related to the prevention and/or management of obesity, diabetes and other diseases, but also with the aim to prevent disability and sick leave. Running is a good example of such a form of physical exercise, and is promoted because of its easy accessibility, i.e. basically only running shoes are needed. Although running contributes to a healthy lifestyle, this thesis focuses on the concerns that have been raised about the high incidence of injuries among athletes, especially runners. Since marathons and long-distance running are seen as an ultimate challenge of physical fitness, more and more people are training for big marathon events such as those in New York, Boston, London and Rotterdam. Previous studies reported that injuries often occur during the preparation for or during a marathon run.[1-4] These injuries can result in non-completion of a race and (if serious) may eventually lead to an inactive lifestyle: it is reported that the most important reason for quitting exercise is physical injury.[5]
However, knowledge on the impact of running injuries and on the medical consumption as a consequence of these injuries is still scarce. Therefore, chapters 2 to 5 present our investigations into the impact (i.e. incidence, prevalence and consequences) of such running injuries. In these studies, the knee was found to be the most predominantly injured site. To gain more insight into these knee injuries, data of the HONEUR knee cohort were used to examine differences in type of knee complaints, the general practitioner's (GP) initial policy, and to compare medical consumption between athletes and non-athletes. We also investigated whether there is a difference in the prevalence and incidence of musculoskeletal complaints (especially those of the knee) between athletes and non-athletes. To address this question data of an open population-based study (the DMC3 study) on musculoskeletal complaints was used. The previous chapters describe these investigations and address some limitations related to our studies.

In this chapter we discuss our research findings and place them in a broader context. In addition, implications for clinical practice are addressed and suggestions for further research are made.

INCIDENCE AND PREVALENCE OF RUNNING INJURIES

The systematic review presented in chapter 2 shows that well-designed studies investigating risk factors for running injuries are needed in order to gain more insight into this topic. Therefore, the Rotterdam marathon study was set up among 1500 marathon runners. The results of this study revealed that the injury prevalence among recreational marathon runners is relatively high. More than 50% of the runners suffered at least one running injury during the year preceding the baseline measurement. A running injury was defined as a self-reported *"injury to muscles, joints, tendons and/or bones of the lower extremities (hip, groin, thigh, knee, lower leg, ankle, foot, toe) that the participant attributed to running"*. The problem had to be severe enough to cause a reduction in distance, speed, duration or frequency of running. Using this definition of injury resulted in 18% new reported injuries occurring shortly before or during the marathon. In agreement with other studies, we also identified the knee to be the most predominantly injured site.

Our systematic review revealed that a large variety of definitions of 'injury' were used in the included studies. This diversity has probably contributed to the wide range in reported incidence of injury between the studies. Worldwide consensus on the definition of a running injury is still lacking. The definition used in the Rotterdam marathon study was derived from the definition of Macera et al.[6] After conducting our study we realised that it might have been useful to have included a unit of time in the injury definition, together with any limitations related to training characteristics. This would have helped to filter out less severe injuries, such as cramps. Nevertheless, for future research it would be useful to have a worldwide-accepted running injury definition that can be applied in different sports. Recently, such a consensus statement has been published with regard to the injury definition in the field of rugby.[7] In this publication agreement was reached on definitions for injury, recurrent injury as well as training and match exposures. This type of consensus would also be very useful for running injuries. Furthermore, by means of such worldwide-accepted definitions, incidence rates become much more precise within each type of sport.

It is noteworthy that a large number of the studies in our review included runners participating in a (half) marathon or in a different type of race. This study characteristic may be related to the fact that running is generally an 'unorganised' sport activity, making it more difficult to recruit runners from the open population for participation in a research project. In contrast, marathons and other organised races are an easier way to recruit study participants and to define specific inclusion criteria. It is, however, debatable whether these populations are representative for the vast majority of recreational runners worldwide. Because most runners in the Netherlands are not registered with an athletics association and a great part of the recreational runners do not participate in races, it may be useful to investigate this particular unorganized group of runners. Our systematic review searched for long-distance runners only (5 or more kilometres per training and/or race). Except for the study of Lun et al.[8] all the included studies selected runners who trained for or participated in a race, including the marathon. Thus it remains largely unknown whether the incidence of running injuries among marathon and racerunners is the same as the incidence among recreational runners who do not participate in races, and whether risk factors for running injuries differ between subgroups.

RISK FACTORS FOR RUNNING INJURIES

The systematic review presented in chapter 2 found strong evidence for a higher risk of running injuries in the case of previous running injuries and a weekly training distance higher than 65 km. Further, strong evidence was found for a protective effect of an increasing running distance on knee injuries. An earlier review from Van Mechelen[9] found associations between running injuries and previous injury, lack of running experience, running to compete, and excessive weekly running distance. The Rotterdam marathon study partly confirmed the findings emerging from our recent systematic review.

Previous running injuries

A previous running injury is a strong predictor for future running injuries. Many studies have reported on the positive association between previous injuries and the risk for future running injuries.[6, 10-12] However, the mechanism behind this relationship remains unclear. Described below are some possible explanations for the increased risk of injuries in the case of a previous injury.

Because of the individual character of the running sport, the possibility of advice from e.g. a trainer or physiotherapist after an injury has occurred is often lacking. Therefore, runners might start running again without an individually-adapted training program or sufficient rest. This may lead to an increased risk for new injuries.

In addition some runners might continue running in spite of small injuries, which can lead to more serious injuries. The phenomenon called "runner's high" (whereby runners are addicted to running) might play a role in this respect. The endorphins produced by the body during running can result in repression of pain and can cause a feeling of euphoria and happiness.[13, 14] Also, some runners may simply not be 'made' for running because of their physical constitution, such as joint alignment, instability and/or running style. However, we cannot confirm or reject this hypothesis because we did not measure these factors in the Rotterdam marathon study. Two studies[8, 12] did investigate the relationship between running injuries and alignment, but found no strong association between alignment of the hip, knee, ankle, foot and injuries. Thus there is no reason to assume that alignment plays an important role in the prediction of risk for running injuries. There are some indications that certain biomechanical factors might play a role in the occurrence of injuries due to overuse in running. Hreljac et al.[15] found that runners who have developed stride patterns that incorporate relatively low levels of impact forces and a moderately rapid rate of pronation are at a reduced risk of incurring overuse running injuries. Therefore a combination of training variables, intrinsic factors and biomechanical factors considered together may better predict future injuries. Both internal (intrinsic) and external (extrinsic) risk factors could, for example, be embedded in a theoretical multi-factorial model of athletic injury aetiology as developed by Meeuwisse et al.[16] (Figure 1). Their model highlights the importance of examining intrinsic predisposing factors

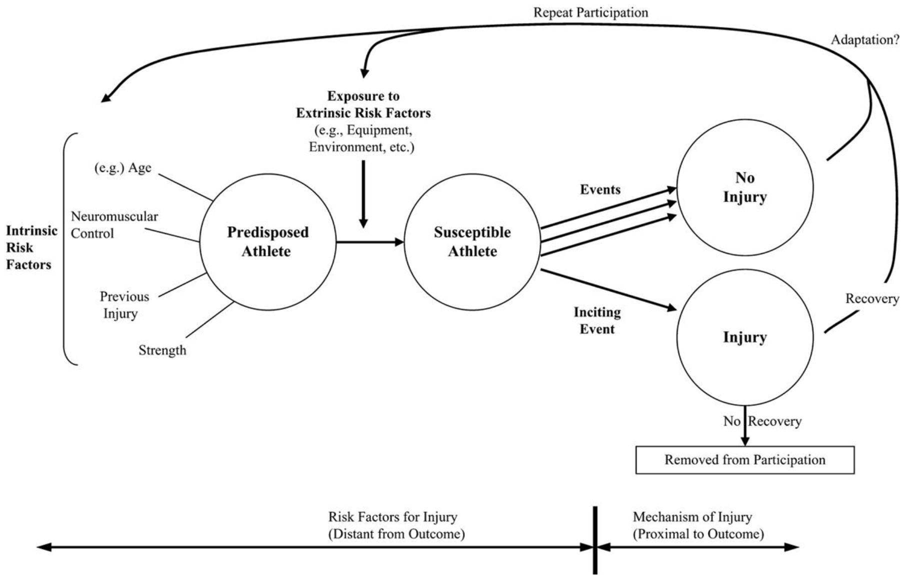

Figure 1. A dynamic, recursive model of aetiology in sport injury.
From: Meeuwisse: Clin J Sport Med, Volume 17(3):May 2007;215-219.

as well as those extrinsic factors that interact to make an athlete susceptible to injury, before an injury-inciting event occurs. Further, the model takes in consideration the implications of repeated exposure, whether such exposure produces adaptation, maladaptation, injury or complete/incomplete recovery from injury. Based on the idea that some runners are simply not 'made' for running, it would be interesting to analyse these runners with previous injuries with respect to the specific type of injuries and whether these injuries occur at the same sites, or whether this group is simply an easily injured group of runners.

Many runners practice running as an unorganised type of sport (i.e. they do not belong to an athletic association, or to a running group) and probably do not have a trainer to guide them. It could therefore be possible that there are some runners who do make mistakes during training and continue to make them over time. This was not confirmed in our marathon study: i.e. we did not find any specific training characteristic that increased the risk for running injuries.

Running distance

The relationship between running distance and injuries seems complex. Van Mechelen[9] concluded that the weekly running distance is a strong determinant of running injuries. Although the role of running frequency and weekly running time remains unclear, our systematic review found strong evidence that a greater training distance per week (more than 64 km/week) is a risk factor for male runners. However, this relationship was not confirmed in our Rotterdam marathon study. We did find a univariate association of mean training distance per training session, but this association did not remain in the multivariate model. Nevertheless, we did find a protective association between a training distance of less than 40 kilometres a week and calf injuries. Therefore, there seems to be an association between running distance and specific running injuries. Generally speaking the relationship between distance per session and injury remains unclear. Although earlier studies did not report on the relationship between distance per training session and running injuries, a fine balance probably exists between overuse and under-training, expressed in training distance per training session or weekly distance. The fact that we did not find an association between training distance and injuries might be related to the relatively older and more experienced males included in our study population. The phenomenon 'survival of the fittest' might have played a role in our results because a marathon population has to be relatively fit. The systematic review advised (for males and females) not to exceed 64 training kilometers per week. In the Rotterdam marathon study, however, this advice did not seem applicable to that particular study population. The finding of a protective association between calf injuries and running less than 40 kilometres per week suggests that the relationship between training distance and running injuries is also location specific.

Limitations

The primary aim of chapter 4 was to identify modifiable risk factors for male marathon runners. The Rotterdam marathon study showed that the strongest predictor for running injuries is the non-modifiable risk factor 'previous injuries'. However, it must be mentioned that the predictive discrimination of the predictive model for risk injuries is only moderate. This might be related to one of the shortcomings of the study i.e. because no physical examination and measurements were made, very few data on personal intrinsic factors were available. Further, our study population was heterogeneous regarding the localisation and type of injuries. Because of this diversity and the limited number of included runners, it was not possible to analyse the data in subgroups with respect to localisation and type of injury. Moreover, the included runners were also heterogeneous with respect to the time of inclusion; i.e. the running experience. All included runners had a different time span of running experience; this means that we 'excluded' runners who had already stopped running because of injuries. For this reason it is better to set-up an inception-cohort study whereby the amount of experience and level of each runner is more or less equal at the time of inclusion.

COURSE AND PROGNOSTIC FACTORS OF RUNNING INJURIES

In the Rotterdam marathon study, the 3-month follow-up measurement of the injured runners provided data on the percentage of relatively long-lasting running injuries. About 25% of the injured runners had persistent complaints at 3 months follow-up, but the consequences for

their work and activities of daily living (ADL) were minor. To our knowledge, ours is the first study with a follow-up measurement of running injuries. However, because the follow-up period was only limited to 3 months, more research is needed on the consequences of injuries among runners and other athletes to increase our knowledge on the impact of injuries.
The marathon study was also designed to identify prognostic factors for persistent complaints related to the injuries. These prognostic factors can then be used to inform runners about the prognosis, to help identify subgroups of runners who may benefit from early interventions, or to intervene in some way if these factors seem to be modifiable. The present study showed that runners with non-musculoskeletal co-morbidities (e.g. disorders of the nervous system, gastrointestinal tract and cardiac diseases) are at higher risk for persistent complaints. Therefore, these runners could be informed about the probably longer recovery period involved if they have a running injury. Future intervention trials should be aware of those at higher risk for persistent complaints, and may consider stratification for this particular subgroup.
We also found that calf injuries do recover relatively quickly, but we have no details on the diagnoses of these calf injuries because no physical examination or imaging was carried out within this study. It is assumable that some of these calf injuries are 'overload' injuries, such as cramps and (minor) tears in muscles or tendons, which do tend to recover relatively quick. This might explain the inverted relationship found between calf injuries and persistent complaints.
The reason we did not find any modifiable prognostic factors may be related to the heterogeneity of the injuries in this study.

SPORT INJURIES AND MEDICAL CONSUMPTION

Runners

The follow-up data of the Rotterdam marathon study show that the medical consumption among injured marathon runners is relatively high. Almost 25% of the injured runners visited a physiotherapist and about 16% visited their GP because of a running injury. Although the results also show that the impact of running injuries on daily living is relatively low among marathon runners, these runners are inclined to visit the GP and the physiotherapist for their complaint. The mean frequency of visits to the physiotherapist was 5.5, which indicates that these visits were primarily for treatment and not for diagnostics. Apparently these runners prefer an active strategy to deal with their injuries while these injuries have very little impact on their daily life. It seems that many marathon runners do not want to 'wait and see' but take direct action in order to deal with their injury.

Knee complaints in general practice

Knee complaints rank among the most frequent reasons for consulting primary care physicians. Since the knee was the most frequently injured site in runners, data of the HONEUR knee cohort were analysed.[17] This study provides insight into the type of knee complaints of athletes seen in general practice and, for comparison purposes, of non-athletes. It appears that the GP's management of these complaints does differ between athletes and non-athletes. The athletes were more frequently advised to 'go easy on the knee' compared to the non-athletes. This advice is probably based on differences in the type of knee complaints, or perhaps also on the intensity and frequency of the physical activities performed. It is, however, unknown whether the GP is actually aware of the physical activities of each individual patient. Apparently this advice does not always lead to sufficient recovery, because more than 35% of the athletes revisit the GP for their knee complaint.

Further, we found a positive relationship between athletes and visits to a specialist or therapist. Because of the expected relationship between type of knee complaints and referrals to a therapist or specialist, the analyses were also adjusted for traumatic or non-traumatic complaints. There are of course differences within, for example, the non-traumatic complaints for which we could not adjust the analyses. Nevertheless, the relationship between athletes and visits to specialist or therapist was even more dependent on the higher frequency of revisits of athletes to the GP than on being an athlete or not. Hence, it seems that both being an athlete and revisits to the GP play an important role in the visits to a therapist or specialist. The role of the GP in this relationship remains unknown, i.e. is the GP aware of the physical activity level of the individual patient? Or is there a relationship because of the uncertainty of the GP about the prognosis and treatment of sport injuries, whereby he/she is inclined to refer a patient with a sport injury? Nevertheless, we can conclude that the GP is inclined to refer an athlete to a therapist or specialist at a second visit to his/her practice.

Sport injuries in the open population

To investigate whether athletes report more musculoskeletal complaints than non-athletes, and whether there is a higher rate of GP consultation and other medical consumption among athletes, it was necessary to analyse data of an open population study. Chapter 7 presents a study in which athletes and non-athletes (from the open population) were compared with regard to musculoskeletal pain. Non-athletes reported more upper extremity complaints than athletes, whereas lower extremity complaints (including the knee) were not reported more often by athletes than non-athletes. Therefore, we cannot assume that a higher medical consumption among athletes is due to a higher prevalence or incidence of lower extremity complaints. However, athletes had a higher frequency of visits to the physiotherapist than non-athletes: athletes with incident complaints were more inclined to visit the physiotherapist than non-athletes. Further, non-athletes with chronic complaints were more inclined to visit the GP than athletes with chronic complaints.

Limitations

In the studies described in chapters 6 and 7, various comparisons are made between athletes and non-athletes. Unfortunately, neither of these studies were primarily designed to compare these two groups so that, for example, there were differences in the baseline characteristics. However, all analyses were adjusted for available and relevant baseline characteristics. It was noteworthy that in both studies the athletes were on average younger, included more males and had a lower BMI than the non-athletes.

Further, it is assumable that included subjects in chapter 6 and 7 were not the fittest subjects of the open population: The responders in chapter 6 (patients with knee complaints) were relatively older than the non-responders.[17] Also the responders of the open population study in chapter 7 were relatively old and an overestimation of point-prevalence was expected.[18] Therefore, the two study populations may not be truly representative for the general population in the Netherlands.

Although the HONEUR knee cohort study was not primary designed to distinguish athletes from non-athletes, the baseline questionnaire included questions on sport participation, which allowed to divide the study population into athletes and non-athletes; this division was based on type of sport and the intensity level within the sport. Almost 75% of the athletes practiced walking and cycling as their main sport activity and we made the arbitrary decision to include both of these activities in our study. It could, however, be debated whether these activities should be considered as sport activities. The fact that almost 75% of the athletes were cyclists and walkers may explain why we found no substantial differences within type of knee complaints between the athletes and non-athletes.

The DMC3 study used the SQUASH questionnaire to evaluate the activity levels of the subjects, and in the HONEUR knee study a comparable questionnaire was used. Unfortunately, these questionnaires do not distribute information about sport activities in the past, or possible reasons for quitting these activities. Such information might have been useful to evaluate causal relationships between sport and musculoskeletal complaints.

TREATMENT OF SPORT RELATED LOWER EXTREMITY COMPLAINTS

After analysing the results of the studies in chapter 5, 6 and 7 we can conclude that a substantial part of the athletes prefer a more active strategy to recover from their musculoskeletal complaint than non-athletes, i.e. they are more likely to visit a physiotherapist than non-athletes. Chapter 5 shows a high frequency of visits to the physiotherapist by marathon runners; this is surprising since there is little evidence for the effectiveness of interventions for frequently occurring injuries such as the runners' knee and iliotibial band friction syndrome.[19] Chapters 6 and 7 also reveal more frequent visits of athletes to the physiotherapist. Evidence for the effectiveness of physical therapy in sport injuries is scarce, whereas there is sufficient evidence for the effectiveness of e.g. exercise in osteoarthritis of the knee (chronic knee complaints).[20,21] The Dutch NHG-standard (Practical Guideline of The Dutch College of General Practitioners) for non-traumatic knee complaints provides no specific indications for the effectiveness of interventions such as physiotherapy, stretching exercises and adaptations to shoes. Since the introduction of the new Dutch healthcare system in 2006, a referral from the GP is no longer necessary in order to visit a physiotherapist; therefore the frequency of visits to the physiotherapist will probably increase. This stresses the need for more knowledge regarding treatment strategies for running and other sport injuries.

In spite of the lower level of pain and discomfort during work and ADL reported by athletes, their medical consumption is higher compared to non-athletes. It seems that athletes make more demands on their body than non-athletes. In addition, medical consumption (especially visits to a physiotherapist) may be even higher among athletes participating in unorganized sports.

IMPLICATIONS FOR DAILY PRACTICE AND FUTURE RESEARCH

The information presented in this thesis does not provide practical tools for the treatment or prevention of sport-related injuries, but does provide basic information needed to design and conduct intervention, prevention and cohort studies. As already mentioned, knowledge on the incidence and prevalence of running injuries is still scarce, and even less is known about the aetiology and value of diagnostics and interventions for running injuries. Ideally, we should clarify the aetiology, risk factors and prognostic factors before preventive and (subsequently) intervention trials are started. On the other hand, intervention trials can be started in order to acquire practical experience and to evaluate frequently already applied interventions for which the effectiveness is not yet established.

Daily practice

The Rotterdam marathon study has shown that (currently) the strongest predictor for running injuries is the non-modifiable risk factor 'previous injury'. Although it is difficult to influence this risk factor, we can educate and inform people about the high risk of recurrent injuries to those who are already injured. The Internet could play an important role in this, whereby researchers could be stimulated to cooperate with webmasters of frequently visited websites such as runnersweb and *Consument en Veiligheid* (www.voorkomblessures.nl).

Non-musculoskeletal co-morbidities are a predictive factor for persistent complaints of running injuries. Therefore physicians should be aware of a possibly long recovery period after a running injury, and future intervention studies should also take this group into consideration and consider stratification for this particular group.

Further, given the high frequency of visits to the GP and physiotherapist by athletes, it is surprising that no guidelines are available for frequently seen sport-related injuries of the lower extremities. Both the Dutch guidelines for general practice (NHG) and the guidelines for physiotherapists (KNGF) hardly address diagnostic, management or treatment guidelines for sports-related injuries of the lower extremities.

Future research

Knowledge on the prevalence and incidence of running injuries is still very limited and even less is known about aetiology and the value of diagnostics and interventions related to running injuries. Until now, the Rotterdam marathon study is the first with a follow-up measurement of injuries occurring among long-distance runners; however, the follow-up period was limited to 3 months. A longer follow-up may provide more precise data as to which runners return to running or other sports, or do not return to running because of their running injuries. Nevertheless, the present study showed a high incidence of running injuries and because there are many runners worldwide, the overall impact to society may be relatively high. We also found a higher medical consumption (to GP and physiotherapists). Investigation of overuse injuries in runners will provide more information about overuse complaints and syndromes in general; for example, as also frequently seen in specific work environments. All the above-mentioned points argue for more research on running injuries. However, for most of these injuries the specific diagnosis is lacking or unknown. Because most research is performed in a wide spectrum of subjects with lower extremity injuries, the risk factors are overall risk factors for lower extremity injuries and not for any particular disorder. Future research should preferably focus on a particular type or site of an injury and attempt to fill in the model of Meeuwisse et al.[16] with underlying aetiology and risk factors.

As already mentioned, a worldwide consensus on the definition of a running injury is still lacking. Researchers should aim to reach a consensus about methods to be used in sports medicine in terms of definitions of injuries of outcome measures and, of sport impact on subjects. Then injury incidence can be expressed in exposure time in injuries per 1000 hours of sport participation in all studies. Such consensus statements should lead to improvement in the quality of research in sports medicine.

Because one of the most important risk factors for running injuries is a previous injury, it would be interesting to investigate in future research novice runners without a previous injury. Such a study is already underway in The Netherlands: The GRONORUN study was setup to examine the effect of a graded training program for novice runners in preparation for a 4-mile running event, on the incidence of running-related injuries. Because physical examinations are included in this study, the data will provide us with more information about the diagnostics of the injuries. Also, the follow-up measurements will provide information about the possible consequences any injuries: did they drop out of running or did they maintain? As discussed in chapter 7, it is important to investigate reasons for dropping-out of sport activities because of the potential negative consequences of inactivity. Future research should therefore include questions concerning exercise history and reasons for dropping-out.

Since the knee is the most frequently injured site in runners, future research should be directed to these types of injuries. A cohort study focussing on knee injuries in runners will yield information about the course of injuries and prognostic factors, as well as any interventions applied. Such a study could also provide information about the need to distinguish between different types of knee injuries. When there are no major differences in prognosis and treatment effect, one should question the relevance of diagnostics in this type of injuries. Knowledge on the course of injury and prognostic factors are necessary to inform patients, and to design intervention trials in order to determine effectiveness of treatment strategies.

As stated before, exercise therapy is a commonly applied treatment strategy in all kinds of sport-related injuries but limited evidence for these treatment strategies is available. Thus future research should certainly include randomized clinical trials of exercise therapy. For example, hip abductor strengthening and iliotibial band stretching as a treatment for the iliotibial band friction syndrome should be investigated by means of a randomized clinical trial.[22] A frequently seen knee overload complaint, also in athletes, is the patellofemoral pain syndrome (PFPS). For this type of knee complaint the literature provides only limited evidence regarding the effectiveness of exercise therapy.[23] Currently, a randomized controlled trial (The Pex-study) is evaluating the additive effect of exercise therapy in PFPS patients versus usual GP management.[24] From the total study population 75.6% are athletes; the results of this study will likely improve the evidence-based management of these (often) sport-related complaints.

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Summary

Running is one of the most accessible sports, and probably for this reason, is practiced by many persons all over the world. However, besides the positive health effects of running there are some concerns about the high incidence of running injuries, especially to the lower extremities. The Rotterdam marathon study was setup to investigate the incidence, risk factors and prognosis of running injuries related to the Rotterdam marathon of 2005.

Chapter 2 presents the results of a systematic review of lower extremity injuries of long-distance runners. Of the eleven selected studies, the incidence of lower extremity running injuries ranged from 19.4% to 79.3%; thus, the overall incidence data show a wide range of lower extremity running injuries. The most predominant site of these injuries was the knee. For many determinants only conflicting or limited evidence was found for associations with lower extremity running injuries. Strong evidence was found for an increased risk of running injuries in the case of a long training distance per week in male runners, and for a history of previous injuries. Strong evidence was also found for a protective effect for knee injuries of an increase in training distance per week.

The incidence and prevalence of running injuries related to the Rotterdam marathon study is reported in **chapter 3**. The aim of this study was to describe the prevalence and incidence of lower extremity injuries occurring before and during the Rotterdam marathon, and to evaluate the impact of the injuries. A cohort study was compiled of recreational male participants in the 2005 Rotterdam marathon. Demographic data and information on previous injuries were obtained from participants using a baseline questionnaire. Information on injuries sustained shortly before or during the marathon was obtained from a post-race questionnaire. A total of 725 (48.3%) participants returned the baseline questionnaire. The one-year prevalence of running injuries was 54.8%. In the post-race questionnaire, 15.6% of all respondents reported at least one new lower extremity injury in the month preceding the Rotterdam marathon. The incidence of lower extremity injuries occurring during the marathon was 18.2%; most of these injuries occurred in the calf, knee and thigh. Immediately after the marathon the median score of pain intensity at rest was 2 points versus 4.5 points during physical exercise. Hence, we can conclude that running injuries are very common among recreational male marathon runners. However, the pain severity and consequences for work and daily activities seem to be relatively low one week after the marathon.

Chapter 4 focuses on risk factors for lower extremity running injuries, occurring shortly before or during the Rotterdam marathon. Possible risk factors were obtained from a baseline questionnaire one month before the start of the marathon. Information on injuries sustained shortly before or during the marathon was obtained using a post-race questionnaire. Of the 694 male runners who responded to the baseline and post-race questionnaire, 28% suffered a self-reported running injury on the lower extremities in the month before or during the marathon run. The following factors were associated with the occurrence of lower extremity injuries: participating more than six times in a race in the previous 12 months (OR 1.66; CI 1.08 – 2.56), a history of running injuries (OR 2.62; CI 1.82 – 3.78), high education level (OR 0.73;

CI 0.51 – 1.04) and daily smoking (OR 0.23; CI 0.05 – 1.01). Among the modifiable risk factors studied, a training distance less than 40 kilometres a week is a strong protective factor of future calf injuries, and regular interval training is a strong protective factor for knee injuries. Other training characteristics appear to have little or no effect on future injuries.

Chapter 5 describes the 3-month course and possible prognostic factors for persistent complaints of running injuries occurring shortly before or during the Rotterdam marathon. The study population included 165 recreational marathon runners who reported a new running injury in the month before or during the Rotterdam marathon 2005 and who were available for follow-up. At 3-months follow-up, 25.5% of the 165 injured runners reported persistent complaints; they had little pain during exercise and almost no pain in rest. Of all 165 male runners, 16.4% visited a general practitioner (GP) because of their running injury and 24.2% visited a physiotherapist (218 times in total). Persistent complaints at 3-months follow-up were associated with non-musculoskeletal co-morbidities (OR 3.23; 95%CI 1.24-8.43), and calf injuries (OR 0.37; 95%CI 0.13-1.05). Thus it can be concluded that 25% of the runners had persistent complaints of their marathon-related running injury at 3-months follow-up. However, the clinical and social consequences of the injuries seem to be relatively mild. Non-musculoskeletal co-morbidities at baseline are related to poor recovery, whereas recovery is also location specific.

In **chapter 6** we investigated the differences in type of knee complaints between athletes and non-athletes presenting in general practice. Further, differences in the initial policy of the GP, medical consumption, and outcome at one-year follow-up were also investigated. Patients consulting their GP for a new episode of knee complaints were invited to participate in the study. From the total HONEUR knee cohort population (n=1068) we extracted patients who were athletes (n=421) or non-athletes (n=388). The results showed that acute distortions of the knee were more often diagnosed in athletes than in non-athletes (p=0.04). More athletes were advised by their GP to 'go easy on the knee' than the non-athletes (p<0.01). Medical consumption was higher among athletes. No differences were found between the two groups for recovery at one-year follow-up. Therefore, we can conclude that there are hardly any differences in knee complaints between athletes and non-athletes presenting to the GP. Athletes are, however, advised more often to 'go easy on the knee' and to rest than the non-athletes. Further, there is a trend towards increased medical consumption among athletes while functional disability and pain are less severe compared to non-athletes. Despite the GP's advice and increased medical consumption, athletes do not have a better prognosis regarding their recovery at one-year follow-up.

In **chapter 7** we focused on the complex relationship between sport activity and musculoskeletal complaints. In order to provide better insight into this relationship we studied the pattern of musculoskeletal pain among athletes and non-athletes in a general population with respect to: 1) prevalence, incidence, severity and cause of complaints 2) type and intensity of sports activity, and 3) medical consumption as a consequence of musculoskeletal pain. The

study population included a random sample of the Dutch population aged 25 years or older (baseline n=3664, follow-up after 6 months n=2337). The baseline population consisted of 1162 athletes and 2502 non-athletes. Data collection included musculoskeletal pain (different sites), severity of complaints, sport activity, type of sport activity and medical consumption. At 6-months follow-up, non-athletes reported more upper extremity pain compared to the athletes ($p<0.01$). Half of the intensive athletes attributed their incident hip or knee complaint to sport activity while only 24.5% of the moderate athletes attributed their hip or knee complaints to sport activity ($p<0.05$). Among the subjects reporting pain, athletes report a higher medical consumption (physiotherapist) compared to the non-athletes. The results of this study showed that there are no large differences in the prevalence of musculoskeletal pain between athletes and non-athletes. However, there is some indication that engaging in sport activities is protective towards upper extremity complaints and, on the other hand, that sport activity contributes to lower extremity complaints, in both athletes and non-athletes. In addition, athletes seem to have a different pattern of health care utilization (i.e. using more physiotherapy) when they have pain.

Chapter 8 addresses the findings in this thesis and makes recommendations for clinical practice and research. Possible explanations for the risk factors for running injuries are discussed. Further, the relatively high medical consumption of athletes is discussed in relation to the relatively low impact of the lower extremity complaints or injuries that occurred. Finally, because of the relatively scarce knowledge on the diagnostics, aetiology and risk factors for running and other sport injuries, further research is required on this subject. Future studies should include randomised clinical trials of treatment strategies applied for the frequently occurring running injuries.

Samenvatting

Hardlopen is op dit moment één van de populairste sporten in Nederland. Naast de positieve effecten op de algemene gezondheid, kan hardlopen echter ook negatieve consequenties hebben, met name hardloopblessures. De Rotterdam marathon studie is opgezet om inzicht te krijgen in de incidentie, de risicofactoren en de prognose van hardloopblessures die zijn ontstaan voor of tijdens de Rotterdam marathon in 2005.

Hoofdstuk 2 beschrijft de resultaten van een systematische review naar de incidentie en risicofactoren van hardloopblessures bij langeafstandslopers. De incidentie van hardloopblessures aan de onderste extremiteiten varieerde binnen de 11 geselecteerde studies van 19.4% tot 79.3%. Binnen deze grote range was de knie de meest gerapporteerde locatie. Voor veel risicofactoren werd onvoldoende bewijs gevonden voor een associatie met hardloopblessures aan de onderste extremiteiten. Er werd echter sterk bewijs gevonden voor een verhoogd risico op een blessure bij een grote trainingsafstand per week voor mannen. Daarnaast hebben lopers met eerdere blessures een verhoogd risico op een hardloopblessure aan de onderste extremiteiten. Ook werd er sterk bewijs gevonden dat een toename van de wekelijkse trainingsafstand beschermend is voor knieblessures.

De incidentie en prevalentie van hardloopblessures rondom de Rotterdam marathon in 2005 zijn beschreven in **hoofdstuk 3**. Het doel van deze studie is inzicht te krijgen in de prevalentie en incidentie van blessures aan de onderste extremiteiten rondom de marathon en om de gevolgen van deze blessures te beschrijven. Er is een cohort studie opgezet onder de mannelijke deelnemers aan de Rotterdam marathon van 2005. Met behulp van de baseline vragenlijst is er informatie verzameld over demografische gegevens en over blessures in het verleden. Een tweede vragenlijst, die direct na de marathon werd verstuurd, verzamelde informatie over eventuele nieuwe blessures kort vóór en tijdens de marathon. In totaal retourneerden 725 mannelijke hardlopers de eerste vragenlijst (48.3%). De éénjaars prevalentie van hardloopblessures in deze groep was 54.8%. In de tweede vragenlijst rapporteerde 15.6% van de respondenten een nieuwe hardloopblessure kort voor de Rotterdam marathon. De incidentie van blessures tijdens de marathon was 18.2%. De meeste lopers hadden blessures aan kuit, knie en bovenbeen. De mediaan score van de pijnintensiteit (schaal 0-10) van deze blessures was 2 punten in rust en 4.5 punt tijdens inspanning. Er kan geconcludeerd worden dat hardloopblessures onder recreatieve marathon lopers zeer frequent voorkomen. Desalniettemin zijn de pijnintensiteit en de consequenties voor dagelijkse activiteiten één week na de marathon relatief laag.

Hoofdstuk 4 beschrijft de mogelijke risicofactoren voor hardloopblessures rondom de marathon. Informatie over mogelijke risicofactoren werd verkregen uit de baseline vragenlijst, één maand voor de start van de marathon. Informatie over eventuele blessures kort vóór en/of tijdens de marathon werd verzameld uit de tweede vragenlijst. Van de 694 hardlopers die de tweede vragenlijst retourneerden, rapporteerde 28% een nieuwe blessure aan de onderste extremiteiten in de maand vóór of tijdens de marathon. Lopers die meer dan zes wedstrijden liepen in het voorgaande jaar (OR 1.66; 95%CI 1.08-2.56) en lopers die in het voorgaande jaar al eens een blessure hadden (OR 2.62; 95%CI 1.82-3.78), hebben een verhoogd risico op het krijgen van een blessure, terwijl lopers met een hoog opleidingsniveau (OR 0.73; 95%CI 0.51-1.04) en dagelijkse rokers (OR 0.23; 95%CI 0.05-1.01) minder kans hebben op een hardloopblessure. Onder de modificeerbare factoren was een wekelijkse trainingsafstand van minder dan 40 kilometer een beschermende factor voor het krijgen van kuitblessures en was regelmatige interval training een beschermende factor voor het krijgen van knieblessures. Andere trainingsfactoren bleken weinig tot nauwelijks invloed te hebben op het wel of niet ontwikkelen van blessures.

In **hoofdstuk 5** wordt het 3-maands beloop van hardloopblessures, opgelopen kort vóór of tijdens de marathon, beschreven. Daarnaast zijn mogelijke prognostische variabelen voor persisterende klachten beschreven. De totale studiepopulatie bestaat uit 165 recreatieve hardlopers die een nieuwe blessure opliepen in de maand vóór of tijdens de marathon. Drie maanden na de marathon had 25.5% van deze hardlopers nog klachten. Zij rapporteerden echter weinig pijn tijdens inspanning en nauwelijks pijn tijdens rust. De huisarts werd door 16.4% van de lopers geconsulteerd en de fysiotherapeut werd door 24.2% van de lopers bezocht (218 keer). Persisterende klachten van hardloopblessures zijn geassocieerd met co-morbiditeiten die niet gerelateerd zijn aan klachten van het bewegingsapparaat (OR 3.23, 95%CI 1.24 - 8.43) en kuitblessures (OR 0.37, 95%CI 0.13 - 1.05). Er kan geconcludeerd worden dat een kwart van de hardlopers met een blessure drie maanden na de marathon nog steeds last heeft van deze blessure. Echter, er zijn relatief weinig klinische en sociale consequenties.

Hoofdstuk 6 beschrijft de verschillen in type knieklachten tussen sporters en niet-sporters in de huisartsenpraktijk. Daarnaast worden ook de mogelijke verschillen in het beleid van de huisarts, de medische consumptie en de uitkomsten na één jaar geanalyseerd. Patiënten die de huisarts voor de eerste keer bezochten in verband met knieklachten werden uitgenodigd deel te nemen aan de studie. Uit de totale studie populatie (n=1068) van het HONEUR knie cohort werden sporters (n=421) en niet-sporters (n=388) geselecteerd. Acute distorsies werden door de huisarts significant meer gediagnosticeerd bij sporters dan bij niet-sporters (p=0.04). Verder werden sporters vaker geadviseerd om 'het rustig aan te doen' met de knie dan niet-sporters (p<0.01). De medische consumptie onder sporters was hoger dan onder niet-sporters. Er werden echter geen verschillen gevonden tussen sporters en niet-sporters betreffende het herstel van de knieklachten na één jaar follow-up. Er kan geconcludeerd worden dat er nauwelijks verschillen zijn in type knieklachten, gepresenteerd in de huisartsenpraktijk, tussen sporters en niet-sporters. Sporters werden echter vaker geadviseerd om de knie 'te sparen' en 'het rustig aan te doen' in vergelijking met niet-sporters. Verder was er een positieve trend in medische consumptie van de sporters terwijl de functionele beperkingen en de pijn minder waren in vergelijking met de niet-sporters. Ondanks de adviezen van de huisarts en de hogere medische consumptie van de sporters was er geen verschil in het herstel van de knieklachten na één jaar follow-up.

Hoofdstuk 7 richt zich op de complexe relatie tussen sporten en klachten aan het bewegingsapparaat. Om beter inzicht te krijgen in deze relatie zijn klachten aan het bewegingsapparaat van sporters en niet-sporters geanalyseerd met betrekking tot 1) prevalentie, incidentie, ernst en oorzaak van de klachten 2) type en intensiteit van sportactiviteiten, en 3) medische consumptie als gevolg van klachten aan het bewegingsapparaat. De studiepopulatie omvatte een steekproef uit de Nederlandse populatie van 25 jaar of ouder (baseline n=3664, follow-up na 6 maanden n=2502). De baseline populatie bestond uit 1162 sporters en 2502 niet-sporters. Er werden data verzameld over klachten aan het bewegingsapparaat (verschillende locaties), ernst van de klachten, sportactiviteiten, type sport en medische consumptie. Na 6 maanden follow-up rapporteerden de niet-sporters meer klachten aan de bovenste extremiteiten in vergelijking met de sporters. De helft van de intensieve sporters weet hun heup- en knieklachten aan sportactiviteiten, terwijl 24.5% van de gematigde sporters hun heup en knieklachten toekenden aan sportactiviteiten ($p<0.05$). De fysiotherapeut werd door sporters met klachten aan het bewegingsapparaat frequenter bezocht dan door niet-sporters met klachten aan het bewegingsapparaat. De resultaten van deze studie laten geen grote verschillen zien in de prevalentie van klachten aan het bewegingsapparaat tussen sporters en niet-sporters. Er zijn echter wel aanwijzingen dat sporten beschermend zou kunnen zijn voor klachten aan de bovenste extremiteiten en dat aan de andere kant, sport een bijdrage levert aan klachten aan de onderste extremiteiten, zowel bij sporters als bij niet-sporters. Verder lijken sporters een ander gebruik van de gezondheidszorg te hebben, hetgeen zich uit in meer bezoeken aan de fysiotherapeut.

Hoofdstuk 8 is een reflectie op de resultaten van dit proefschrift en geeft aanbevelingen voor toekomstig onderzoek. Mogelijke verklaringen voor gevonden risicofactoren van hardloopblessures worden bediscussieerd. De discussie richt zich tevens op de relatief hoge medische consumptie van hardlopers en andere sporters in relatie tot de lage impact van deze blessures op het dagelijks leven. Tot slot wordt er geconcludeerd dat er meer onderzoek nodig is op het gebied van diagnostiek, etiologie en risicofactoren van hardloopblessures en andere sport blessures. Daarnaast zouden er in de toekomst gerandomiseerde effect studies naar diverse behandelstrategieën bij veel voorkomende hardloopblessures uitgevoerd moeten worden.

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Curriculum vitae

Marienke van Middelkoop is op 31 mei 1981 geboren in Ameide. Na het behalen van haar VWO diploma aan het Dr FH de Bruijne Lyceum in Utrecht begon zij in 1999 aan de studie Bewegingswetenschappen aan de Vrije Universiteit in Amsterdam. Tijdens haar afstudeeronderzoek onderzocht zij het gangbeeld van patiënten met een enkel arthroplastie. Daarnaast liep zij stage in het bewegingslaboratorium van de afdeling Revalidatie in het Erasmus MC. In november 2004 studeerde zij af in de richting Gezondheidszorg. Sinds december 2004 werkt zij op de afdeling Huisartsgeneeskunde van het Erasmus MC, waar zij als onderzoeksassistent werd aangesteld op de Pex-studie (studie naar de effectiviteit van oefentherapie bij het patellofemorale pijnsyndoom). Daarnaast werkte zij aan de in dit proefschrift beschreven studies. Verder is zij betrokken bij de PROOF-studie (preventie van knieartrose bij zwaarlijvige vrouwen) en zal zij in 2008 starten met een nieuw project over de behandeling van chronische aspecifieke lage rugklachten.