Foot pronation is not associated with increased injury risk in novice runners wearing a neutral shoe: a 1-year prospective cohort study

Rasmus Oestergaard Nielsen,[1,2] Ida Buist,[3] Erik Thorlund Parner,[4] Ellen Aagaard Nohr,[5] Henrik Sørensen,[1] Martin Lind,[6] Sten Rasmussen[2]

[1]Section of Sport Science, Department of Public Health, Aarhus University, Aarhus, Denmark
[2]Orthopaedic Surgery Research Unit, Science and Innovation Center, Aalborg University Hospital, Denmark
[3]Center for Sports Medicine, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands
[4]Section of Biostatistics, Department of Public Health, Aarhus University, Aarhus, Denmark
[5]Section for Epidemiology, Department of Public Health, Aarhus University, Aarhus, Denmark
[6]Department of Orthopaedics, Aarhus University Hospital, Aarhus, Denmark

Correspondence to
Mr Rasmus Oestergaard Nielsen, Section of Sport Science, Department of Public Health, Aarhus University, Dalgas Avenue 4, DK-8000 Aarhus C, Denmark: Roen@sport.au.dk

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ABSTRACT

Objective To investigate if running distance to first running-related injury varies between foot postures in novice runners wearing neutral shoes.

Design A 1-year epidemiological observational prospective cohort study.

Setting Denmark.

Participants A total of 927 novice runners equivalent to 1854 feet were included. At baseline, foot posture on each foot was evaluated using the foot-posture index and categorised into highly supinated (n=53), supinated (n=369), neutral (n=1292), pronated (n=122) or highly pronated (n=18). Participants then had to start running in a neutral running shoe and to use global positioning system watch to quantify the running distance in every training session.

Main outcome measure A running-related injury was defined as any musculoskeletal complaint of the lower extremity or back caused by running, which restricted the amount of running for at least 1 week.

Results During 1 year of follow-up, the 1854 feet included in the analyses ran a total of 326 803 km until injury or censoring. A total of 252 participants sustained a running-related injury. Of these, 63 were bilateral injuries. Compared with a neutral foot posture, no significant body mass index-adjusted cumulative risk differences (RD) were found after 250 km of running for highly supinated feet (RD=11.0% (−10% to 32.1%), p=0.30), supinated feet (RD=−1.4% (−8.4% to 5.5%), p=0.69), pronated feet (RD=−8.1% (−17.6% to 1.3%), p=0.09) and highly pronated feet (RD=9.8% (−19.3% to 38.8%), p=0.51). In addition, the incidence-rate difference/1000 km of running, revealed that pronators had a significantly lower number of injuries/1000 km of running of −0.37 (−0.03 to −0.70), p=0.03 than neutrals.

Conclusions The results of the present study contradict the widespread belief that moderate foot pronation is associated with an increased risk of injury among novice runners taking up running in a neutral running shoe. More work is needed to ascertain if highly pronated feet face a higher risk of injury than neutral feet.

INTRODUCTION

Running-related injuries are common, especially among novice runners taking up a running regime.[1] Foot pronation is believed to be a strong risk factor for injury, and a correct choice of footwear based on the runner's foot type has been suggested as a major intervention to prevent such injuries.[2] Motion control shoes are commonly prescribed to runners with highly pronated feet to pronated feet while stability shoes are recommended to persons with neutral to pronated feet and neutral shoes to persons with neutral to supinated feet.[3] This strategy, which has been used over three decades, has affected runners' choice of running shoes since 73% of all cross-country runners identify foot posture compatibility with shoe design as the most important factor in choosing a running shoe.[4] However, in a review from 2009, Richards *et al*[2] concluded that prescribing a specific shoe type based on the foot posture to distance runners was not evidence-based.

Ryan *et al*[5] recently questioned the efficacy and safety of prescribing motion control shoes to distance runners. On the basis of their findings in a randomised controlled trial, persons running in motion control shoes sustained both a greater number of injuries and had a higher risk of missed training days than persons running in stability or neutral shoes. In another study, no significant difference in injury risk was found between persons who were selected to receive motion control, stability or neutral shoes based on the foot's plantar shape compared with persons who received a stability shoe regardless of plantar shape.[6] This result was confirmed in two later studies.[7 8]

Recent evidence therefore seems to contradict the traditional position that presupposes that supinated feet are best served in neutral shoes, highly pronated feet in motion control shoes and neutral feet in neutral or stability shoes. If, in fact, foot pronation is no strong risk factor for running-related injury, interventions to control foot movement among healthy individuals taking up a running regime may be superfluous. If this is true, pronators and neutrals should face a similar risk of sustaining running-related injuries when taking up running in a conventional, neutral running shoe. However, such hypothesis remains to be investigated. The purpose of the present study was to investigate if running distance to first running-related injury varied between foot postures in novice runners wearing neutral shoes. The prespecified hypothesis was that the running distance to first running injury will not vary across different foot postures running in a neutral running shoe.

METHODS

The DAnish NOvice RUNning study (DANO-RUN) was designed as an epidemiological observational prospective cohort study with a 1-year follow-up.[9] Reporting of the study followed the STROBE statement.[10] All participants provided written consent prior to baseline investigation. Recruitment of individuals took place from June 2011 to August 2011 and was assisted by advertisements in the local media. Furthermore, posters and mails were distributed at local companies and at organisations to recruit individuals who were interested in taking up running. Individuals who were interested in participating completed an online questionnaire. The questionnaire contained questions about gender, age, running experience, health, previous running-related injuries and previous injuries not related to running. Individuals were included in the study if they were healthy, between 18 and 65 years, had no injury of the lower extremity for at least 3 months prior to the start of study, had access to the internet, had an email address and did not run on a regular basis (<10 km over the previous 12 months). Thus, persons running, for instance, two times 2 km the last year were eligible to participate, while persons running a total of four times 5 km during the last year were excluded. Individuals who had been running on a regular basis, but for some reason did not run the preceding 12 months, were eligible to participate. These individuals were classified as novice runners with previous running experience. Individuals were excluded if they participated in other sports for more than 4 h/week, used insoles during training, were pregnant, reported a history of strokes, heart disease or pain in the chest during training or were unwilling to use the neutral running shoe or the global positioning system (GPS) watch to upload their training sessions. Persons eligible for inclusion were contacted by phone for an interview after screening the online-based questionnaire. In case no contradictions were found, an appointment for baseline investigation was made.

At baseline, persons were again screened for eligibility. If they were included in the study, participants received the same pair of neutral running shoes (Supernova Glide 3 Male or Female, Adidas, Herzogenaurach, Germany; this shoe was a conventional neutral running shoe with a midsole made of adiPRENE and EVA foam material with a 30 mm heel and an 18 mm forefoot corresponding to a 12 mm heel-forefoot drop altogether) and a GPS watch (Forerunner 110 M, Garmin International Inc, Olathe, Kansas, USA). Participants were then instructed to use http://www.vilober.dk/as their personal training diary and to upload data from every training session (running only) saved on the GPS watch in the following year. GPS has previously proven to be a valid method in order to quantify running distance among runners.[11] Participants were told that they had to run in the neutral running shoe at all times. The participants were not allowed to replace the insole in the shoe with another insole. In addition, participants had to report the type of running shoe they used in each of the training sessions they uploaded. By doing so, it was possible to identify if a participant had used other types of shoes than the neutral shoes they were supposed to use. After baseline, the participants had to start running. Participants decided for themselves when and where to run with no restrictions with regard to distance, duration or intensity in each training session. Thus, shoes and GPS watch were donated for free if a participant completed a total of 52 training sessions during the 1-year follow-up. In case of missing GPS data, they should upload the time and distance manually.

The dependent variable of interest was running-related injuries during follow-up. The injury definition was a modified version of the definition used by Buist *et al*[12]; 'A running-related injury was defined as a musculoskeletal complaint of the lower extremity or back caused by running, which restricted the amount of running for at least 1 week'. If the participants sustained an injury during the follow-up period, they were instructed to contact the research group via their personal training diary. The participant was then contacted by telephone and an appointment for a clinical examination was made. At the clinical examination, the injury was diagnosed by one of the three sports physiotherapists and classified as running related or other (injuries from other sports). Only injuries which the participant classified as developed because of running only or classified as developed because of running in combination with other activities were included in the analyses. If the physiotherapist was unable to diagnose the injured participant, referral to a professor in sports traumatology at a nearby hospital was made. At the hospital, the clinical examination was, in most cases, assisted by diagnostic imaging. The clinicians performing the examinations were blinded to the foot posture score assessed at baseline, but not blinded to the foot while examining the injured participant.

The independent variable of interest was foot posture. The assessment of foot posture was based on the six-item version of Foot Posture Index (FPI).[13–15] This method has previously proven to be valid.[13 14] On the basis of the FPI score, each foot was categorised into one of five exposure groups: highly supinated, supinated, neutral, pronated or highly pronated. The normative values presented by Redmond *et al*[15] were used as reference values. Reference values for persons between 18 and 60 years of age and persons above 60 years are presented in table 1. Three different physiotherapists who had been performing FPI evaluations in a pilot study[11] performed the evaluations assisted by two physiotherapy students. To improve the intratester and intertester reliability, we used the findings presented by Cornwall *et al*[16]; all raters had to perform at least 30 evaluations before evaluating a participant on their own. The participants were not blinded to the evaluation of their foot posture.

Statistical analyses

Descriptive data for the demographic characteristics were presented as counts and percentage for dichotomous data, and as mean, SD and 95% CI for continuous data. The assumption of normality was for continuous data examined by histograms and probability plots. Time to first injury was analysed using cumulative running distance as time scale. The unit of analysis was the individual leg. Participants were right-censored in case of pregnancy, disease, lack of motivation, non-running-related injury causing a permanent stop of running, unwilling to attend clinical examination in case of injury, use of a different shoe than the neutral shoe, if more than 10% of all training sessions were uploaded manually (they were censored at the time the first manual upload occurred) or end of follow-up after 1 year, whichever came first. If one leg sustained an injury, the other leg was still followed until injury or end of follow-up. The injury

Table 1 Reference values for categorisation of right and left foot into exposure groups based on the Foot Posture Index

	Highly supinated	Supinated	Neutral	Pronated	Highly pronated
Age 18–60	<−3	−3 to <−1	+1 to <+7	+7 to <+10	>+10
Age 60+	<−3	−3 to <−1	+1 to <+8	+8 to <+11	+12

proportion as a function of running distance was estimated using the Kaplan-Meier curve. To correct for the potential dependence between the two legs, cumulative risk difference in injury survival across foot postures was analysed performing a generalised linear regression using the pseudo values method allowing for clusters.[17] One individual was considered as one cluster (with 2 feet). As we had hypothesised that body mass index (BMI) might be a confounder, we present results from both crude analyses and BMI-adjusted analyses. In table 2, the results revealed that no associations between foot posture and other possible confounders were present. On the basis of this, gender, previous running-related injuries, previous injuries not related to running and previous running experience were rejected as confounders. Since more than 95% all participants utilised a rear-foot strike,[18] the foot strike pattern was also rejected as confounder. Age has previously been shown to influence the foot posture[15] and age has been associated with the development of injury.[19 20] Then, age may be a confounder on the association between foot posture and injury. But, because foot posture categorisation was made based on the age, age was not included as a confounder.

In addition to the survival analyses, the incidence-rate difference per 1000 km of running and incidence-rate difference per 1000 h of running between the foot posture groups were calculated.

Prior to the study, no sample size calculation based on a non-inferiority model was made. Instead, we aimed to include at least 40 feet in each of the five exposure groups. In order to do so, a sample of 800 persons was needed since only 5% from a normal population can be expected to be categorised as highly supinated and as highly pronated.[15] Finally, at least 900 persons had to be included to allow for dropouts during follow-up. Differences were considered statistically significant at $p<0.05$, and estimates are presented with 95% CI. All analyses were performed using STATA/SE V.12.

RESULTS

A total of 927 participants (466 men/461 women) were included in the analyses after excluding 6 persons due to missing data on the foot posture (n=3), missing data on the injured leg (n=1) and injuries sustained prior to baseline (n=2). The mean age was 37.1 (95% CI 36.5 to 37.8) and the mean BMI was 26.3 (95% CI 26.0 to 26.6). On the basis of the assessment of foot posture, the right and the left foot of each participant were categorised into one of five exposure groups: highly supinated (n=53), supinated (n=369), neutral (n=1292), pronated (n=122) or highly pronated (n=18). During 1 year of follow-up, the 1854 legs ran a total of 326 803 km until injury or censoring. Highly supinated feet and supinated feet ran an average of 36 (95% CI 30 to 42) and 39 (95% CI 36 to 42) training sessions before injury occurrence or censoring, while neutrals ran 41 (95% CI 39 to 43), pronated ran 43 (37 to 49) and highly pronated ran 35 (95% CI 22 to 47). A running-related injury was sustained by 252 participants of whom 63 suffered bilateral injuries. After 500 km, a total of 70.6% (95% CI 66.8% to 74.0%) legs remained injury-free. A total of 197 participants were censored for other reasons than injury before the end of follow-up (see figure 1). Of these, 18 persons were censored because they started running in other shoes than the neutral shoes. Two persons sustained an injury while running in another shoe (in both cases minimalist shoes) for the first time. These two injuries were not included in the analyses. Table 3 presents the number of injury-free legs and number of injured legs in each of the five foot posture groups for the left and the right foot. In addition, the numbers of injured legs are presented for medial tibial stress syndrome, patellofemoral pain, iliotibial band syndrome, Achilles tendinopathy and other injuries.

For first-time injuries, the cumulated 1-year incidence proportion was 17.4% for neutral feet, 17.9% for supinated feet, 24.5% for highly supinated feet, 13.1% for pronated feet and 33.3% for highly pronated feet. In figure 2, the Kaplan-Meier plots of injury survival across feet with different foot postures are presented.

Results from the survival analyses performed at 50, 100, 250 and 500 km showed no significant risk differences (unadjusted) between highly supinated, supinated, pronated and highly pronated feet compared with the neutral feet. The results are

Table 2 Characteristics of the participants included in each of the five foot posture groups

	Gender Count (m/f)	Previous injuries Count (y/n)	Previous RRI Count (y/n)	Running experience Count (y/n)	Age Mean (SE)	BMI Mean (SE)
Right foot						
Highly supinated	12/13	13/12	8/17	8/17	37.6 (2.05)	25.8 (0.79)
Supinated	94/104	75/123	31/167	80/118	36.0 (0.69)	26.7 (0.33)
Neutrals	323/321	235/409	111/533	259/385	37.4 (0.41)	26.2 (0.17)
Pronated	32/20	24/28	13/39	18/34	37.9 (1.28)	26.0 (0.64)
Highly pronated	5/3	3/5	2/6	1/7	34.9 (4.67)	27.5 (1.57)
p Value	0.44	0.39	0.18	0.44	0.42	0.49
Left foot						
Highly supinated	17/11	11/17	8/20	13/15	34.1 (1.78	25.2 (0.70)
Supinated	81/90	65/106	29/142	62/109	37.4 (0.75)	26.7 (0.34)
Neutrals	327/321	242/406	110/538	270/378	37.2 (0.40)	26.1 (0.17)
Pronated	33/37	26/44	14/56	18/52	37.5 (1.37)	26.8 (0.58)
Highly pronated	8/2	6/4	4/6	3/7	34.4 (2.53)	27.3 (1.33)
p Value	0.23	0.70	0.18	0.07	0.51	0.26

The p values represent the significance level of each test: in case of categorical data χ^2 (R×C) tests were used while one-way analysis of variance was used in case of continuous data. Running experience (yes) was defined as 'had been running on a regular basis before but not in the previous 12 months preceding the baseline investigation'. Previous injuries are defined as muscular-skeletal complaints not related to running.
f, female; m, male; n, no; y, yes; RRI, running-related injury; SE, standard error.

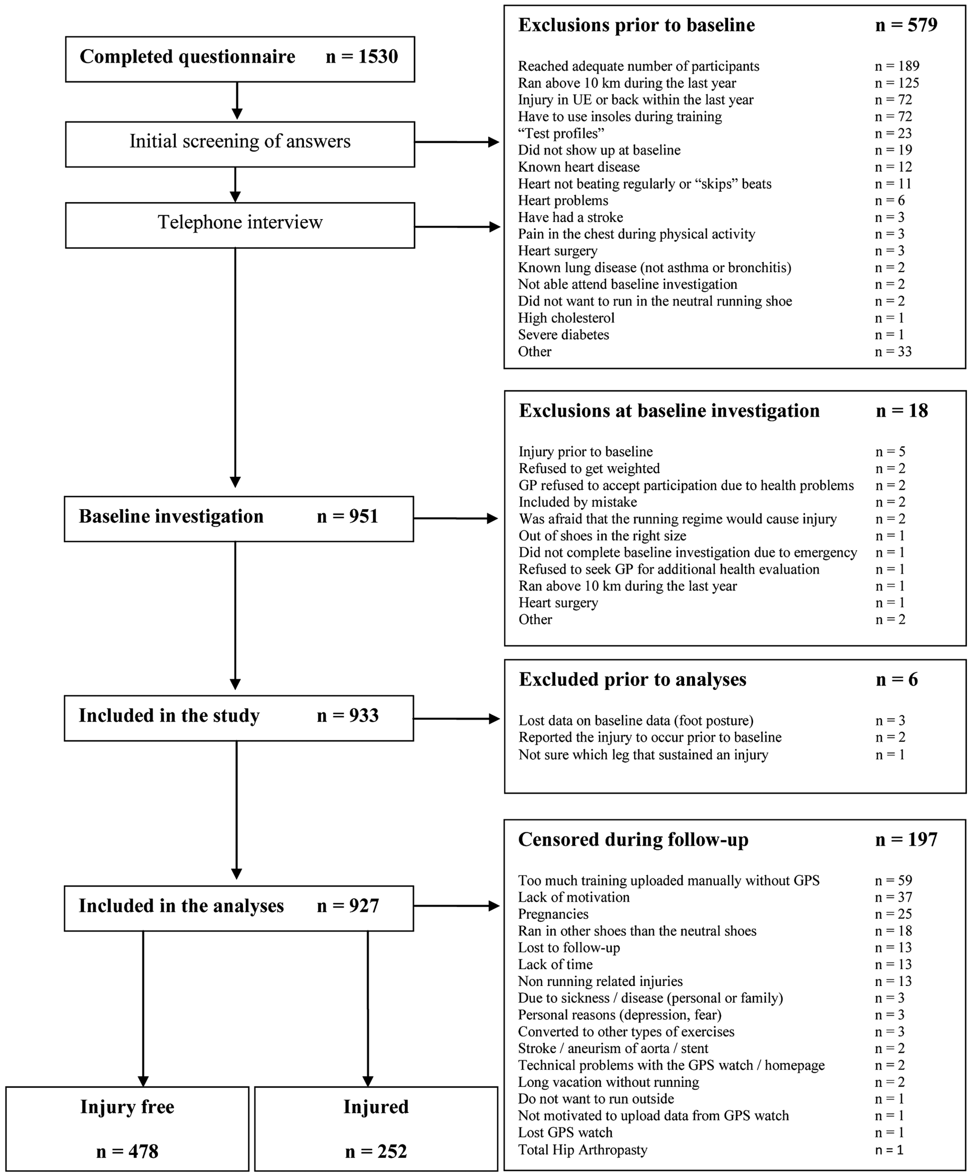

Figure 1 Danish Novice Running flow chart.

presented in table 4. No relevant changes in estimates were observed after adjustment for BMI. After 50 and 100 km, the adjusted χ^2 test for difference across all five exposure groups revealed non-significant p values: 0.67 and 0.46, respectively. The adjusted risk differences after 250 km of running for highly supinated and supinated feet compared with neutral groups were 11% (95% CI −10.0% to 32.1%), p=0.30 and −1.4% (95% CI −8.4% to 5.5%), p=0.69, respectively. Among pronated and highly pronated feet compared with neutral feet, the BMI-adjusted risk differences were −8.1% (95% CI −17.6% to 1.3%), p=0.09 and 9.8% (95% CI −19.3% to 38.8%), p=0.51. Similarly, the adjusted risk differences after 500 km for persons with highly supinated feet were 13.1% (95% CI −8.5% to 34.7%), p=0.24, supinated 8.9% (95% CI −3.3% to 21.2%), p=0.15 and pronated feet −2.3% (95% CI −16.7% to 12.2%), p=0.76. No highly pronated feet exceeded 300 km and no comparison to the neutrals was, therefore, performed after 500 km.

In table 5, the incidence-rates per 1000 km of running for the five FPI groups are presented. In addition, the incidence rate difference of injuries per 1000 h of running was 14.74 (95% CI 7.78 to 21.70) and 9.96 (95% CI 7.78 to 12.14) in the highly supinated and supinated groups, 9.38 (95% CI 8.26 to 10.49) among neutrals and 6.33 (95% CI 3.44 to 9.22) and 28.85 (95% CI 10.00 to 47.69) among pronators and highly pronators. Between pronators and neutrals, the incidence-rate difference per 1000 h of running of −3.05 (95% CI −6.38 to 0.29) was borderline significant (p=0.07).

DISCUSSION

Principal findings

The present study is the first large-scale prospective cohort study to examine the association between foot postures and injury development among novice runners. A novel approach was used since participants wore the same model of a neutral running shoe and used a GPS watch to quantify the running distance in each running session. No significant differences in distance to first running-related injury were found between highly supinated, supinated, pronated and highly pronated feet when compared with neutral feet. In contrast, pronated feet sustained significantly fewer injuries per 1000 km of running than neutral feet.

Table 3 Number of legs with and without injuries according to foot posture group

Foot posture category	Highly supinated	Supinated	Neutral	Pronated	Highly pronated
Right foot (n=927)					
Legs injury-free	16	160	533	44	5
Legs injured	4	38	111	8	3
Left foot (n=927)					
Legs injury-free	21	145	541	62	7
Legs injured	7	26	107	8	3
MTSS					
Injuries right foot	0	2	27	3	0
Injuries left foot	1	3	27	0	1
PFP					
Injuries right foot	0	3	12	0	0
Injuries left foot	0	4	13	2	0
ITBS					
Injuries right foot	0	1	6	0	0
Injuries left foot	1	1	4	0	0
Achilles tendinopathy					
Injuries right foot	1	4	6	1	0
Injuries left foot	1	2	5	1	0
Other injuries					
Injuries right foot	4	28	62	4	3
Injuries left foot	5	16	60	5	2

ITBS, Iliotibial Band Syndrome; MTSS, Medial Tibial Stress Syndrome; PFP, Patellofemoral Pain.

Strengths and weaknesses of the study

The primary strengths of the present study were (1) the prospective design with a 1-year follow-up period, (2) that the sample consisted of more than 900 individuals, (3) that all participants were equipped with the exact same model of a neutral running shoe, (4) that the participants attended a clinical examination in case of injury and (5) that all participants used GPS to quantify running distance during each training session. A major weakness of the study is the low count in the highly pronated group. Owing to the low count, the results reported between highly pronators and neutrals should be interpreted with caution. The distribution of foot posture was a priori expected to follow a normal distribution. By including 900 individuals, at least 40 feet were likely to be classified as highly pronated.[15] However, only 18 feet in the sample were classified as such. As a consequence, no convincing evidence was provided between highly pronators and neutrals in the present study. In addition, the results between highly supinated and neutrals should also be interpreted with caution because of a relatively small number of highly supinated feet (table 4). Despite the low count in the highly pronated group and highly supinated group, it is fair to conclude, based on the estimates, that there was a trend towards an almost similar risk of injury among highly supinated and neutrals after 50 and 100 km, while the highly pronated feet seem to face an increased risk of injury. A reason of the low count in the highly pronated group may be the exclusion of 72 individuals who had to use insoles in their running shoes. Possibly, many of these individuals had a highly pronated foot posture. We made a subanalysis of the same dataset using the original cut-off values presented in the FPI manual. By doing so, 49 feet were classified as highly pronated. The results from the subanalysis revealed that none of the highly supinated feet or the

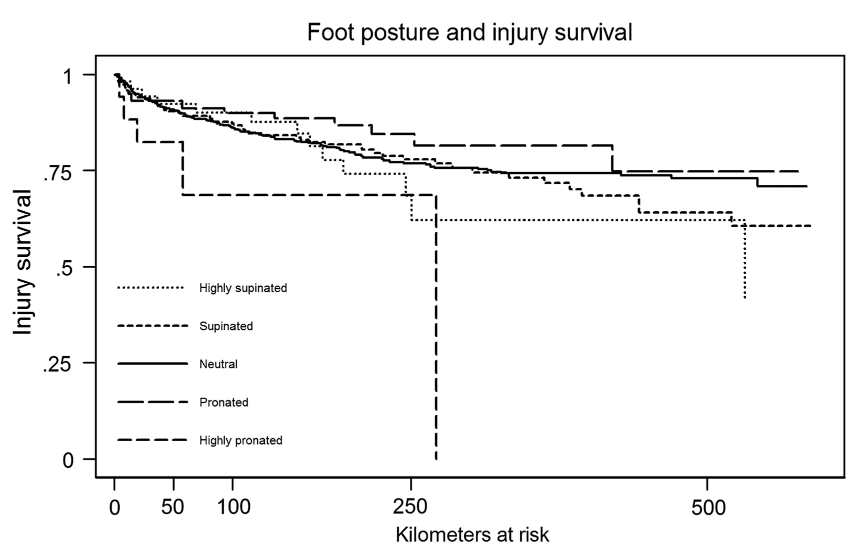

Figure 2 Injury survival among feet categorised as highly supinated, supinated, neutral, pronated and highly pronated.

Table 4 Crude cumulative risk differences (RD) for running injury according to foot posture

Variable of interest	Number of feet (n) remaining	RD	SE	95% CI	p Value
Foot posture index					
Legs analysed: 1854					
Injured legs: 326					
Km at risk: 326.806					
After 50 km					
Highly supinated	41	−1.5%	4.0	−9.4% to 6.3%	0.70
Supinated	234	0.4%	1.9	−3.3% to 4.1%	0.83
Neutral (reference)	798	0			
Pronated	89	−2.3%	2.6	−7.3% to 2.7%	0.36
Highly pronated	14	8.1%	9.8	−11.1% to 27.3%	0.41
All groups*					0.65
After 100 km					
Highly supinated	38	−4.4%	4.8	−13.7% to 5.0%	0.36
Supinated	194	−1.1%	2.2	−5.5% to 3.4%	0.64
Neutral (reference)	679	0			
Pronated	65	−3.8%	3.5	−10.6% to 3.1%	0.28
Highly pronated	8	17.3%	15.0	−12.2% to 46.7%	0.25
All groups*					0.45
After 250 km					
Highly supinated	9	10.4%	10.8	−10.7% to 31.6%	0.33
Supinated	62	−0.9%	3.5	−7.8% to 6.0%	0.79
Neutral (reference)	225	0			
Pronated	21	−7.8%	4.9	−17.4% to 1.8%	0.11
Highly pronated	1	11.0%	14.2	−16.9% to 38.8%	0.44
All groups*					0.32
After 500 km					
Highly supinated	1	12.5%	11.0	−9.0% to 34.1%	0.25
Supinated	5	9.4%	6.2	−2.7% to 21.6%	0.13
Neutral (reference)	37	0			
Pronated	2	−2.0%	7.4	−16.4% to 12.5%	0.79
Highly pronated**	0				
All groups*					0.21

Analyses are presented at 50, 100, 250 and 500 km. The reference risks for the neutral feet were: 50 km=9.2% (7.2% to 11.2%); 100 km=13.9% (11.5% to 16.3%); 250 km=23.1% (19.7% to 26.6%); 500 km=27.0% (22.7% to 31.3%). A total of 1854 legs were analysed. All groups *χ^2 test for difference between all five groups. **since no feet in the highly pronated group exceed 300 km, it is not possible to perform any comparisons after 500 km for this group.

highly pronated feet faced a significantly different distance to first running-related injury compared with the neutral feet. This is in contrast to a recently published hypothesis which suggests that foot postures falling clearly outside the normal range are abnormal and possibly associated with pathology.[15] The authors of the present work would like to stress that this hypothesis is likely not to be true among healthy runners with supinating or moderately pronating feet starting a running regime.

Another limitation may be the statistical approach: part of the statistical approach was to allow individuals to stay in the analyses if they were injured on one leg but not the other. By doing so, the non-injured leg was still at risk of sustaining an injury. However, the recovery period after the first injury was not accounted for in the analyses. By doing so, the kilometres at risk after sustaining a unilateral injury may not entirely reflect the true scenario among runners.

Table 5 Incidence-rate differences/1000 km of running

FPI group	Feet (n)	Injured feet (n)	Kilimetre at risk	Incidence-rate per 1000 km	Incidence-rate difference (95% CI) per 1000 km	p Value
Highly supinated	53	13	10445	1.24	0.24 (−0.44 to 0.93)	0.49
Supinated	369	66	64070	1.03	0.03 (−0.25 to 0.31)	0.83
Neutral	1292	225	225057	1.00	0 (ref)	
Pronated	122	16	25384	0.63	−0.37 (−0.03 to −0.70)	0.03
Highly pronated	18	6	1846	3.25	2.25 (−0.35 to 4.85)	0.09

Comparisons with other studies

The results from the present study provide additional evidence to support the findings by Knapik *et al*[6–8] and Ryan *et al*.[5] In three large-scale studies, Knapik *et al*[6–8] found no significant difference in injury risk between persons who were selected to receive motion control, stability or neutral shoes based on the foot's plantar shape compared with persons who received a stability shoe regardless of plantar shape. Ryan *et al*[5] concluded that the current approach of prescribing in-shoe pronation control systems on the basis of foot type is simplistic and potentially injurious. In their study,[5] pronators running in a motion control shoe had a higher risk of injury than pronators running in a neutral shoe. On the basis of the study by Ryan *et al*,[5] it seems evident that healthy pronators may be well advised to use a neutral running shoe since neutral shoes do not alter the risk of injury among pronators. The results from the present study confirmed that the distance to first running-related injury was not different among pronators compared with neutrals. Although not significant, the results presented in table 4 revealed a trend towards a decreased risk of injury among pronators compared with neutrals. In addition to this, there were a significantly decreased number of injuries/1000 km of running among pronators compared with neutrals ($p=0.02$).

Currently, there are no universally accepted definitions of running-related injuries.[1] Different injury definitions affect the generalisability between our results and the results reported by others. In the study by Buist *et al*,[19] the novice runners included had similar demographic characteristics compared with the participants in the present study and the injury definition was almost similar. The 13-week injury incidence of 25.9% reported by Buist *et al*[19] is, unfortunately, not directly comparable with the 1-year injury incidence of approximately 30% found in the present study because legs ($n=1854$) was used as unit of analysis in the present study, while Buist *et al*[19] used individuals as a unit of analysis. Still, we believe that the injury incidence in the present study was underestimated: some participants were reluctant to report their injuries because they had to attend a clinical examination located at some distance from their municipality. However, we believe that such underestimation does not bias the main results as the injuries not registered were expected to be evenly distributed between the five foot posture groups.

The FPI was used to quantify foot posture which meant that complex measurement techniques were not required to assess foot posture. We assessed the feet as follows: five visual evaluations and one quasi-objective measurement of the rear-foot, mid-foot and fore-foot were performed with the participants standing in a static position.[15] During running, the foot has to move dynamically. Chuter[21] recently conducted a study to ascertain if static evaluation of FPI was an appropriate measure of dynamic movement. The correlation between the FPI score and maximum rear-foot eversion during dynamic movement was found to be strongly positive ($r=0.92$, $p<0.05$). On the basis of this, it was concluded that the static FPI measurement is a strong predictor of dynamic rear-foot position. Still, it remains unclear if the FPI has a strong predictive value for pronation velocity. Therefore, no conclusions on the injury survival and pronation velocity can be drawn from the present study.

Pronation is a commonly used term in the clinical and biomechanical literature.[22] In the present study, the FPI was used to assess foot posture. On the basis of the FPI, each foot was categorised into five groups. There are, however, various other approaches used to assess foot posture and thus definitions of pronation. Therefore, foot pronation may be associated with an increased risk of running-related injury if other methods, dynamic or static, are used to assess foot pronation.

Possible explanations

Foot posture compatibility with shoe design is identified by runners as the most important factor in choosing a running shoe.[4] The results of the present study negate the importance of foot posture, especially moderate foot pronation, as a strong predictor of injury among novice runners taking up running in a neutral running shoe. Other factors like comfort feeling rather than foot posture may therefore be a more relevant criterion for healthy persons on which to base their choice of a running shoe.[23] In connection with the findings of the present study, it is important to stress, however, that motion control shoes may be a feasible choice for injured pronators. More studies are needed to identify if runners with specific injuries are best suited in motion control, stability, neutral or minimalistic shoes—or even no shoes at all.

As a consequence of the little importance of foot posture on injury development, other factors than foot posture may be more strongly associated with injury and thus important to identify. There is a general consensus with regard to the importance of training characteristics,[1] BMI,[24] behavior[25] and previous injury[26] as predictors of injury among novice runners. Training characteristics may be of particular importance, since the training regimen is under the influence of the runners, the coaches and the clinicians. Interestingly, anecdotal evidence suggests that training errors are the cause of 60–70% of all running injuries.[1] In a review of the aetiology and prevention of and intervention for overuse injuries in runners, Hreljac[27] concluded that the causes of all overuse running injuries could be classified as training errors, and thus, all overuse running injuries should be preventable. If this is true, clinicians should focus on guidance in training distance, duration and intensity rather than guidance in shoe selection on the basis of a foot posture evaluation.

What are the new findings

- The results contradict the widespread belief that foot pronation is associated with an increased risk of running-related injury.
- The vast majority of foot types will experience similar injury survival after 250 km of running.
- The number of injuries per 1000 km of running was significantly lower among pronators than among neutrals.

How might it impact on clinical practice in the near future

- Foot pronation may be rejected as a strong risk factor for running-related injury among healthy novice runners wearing a neutral shoe.
- Novice runners may be advised to take into account other risk factors than foot posture to prevent running-related injuries.

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Data sharing statement Dataset (.csv), codebook (.pdf) and statistical code (STATA .do file) are available from the corresponding author at roen@sport.au.dk. Participants did not provide informed consent for data sharing. Therefore, personal information about participants will be deleted or anonymised before data sharing.

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Foot pronation is not associated with increased injury risk in novice runners wearing a neutral shoe: a 1-year prospective cohort study

Rasmus Oestergaard Nielsen, Ida Buist, Erik Thorlund Parner, et al.

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