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Prevention of injuries in long-distance runners

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Abstract. The possibility of reducing the incidence of injuries in long-distance runners was investigated in 41 recreational long-distance runners. They were divided into two matched groups according to age, sex, weight, height, experience, training and incidence of injury during the previous year. The runners in the study group were clinically investigated before the season started, and individual training programmes were drawn up. The other group served as controls. The runners receiving prevention and training programmes improved in training technique and had increased training mileage, race participation and racing mileage. In 1 year a total of 50 injuries were recorded, 29 in the study group and 21 in the controls. The injury incidence per 1000 hours of competition was significantly lower in the study group with a preventive training regimen than in the controls (30.7 versus 62.5).

Key words: Running injuries – Prophylaxis – Long-distance running – Injury incidence

Recreational and competitive running is practised by many individuals to improve cardiorespiratory function and general fitness. The major negative aspect of running is a high rate of overuse injury, especially of the lower extremities. Many otherwise healthy runners are prevented from participating fully in their sport by injuries. Epidemiological studies have demonstrated that 58% were injured during preparation for marathon [10]. Injury incidences of 2.5/1,000 h of marathon training [5, 8] and of 89.4 injuries/1,000 h of marathon running has been reported.

Injuries in long-distance runners are mainly overuse injuries to the lower extremities [1, 5, 6, 8]. The most important risk factors for incurring such overuse injury are training error or, more precisely, excessive mileage, sudden change in training distance or intensity, too much hard interval training and unsuitable running shoes [5, 9, 14]. A history of previous injury and early resumption of running after injury are also known to be high risk factors [3, 9]. Intrinsic factors such as leg length discrepancy, excessive pronation and high long arch of the foot also add to the risk of injury [11, 12, 15, 16]. Although recreational long distance runners practise their sport to improve general well-being, a high percentage train for competition in races at different levels. Competition tends to force the runner to run at higher speed (pace), for longer distances and with lighter running shoes, all further increasing the risk of injury [2, 3, 6, 8]. Prevention of injury by elimination of risk factors is clearly preferable to treatment, and in the case of any injury treatment should include appropriate medical care, rehabilitation exercises and a programmed return to training [14].

The aim of the present study was to reveal the preventive effect on injury incidence and improvement in running ability be elimination of risk factors in long-distance running.

Materials

A group of recreational long-distance runners, 19 men and 2 women, were studied and their results compared with those recorded in a group of 20 runners matched for age, sex, weight, height and experience (Table 1). All runners had already taken part in marathon races and intended to take part in at least two marathons during the year of investigation. Comparison of previous mean mileage and mean number of injuries by Student's *t*-test (SPSS statistical package) revealed no statistically significant difference (Table 2).

Table 1. Runners in study group compared with controls matched for age, sex, weight, height and experience (mean range)

	Study	Controls
Number	21	20
Age (years)	40.6 (24–51)	43.1 (29–56)
Sex (m/f)	19/2	18/2
Weight (kg)	70.4 (54–85)	70.0 (49–87)
Height (cm)	177 (166–189)	175 (156–183)
Experience (years)	8.7 (1–15)	9.3 (2–16)

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Table 2. Comparison of study group runners and matched controls for history of training and history of injury revealed no difference using Student's *t*-test. Mean (range)

	Study	Controls
Basal training previous year		
Distance/week (km)	50 (25–120)	43 (15–80)
Hours/week	4.3 (2–8)	4.0 (2–10)
Days/week	3.8 (2–7)	3.4 (1–6)
Maximal training previous year		
Distance/week (km)	72 (40–150)	65 (20–110)
Hours/week	7.5 (3–30)	5.6 (2–12)
Days/week	4.5 (3–7)	4.5 (2–7)
Mean number of injuries per runner in previous year	1.3	1.3

Method

The recreational long-distance runners were clinically examined and any history of previous injury obtained. Any disability was diagnosed and dealt with by medical treatment, physiotherapy, orthosis or specific training advice. Old running shoes were examined to evaluate any one-sided wear of the soles due to excessive pronation.

All runners were taught to plan their training and informed of the importance of stretching as well as of warming up and warming down. An individual training programme was prescribed according to current running ability. Proper individually fitted running shoes were used, and light competition shoes were not allowed. In the case of any injury, the runner concerned was examined by one of the authors and any treatment or training changes needed were prescribed. A group matched for age, sex, experience, weight and height and history of injuries acted as controls.

Table 3. Training programme based on a 3-kg or 5-kg running test. (*ET* – endurance training)

Week 1	
Day 1	45 min ET 115–125%
Day 2	60 min ET 115–125%
Day 3	60 min ET 115–125%
Day 4	75 min ET 115–125%
Day 5	45 min ET 115–125%
Day 6	120 min ET 125–135%
Day 7	60 min ET 115–125%
Week 2	
Day 1	45 min ET 115–125%
Day 2	2 × 2 × 600 m hill training 95–105%
Day 3	45 min ET 115–125%
Day 4	60 min ET 115–125%
Day 5	3 × 2 × 600 m hill training 95–105%, jogging down 30 min
Day 6	45 min ET 115–125%
Day 7	75 min ET 115–125%
etc.	

Training programme

Based on a 3- or 5-km running test on a track the training was planned according to the pace during the test. The running test was repeated every 12 weeks. The training was basically endurance training mixed with hill training and speed training according to a specific schedule (Table 3).

Records

Every runner kept a running diary recording distance run, pace and technique daily and reported to the Analysis Centre of Aarhus County once a week for 1 year. Training technique were recorded according the percentage amount of five different training techniques per training session: warming up, endurance training, speed training, hill running, warming down. (For example, if the diary says: warm up: 30%, endurance training: 65%, warm down: 5% the runners used 30% of total training time warming up, 65% endurance training and 5% warming down.) It was recorded whether the runner did stretching before and after training. All participation in competition was recorded in weekly reports, and any injury to the musculoskeletal system that was incurred during running and prevented training or competition was reported to one of the authors at once. All the data were computerized and compared using the SPSS statistical package.

Results

On clinical examination only a few major intrinsic risk factors were found. One runner had a history of previous lateral ankle instability and significant lateral instability was revealed. This problem was dealt with by an Aircast ankle brace and a course of proprioceptive physiotherapy, and the patient did not complain of instability during the investigation period. Two runners had marked wear of the medial part of the shoe sole and were given advice on using anti-hyperpronation shoes.

Several runners had a history of overuse injuries, mainly to the Achilles tendon or of shin splints. No runner had any symptoms or objective signs of overuse injury at the start of the investigation.

The mean distance run for training per week was significantly higher in the runners in the study group, with an almost flat course during the year peaking in early spring and early autumn (Table 4, Fig. 1). The time spent during practice was similarly different, giving the same pace (Table 4, Fig. 2). The training technique is described by the percentage of training sessions preceded by warming up, stretching or followed by stretching. As shown in

Table 4. Training distance and time per week in study group and in controls (Student's *t*-test). Mean (95% significance levels); (NS non-significant)

	Study	Controls	Statistics
Distance/week (km)	43.0 (41.6–44.4)	33.4 (32.0–34.9)	$P < 0.001$
Hours/week	3.4 (3.3–3.5)	2.7 (2.6–2.8)	$P < 0.001$
Pace (km/h)	12.5 (12.2–12.6)	12.5 (12.3–12.7)	NS

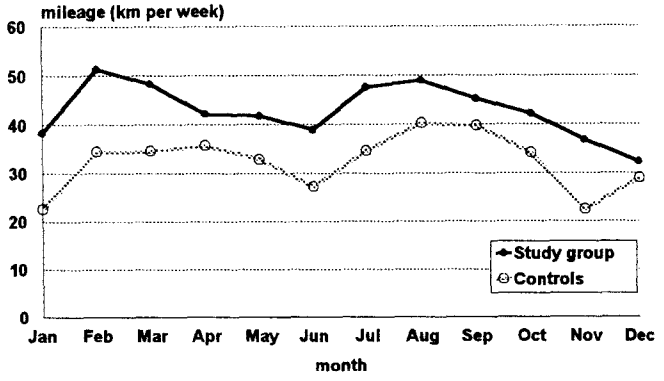

Fig. 1. Average weekly mileage in marathon runners performing an injury prevention programme and their controls during one year

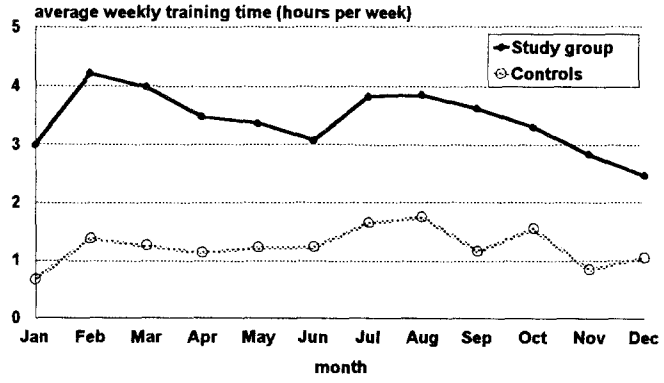

Fig. 2. Average weekly training time in marathon runners performing an injury prevention programme and their controls during one year

Table 5. Training technique evaluated by percentage of sessions preceded by warming up or stretching and sessions followed by stretching

	Study	Controls	Statistics
Warming up	30.3%	9.1%	$P < 0.01$
Stretching before	37.6%	29.7%	NS
Stretching after	94.4%	88.7%	$P < 0.05$

Table 5, runners in the study group warmed up for 30.3% of all sessions and did stretching exercises before 37.6% and after 94.4% of training sessions. The controls warmed up in 9.1% of sessions and did stretching procedures in 88.7 of sessions.

The study group runners took part in 34 marathon races, whereas controls ran in 23 races, and the groups had 3542 and 2504 running kilometres, respectively, in total after competing in races of different lengths. No difference was found concerning participation in races. The marathons and other races were mainly run in April to June and August to October (Figs. 3, 4).

An injury was defined as any injury of the musculoskeletal system that was sustained during running and prevented training or competition. In all, runners sustained 50 injuries, 29 in the study group and 21 in the controls. The runners sustained their injuries during competi-

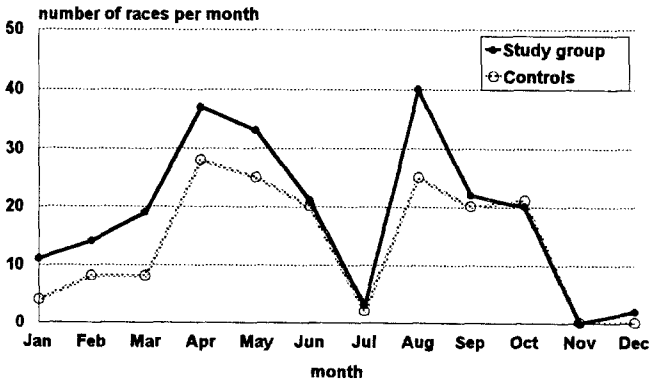

Fig. 3. Participation in running races in 21 marathon runners performing an injury prevention programme and their 20 controls during one year

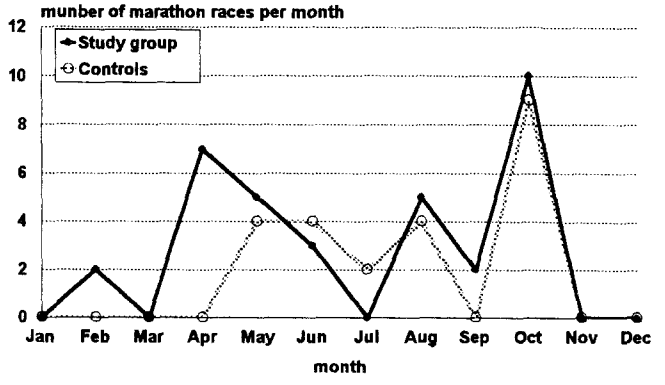

Fig. 4. Marathon runners' participation in marathon races during one year. Study group runners performing an injury prevention programme

Table 6. Injuries in 41 marathon runners during training and competition

	Study	Controls
Number of runners injured	18	13
Number of injuries	29	21
Incurred during competition	8	11
Total training break (days)	337	117

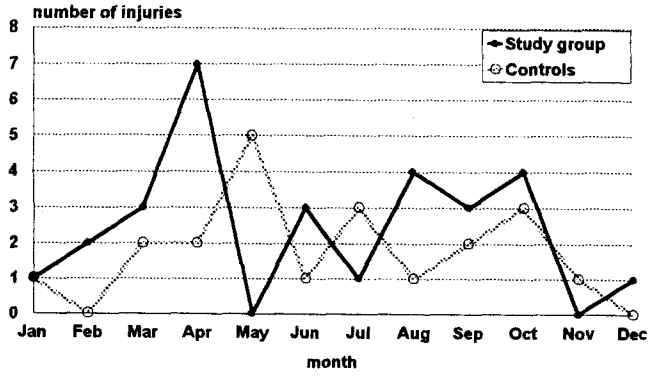

Fig. 5. Number of injuries sustained in a study group of marathon runners and their controls during one year

Table 7. Running injuries diagnosed in long-distance runners

	Study	Controls
Overuse		
Achilles tendonitis	8	2
Runner's knee	2	2
Plantaris fasciitis	1	2
Traction periostitis	4	4
Knee synovitis	2	0
Ankle synovitis	1	0
Low back pain	1	0
Other	3	4
Traumatic		
Costal fracture	0	1
Sprain ankle joint	2	3
Sprain knee joint	1	1
Muscle fibre rupture	4	2

Table 8. Incidence of injuries (injury per 1,000 h) during training and competition in 41 marathon runners (Student's *t*-test)

	Study	Controls
Training	7.4	6.9
Race	30.7***	62.5

tion in 27.5%, whereas controls were injured during competition in 52.4% (Table 6). Total training breaks were significantly more frequent in the preventive training group. Injuries were most frequent in both groups during the spring (Fig. 5). Thirty-six (72%) of the injuries were caused by overuse resulting in plantaris fasciitis, inflammation of Achilles tendon or synovitis of the knee or ankle (Table 7).

The acute lesions were mainly ankle sprains and muscle fibre ruptures. The lower leg was the region affected in 70% of all injuries. No difference was shown between the groups in different overuse or traumatic injuries. As the runners in the preventive training group had trained over longer distances the incidence of injuries per 1,000 h of training was similar (Table 8). The incidence during races was 30.7/1,000 h in the study group and 62.5/1,000 h in controls ($P < 0.005$).

Discussion

Although running is commonly accepted as being beneficial to health and fitness, long-distance running such as marathon running does stress the musculoskeletal system increasing the risk of injuries. Even in recreational runners the incidence of injury during marathon is several times greater than in soccer or handball. The incidence in marathon racing has been shown to be more than 80 per 1,000 h [8], as against 10–20 per 1,000 hours during team ball games [13, 17].

Risk factors for running injuries are accepted to be training errors, such as continual training over long distances, sudden increases in training stretches, due to wrongly planned training or after a training pause imposed by injury [4, 7, 14]. As most endurance runners are, by definition, serious competitors and as injuries in runners are mainly of the over-use type, a programme to reduce the high load on the musculoskeletal system or to prevent sudden changes in mileage without reduction in running capacity is preferable to forced breaks in training and competition. Intrinsic factors play a minor role in causing running injuries, and biomechanical malalignment should be addressed if treatment or prevention is possible.

In the present study, 41 recreational long-distance runners were divided into two matching groups. The groups were comparable according to age, sex, weight, height and experience. Experience is an important factor for injury risk in long-distance runners, experience lowering the risk of injury [6]. The runners, were similar in former running capacity (Table 2).

One of the preventive measures for the study group runners was a clinical examination before the reason started to check for any biomechanical malalignment that could be corrected, such as functional lateral ankle instability and hyperpronation running. Examination of a pair of old runnings shoes was used to evaluate the running style and running shoe type. The runners were then advised to use specific running shoes, and all runners had to wear well-fitting long-distance running shoes for training as well as for competition. Light-weight competition shoes were not allowed. To reduce training errors, all runners in the preventive group were taught about possible training errors, such as rapid increase in training distance. The runners were taught different stretching techniques, and the importance of warming up and of getting treatment for overuse symptoms was explained. Finally, every runner in the study group performed a 3-km or 5-km running test on a track, and according to the result of this an individual training programme was prescribed. The running test was repeated every 12 weeks and the training programme adjusted accordingly.

The information and training programme altered the training of these runners. The study group runners warmed up better before training sessions and did stretching exercises after the running session significantly more often than the control group. They also trained over a higher mileage at the same pace. The number of injuries was higher in the study group, but when adjusted for training time the incidence was similar in the two groups. The risk of injury must be related to the time spent engaged in the sport, and it is therefore correct to use this incidence (injury per time) for comparison.

In this study the incidence of injury during competition was noted to be lower than in earlier reports. This can be explained by the high experience level of the runners. Comparison of the two groups revealed a significantly lower incidence of injury during competition in the preventive group.

As in previous studies, the injuries were mainly overuse injuries to the lower extremities [1, 5, 6, 14]. No difference was found in the types of lesion between the groups. The higher number of non-training days in the preventive group might be thought to have been caused by

more serious lesions in the study group. Clinical examination did not confirm this hypothesis, and the difference is more probably due to the treatment in the prevention group: rest and restriction of the amount of training allowed.

Conclusion

It can be concluded that preventive features such as preseasonal clinical examination, individual training plans, athlete education, and early medical intervention in the case of injury improved training techniques and lowered injury during races without reducing running capacity compared with matched controls. Emphasis on prevention and education and on encouraging runners to plan their training and improve training technique is recommended.

References

1. Collins K, Wagner M, Peterson K, Storey M (1989) Overuse injuries in triathletes. Am J Sports Med 17 : 675–680
2. Guyot WG (1991) Psychological and medical factors associated with pain running. J Sports Med Phys Fitness 31 : 452–460
3. Hoeberigs JH (1992) Factors related to the incidence of running injuries. Sports Med 13 : 408–422
4. Jacobs SJ, Berson BL (1986) Injuries to runners: a study of entrants to a 10,000 meter race. Am J Sports Med 14 : 151–155
5. Jakobsen BW, Krøner K, Schmidt SA, Jensen J (1988) The frequency of injuries in recreational running races. Ugeskr Laeger 150 : 2954–2956
6. Jakobsen BW, Krøner K, Schmidt SA, Jensen J (1989) Running injuries sustained in a marathon race. Ugeskr Laeger 151 : 2189–2192
7. James SL, Bates BT, Osternig LR (1978) Injuries to runners. Am J Sports Med 6 : 40–50
8. Lysholm J, Wiklander J (1987) Injuries in runners. Am J Sports Med 12 : 168–171
9. Marti B (1991) Health effects of recreational running in women. Some epidemiological and preventive aspects. Sports Med 11 : 20–51
10. Maughan RJ, Miller JDB (1983) Incidence of training-related injuries among marathon runners. Br J Sports Med 17 : 162–165
11. McGaw ST (1992) Leg length inequality. Implications for running injury prevention. Sports Med 14 : 422–429
12. Nachbauer W, Nigg BM (1992) Effects of arch height of the foot on ground reaction forces in running. Med Sci Sports Exerc 24 : 1264–1269
13. Nielsen AB, Yde J (1988) Epidimiologic and traumatologic study of injuries in handball. Int J Sports Med 9 : 341–344
14. O'Toole ML (1992) Prevention and treatment of injuries to runners. Med Sci Sports Exerc 24 [Suppl] : 360–363
15. Stacoff A, Kalin X, Stussi E (1991) The effects of shoes on the torsion and rearfoot motion in running. Med Sci Sports Exerc 23 : 482–490
16. Van Mechelen W, Hlobil H, Zijlstra WP, de Ridder M, Kemper HC (1992) Is range of motion of the hip and ankle joint related to running injuries? Int J Sports Med 13 : 605–610
17. Yde J, Nielsen AB (1988) An epidemiological and traumatological analysis of injuries in a basketball club. Ugeskr Laeger 150 : 142–144