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ORIGINAL RESEARCH

NO ASSOCIATION BETWEEN Q-ANGLE AND FOOT POSTURE WITH RUNNING-RELATED INJURIES: A 10 WEEK PROSPECTIVE FOLLOW-UP STUDY

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ABSTRACT

Background/Purpose: There is a paucity of knowledge on the association between different foot posture quantified by Foot Posture Index (FPI) and Quadriceps angle (Q-angle) with development of running-related injuries. Earlier studies investigating these associations did not include an objective measure of the amount of running performed.

Therefore, the purpose of this study was to investigate if kilometers to running-related injury (RRI) differ among novice runners with different foot postures and Q-angles when running in a neutral running shoe.

Methods: A 10 week study was conducted including healthy, novice runners. At baseline foot posture was evaluated using the foot posture index (FPI) and the Q-angle was measured. Based on the FPI and Q-angle, right and left feet / knees of the runners were categorized into exposure groups. All participants received a Global Positioning System watch to allow them to quantify running volume and were instructed to run a minimum of two times per week in a conventional, neutral running shoe. The outcome was RRI.

Results: Fifty nine novice runners of mixed gender were included. Of these, 13 sustained a running-related injury. No significant difference in cumulative relative risk between persons with pronated feet and neutral feet was found after 125 km of running (Cumulative relative risk = 1.65 [0.65; 4.17], p = 0.29). Similarly, no difference was found between low and neutral Q-angle (Cumulative relative risk = 1.25 [0.49; 3.23], p = 0.63).

Conclusion: Static foot posture as quantified by FPI and knee alignment as quantified by Q-angle do not seem to affect the risk of injury among novice runners taking up a running regimen wearing a conventional neutral running shoe. These results should be interpreted with caution due to a small sample size.

Level of Evidence: 2a

Keywords: Foot posture, foot Posture Index, novice runners, running-related injuries, Q-angle

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INTRODUCTION

Injury is the major reason given by a majority of runners to stop an exercise program.[1] Novice runners face a challenge when taking up running because of the high risk of sustaining a running-related injury (RRI) when compared with experienced recreational runners.[2] Numerous modifiable and non-modifiable risk factors have been associated with RRI.[3–6] Of the non-modifiable risk factors, foot posture and knee alignment have been of particular interest among clinicians because malalignment of the foot and knee are believed to be associated with development of RRI.[4] Clinicians have used quick, simple tools in order to quantify foot posture and knee alignment[7,8] including the Foot Posture Index (FPI)[9,10] and the Quadriceps-angle (Q-angle).[8]

Several studies have been conducted to ascertain if foot posture were associated with the development of RRI. A pronated foot has been associated with medial tibial stress syndrome[11,12] and achilles tendinopathy,[13] however, results from other studies do not support these findings.[14,15] Therefore, no final conclusion regarding the relation between foot posture and the development of RRI can be drawn. A foot posture being plus/minus two standard deviations from the mean, as measured by the FPI (−12 supinated characteristics / +12 pronated characteristics) has been described as being malaligned and pathological.[9] However, the rationale that malalignment of the foot is in fact pathological and related to injury among novice runners, is to the authors' knowledge, not supported by scientific documentation.

The association between Q–angle and the development of RRI has been investigated in several studies. A Q-angle greater than or equal to 20˚ has been found to be related to the development of RRI,[16] and in a study comparing runners with and without patellofemoral pain the injured runners had a greater mean Q-angle.[17] However, other studies found no association between the degree of Q-angle and the development of RRI.[18–22]

Several limitations are present in previous studies regarding the association between risk factors and the development of RRI. Measuring both the training characteristics and risk factors objectively is of great importance.[23] Collecting valid and reliable training characteristics objectively may be solved by measuring the training characteristics by a Global Positioning System (GPS).[2] Another important factor to control is the type of running shoe utilized by the runners,[5] because of the many different types of running shoes available. This issue could be solved by providing all the participants with the same type of shoe.

Therefore, the purpose of this study was to investigate if kilometers to running-related injury (RRI) differ among novice runners with different foot postures and Q-angles when running in a neutral running shoe.

METHODS

The study was granted approval from the ethics committee, central Denmark region (M-20100272) and the Danish Data Protection Agency. All participants provided informed written consent prior to inclusion. Participants were recruited from local companies and organizations. Participants signed up by completing an online questionnaire, which contained questions about health, previous injuries and participation in sports. Healthy participants between 18 and 65 years, who had not experienced injuries in the lower extremity three months prior to signing up and who had not been running a total amount greater than 10 km in the previous twelve months, were eligible for inclusion. After an initial screening of the questionnaires, participants were contacted by phone and given verbal information about the study and were scheduled for baseline examination. At baseline, an interview regarding pregnancy, diabetes and running experience was performed to ensure participants met the inclusion criteria.[24] The demographic characteristics of height and weight (SC 330; Tanita Corporation, Tokyo, Japan) were then measured. Finally, a measure of the blood pressure was obtained. In case of high blood pressure (>140 SBP, >90 DBP) acceptance regarding participation had to be provided from the subjects general physician.

All included participants received a neutrally designed running shoe (Supernova Glide 3 Male/Female, Adidas, Herzogenaurach, Germany) and a GPS watch (Garmin Forerunner 110 male, Garmin International Inc, Olathe, Kansas, USA). They were informed to use the shoes and watch when running and instructed to run as much as they wanted with a minimum of two times per week during the following 10 weeks. No further guidelines regarding the training were given. Participants were instructed to upload training data, minimum every second week to a standardized web-based training diary developed by the research group, which was compatible with the GPS software. Data from this study using different exposures is also presented elsewhere.[25]

Exposures of interest

The FPI was performed as described by Redmond et al.[7] Measurements were conducted by an experienced physiotherapist. Previously, the evaluation of the six-item version of the FPI has been described in detail including an objective of each test, how to evaluate each test and how to reach an index of the foot posture. For a detailed description of the FPI procedure, refer to Redmond et al.[7] FPI provides an easily applicable, valid, and reliable method for quantifying static foot posture.[7,10] All measurements were performed by the same physiotherapist. The FPI reference values are classified in two age groups: 18 to 60 and above 60 years old as described by Redmond et al.[9] Each age group are categorized into five groups according to the measured FPI value. The sample in the presented study were categorized according to values appropriate for the five groups in the age group 18 to 60; Very low <–3, Low –3 to 0, Neutral +1 to +7, High +8 to +10, Very high >+10. The Q-angle was measured by an experienced physiotherapist according to guidelines described by Brattstrom.[8] Three anatomical landmarks were located, the tibial tuberosity, the anterior superior iliac spine (ASIS), and the middle of patella, with the participant in supine, the knee fully extended and the quadriceps relaxed.[26] The foot was positioned so that an imaginary line connecting the middle of the heel with the second metatarsal was perpendicular to the ground.[27] A standard goniometer was used. The center of the goniometer was placed upon the middle of the patella. One arm of the goniometer was placed along the line connecting ASIS with the middle of patella. The other arm was placed along the line connecting the middle of patella and the tibial tuberosity. All measurements were performed by the same physiotherapist. Based upon the measured Q–angle, right and left knee from all participants were categorized into one of the following four groups; Low <10°, Neutral 10° to <15°, High 15° to 20° and Very high ≥20°.

In Table 1 normative values for FPI, and Q-angle are presented.[9,16,28]

The training volume was measured by using a GPS watch to estimate kilometers run for each participant. GPS has proven to be a valid method to objectively measure average pace and average distance.[29] In case of missing GPS data, participants were instructed to upload their training session manually by reporting running volume and time spent running. If the participants experienced problems with the GPS device during the 10 weeks, they were asked to contact the DAnish NOvice RUNning projects (DANO-RUN) study group through their diary and were given a new GPS watch.

Outcome of interest

At baseline the participants were presented to the operational injury definition for the study; "*An injury is defined as any musculoskeletal complaint of the lower extremity or back causing a restriction of running for at least one week*". This definition is a modified version of the definition used by Buist et al.[30]

If the participants sustained a running-related injury during the follow-up period, they were instructed to contact the medical team via their personal, web-based training diary. Then, the participant was contacted by telephone and an appointment for a clinical

Table 1. *Reference values for Foot Posture Index (FPI) and quadriceps angle (q-angle). Cm = Centimeter. N / A = Not available.*

	Strata	Very low	Low	Neutral / Reference	High	Very high
FPI (score)	Age 18-60	< -3	-3 to 0	+1 to +7	+8 to +10	> + 10
	Age 60 +	< -3	-3 to 0	+1 to +8	+9 to +11	+ 12
Q-angle (degrees)	All	N / A	<10	10 to <15	15 to 20	≥20

examination was made. At the clinical examination participants were examined and diagnosed by a physiotherapist, preferably no later than one week after initial contact. If the injury was not caused by running, the injury was not included in the analysis. If further clarification was needed, participants were referred to Division of Sports Traumatology, Aarhus University Hospital, for an extensive medical examination.

Statistics

Descriptive data for the demographic characteristics were presented as counts and percentage for dichotomous data, and as mean, standard deviation and 95% confidence interval for continuous data. All continuous data were tested for normal distribution by histograms and probability plots. If data were not normally distributed median and inter quartile ranges were presented. Time to running-related injuries was analysed using each leg as an independent unit and using cumulative kilometres of the training sessions as the time scale.

Participants were right censored from participation in case of pregnancy, disease, lack of motivation, injury not related to running but causing a permanent stop of running, and unwillingness to attend clinical examination in case of RRI or end of study at 10 weeks, whichever came first. In case of injury in one leg (e.g. left), the other leg (right) was censored at the same kilometre, even though this leg (right) was injury free. The RRI proportion as a function of follow-up kilometres was estimated using the Kaplan-Meier curve. The cumulative relative risk of sustaining an injury up to 125 kilometres was analyzed performing a generalized linear regression model using the pseudo values method.[31] Differences were considered statistically significant at $P < .05$. Prior to the study, we hypothesized that no differences in injury survival existed between exposure groups. Since the injury risk was hypothesized to be similar, no power calculations or sample size calculations were performed. In addition to this, no sample size calculation based upon a non-inferiority model was made because this study was a pilot study preceding a large scale study.[32,33] All analyses were performed using STATA version 11.2.

RESULTS

A total of 60 healthy participants (32 males, 28 females, 39.8 ± 9.3 years, BMI 25.5 ± 3.9) from the Central Region, Denmark, were included. One participant did not upload any data and was excluded from the analysis. A total of 13 participants sustained a running-related injury during follow-up. Three participants were censored for other reasons than RRI during follow-up due to: other injuries than running injury (n = 2) and lack of motivation (n = 1). Demographic characteristics and anthropometrics are presented in Table 2.

Significant differences between healthy and injured participants were found in weight, height, and shoe size, while no differences were found for gender, age, foot posture, and Q-angle. Based on the reference values presented, the 118 legs of the 59 included participants were categorized into groups. A total of 16.4% of the 110 legs included in the analysis of foot posture and 18.9% of the 111 legs included in the analysis of Q-angle sustained injuries. The number

Table 2. *Demographic characteristics and antropometrics of the included participants. SD = standard deviation. Kg = kilogram. iqr = interquartile range. cm = centimeter. FPI = Foot Posture Index. Q-angle = Quadriceps angle. [a] = t-test with equal variances used. [b] = chi² test used. [c] = Wilcoxon rank sum test used.*

Variable	Unit	All n = 59	Injury free n = 46	Injured n = 13	*P*
Gender (n)	Male / female	31 / 28	22 / 24	9 / 4	0.17[b]
Age (mean, SD)	Years	39.6 ± 9.3	38.7 ± 9.5	43.0 ± 7.8	0.14[a]
Weight (mean, SD)	Kg	79.3 ± 15.0	76.3 ± 14.0	89.9 ± 14.1	0.003[a]
Height (mean, SD)	Centimetre	176.2 ± 9.3	174.9 ± 9.1	180.8 ± 8.8	0.04[a]
Shoe size (median, iqr)	US size	9 ± 3	9 ± 2	11 ± 3	0.01[c]
Foot Posture (median, iqr)	FPI – left	5 ± 4	5 ± 4	6 ± 5	0.29[c]
	FPI – right	6 ± 3	6 ± 4	6 ± 3	0.18[c]
Q-angle	Degree – left	10.4 ± 4.5	11.1 ± 4.4	8.2 ± 4.5	0.04[a]
	Degree – right	10.6 ± 4.9	11.1 ± 5.0	9.1 ± 4.5	0.19[a]

Table 3. *Counts in each exposure category of the 118 legs included in the analysis. Foot Posture Index (FPI) and Quadriceps angle (Q-angle).*

	Strata	Very pronated	Pronated	Neutral / Reference	Supinated	Very supinated
FPI	Age 18 – 60	4	17	93	4	0
	Injury free	1	14	79	0	0
	Injured	3	4	14	0	0
		Very low	**Low**	**Reference**	**High**	**Very high**
Q-angle	All	0	36	75	4	3
	Injury free	0	25	65	4	3
	Injured	0	11	10	0	0

Table 4. *Cumulative relative risk at 125 kilometres (km) of sustaining an injury between neutral foot posture and pronated foot posture, and neutral Q-angle and low Q-angle, respectively. CI = Confidence interval.*

Variable of interest	Cumulative relative risk	Standard error	95% CI	p-value
Foot Posture Index Legs analyzed: 110 Injured legs: 18 Km at risk: 7627				
Neutral foot posture (reference)	1			
Pronated foot posture	1.65	0.78	[0.65; 4.17]	p= 0.29
Quadriceps angle Legs analyzed: 111 Injured legs: 21 Km at risk: 7555				
Neutral Q-angle (reference)	1			
Low Q-angle	1.26	0.61	[0.49; 3.23]	p= 0.63

of legs in each category stratified by injury status is presented in Table 3.

Because of the low counts of participants in the very low, high, and very high groups, no comparisons on the cumulative relative risk of sustaining an injury between these groups and the neutral reference group were made. Results from the generalized linear regression revealed no significant differences in cumulative relative risk between novice runners with pronated foot posture or low Q-angle compared with the neutral group. The results from the crude associations between FPI and Q-angle with development of RRI are presented in Table 4.

In Figure 1, the Kaplan-Meier plots of RRI survival according to kilometres at risk between participants with different foot postures and Q-angles are presented. Approximately 25% to 45% sustained an RRI during the 10-week follow-up period.

DISCUSSION

In this study, the associations between different foot postures and Q-angles and the development of RRI were investigated. No significant differences in cumulative relative risk between novice runners with pronated feet and neutral feet were found after 125 km of running (Cumulative relative risk = 1.65 [0.65; 4.17], p = 0.29). Similarly, no differences were found between low and neutral Q-angle (Cumulative relative risk = 1.25 [0.49; 3.23], p = 0.63). Based on this finding foot posture and Q-angle do not seem to influence the risk of injury among novice runners

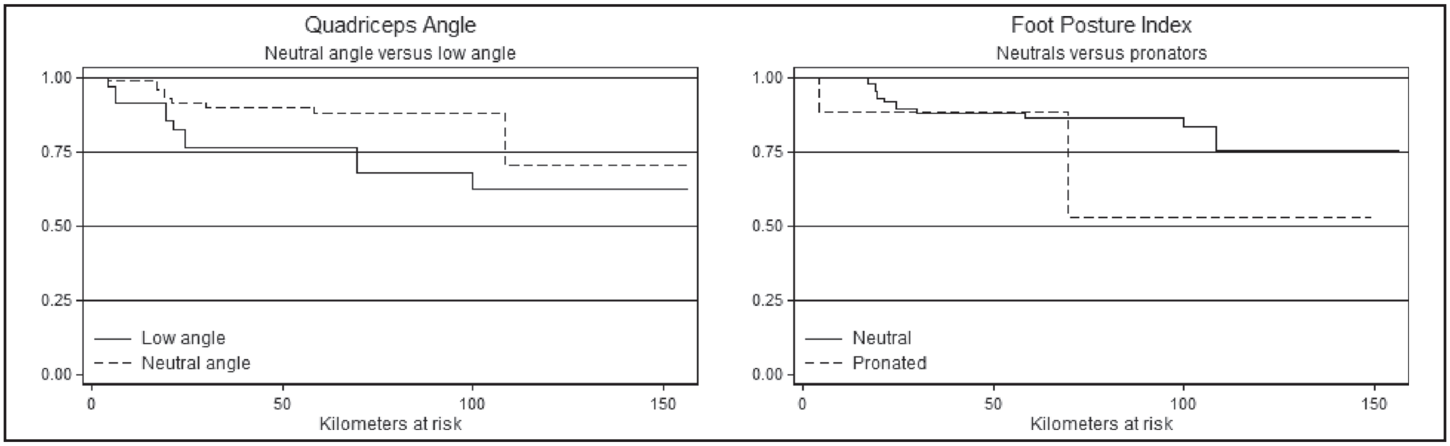

Figure 1. *Kaplan-Meier plots of RRI (running related injury) survival.*

taking up a running regimen wearing a neutral, conventional running shoe. However, results should be interpreted with caution; because of the small sample size this study must be considered exploratory in nature. The low count in the supinated and very pronated groups made comparison between these groups and the neutral foot posture group statistically invalid and no comparison was, therefore, made. Similarly, no comparisons were made for high Q-angle and very low Q-angle groups to the neutral Q-angle group.

Studies including sufficient samples in the categorized groups of runners with different foot postures and Q-angles, are needed to ascertain if any differences in cumulative relative risk exist between neutrals and other groups. Recently, a large scale study on 927 runners was published and no increased risk of injury was observed among runners with pronated and supinated feet.[33] Based on the results from this study and the present study, other risk factors like training volume, pace, BMI, and previous injuries may be more strongly related to development of RRI than foot posture and Q-angle. The present study adds some preliminary evidence which may contribute to the ongoing assessment of foot posture and Q-angle as risk factors for injury development among novice runners.

Generalized linear regression model was performed using the pseudo values method to estimate the cumulative risk of injury between groups. One assumption behind this method is independent censoring of the legs included in the dataset. However, it must be questioned if there is a correlation of the risk of sustaining an injury between right and left foot in the same individual because individuals can have markedly different foot mechanics between their left and right feet. Most likely such correlation exists because the observations are not discrete, rather they are paired in a given individual. This correlation was not accounted for in the analysis performed in the current study, which must be considered as a major limitation of this study.

The novelty of running among participants in the study was assessed by questions regarding training experience and volume and were asked prior to and at the baseline investigation. Since the level of running experience may be linked to the development of RRI[2,14] it was important only to include novice runners. However, the inclusion of participants with a running experience categorized as novice was based on subjective information. Since participants received a free pair of shoes and a GPS watch at inclusion, some participants may have categorized themselves as novice, even though they were recreational runners. Therefore, a potential risk of selection bias exists. However, no significant differences in age ($p = 0.88$) or weight ($p = 0.44$) were found between persons included in the current study and novice runners included in a study by Buist et al.[30] In the study by Buist et al., the participants did not receive equipment for free. These non-significant differences between the two sample populations in the two studies, makes it reasonable to conclude that the age and weight of runners in the current study was representative of novice runners. Still, the validity of the assessment of the amount of running participants had performed in the 12 months preceding the baseline investigation may be biased because the participants received free gear.

All participants were instructed to run in the same neutral running shoe regardless of their foot posture. Persons with a pronated foot type running in a conventional, neutral running shoe did not face an increased risk of injury compared to persons with a neutral foot posture running in the same type of shoe. Previously, motion control shoes have been recommended to individuals with a pronated foot posture, while neutral shoes were recommended to individuals with a neutral foot posture. This approach is still used in shoe stores and in clinical practice. In studies from the 1990s, risk factors for injury development were identified by recruiting participants and instructing them to start running in individually fitted running shoes.[34]

However, in a systematic review by Richards et al[35] it was concluded that prescription of motion control running shoes is an unproven technology with a potential risk to cause harm. A similar conclusion was reported in a recent randomized controlled trial study conducted by Ryan et al.[36] Ryan et al reported that the provision of motion control shoes to neutral or pronated foot types imposed a significant risk of sustaining a RRI in women training for a half marathon. Of note, runners with pronated foot posture wearing motion control shoes all reported an injury. In studies by Knapik et al,[37,38] running shoes were randomly assigned to military recruits based on plantar foot shape. They concluded that if the goal is to prevent injuries, it is not necessary to assign running shoes based on plantar foot surface. The results from the current study support the findings of these other studies[34,35,37,38] and questions current recommendation guidelines used in shoe stores and clinical practice when assigning running shoes to novice runners. The small sample size in the current study was instructed to run in the same type of neutral running shoe. The current study tests these guidelines, based on conclusions from other studies but since this was done on a small sample size, this method should be employed with larger studies in the future" with the current study tests the generally accepted shoe guidelines, based on conclusions from other studies.[34,35,37,38]

To the authors' knowledge, the approach by using GPS to quantify running volume among participants included in a prospective study, is a novel approach. With the use of GPS in collecting training data, a possible information bias caused by participants self-reporting their training data, may be minimized. This minimization of an information bias is important, because of the association between activity specific participation and the development of injury, when studying causal pathways, as addressed by Meeuwisse.[23]

The authors' found the GPS to be a feasible method to gather information on the running volume among the participants. Furthermore, the GPS has been found to be valid and reliable as an instrument used to collect data on human movement.[29]

The exposures of interest were measured at baseline using static measurement methods as described by Redmond et al.[7] and Brattstrom.[8] In the ideal scenario, the foot posture and Q-angle are evaluated or quantified dynamically since running-related injuries are developed while running.[39,40] If static measures of foot posture are used when studying risk factors to injury development, the static measure has to be predictive of dynamic function. In the present study, FPI was used to assess information on static foot posture. Chuter[42] found the variation in FPI to explain 45% of the variance in maximum eversion during stance phase of walking. Based on this, the results from the current study on the association between FPI and injury development should be interpreted with respect to the static measurement and the possibility that the foot posture during dynamic movement may be different. FPI is valid as a static measure ($p < 0.001$)[7] and both intra- (ICC > 0.90) and intertester (ICC 0.62 – 0.91) reliability is good.[10,11,43] However, no studies have been identified investigating the predictive value of a static measure of Q-angle to a dynamic measure. Therefore, the results on the association between Q-angle and development of RRI may be interpreted with caution. The Q-angle was measured in supine rather than standing as in the study by Rauh et al.[16] The standardization of the foot position and assurance that the quadriceps was relaxed are important factors to control conducting this measurement.[44] It was agreed upon by the authors that controlling these factors were best assured in supine. The Q-angle measurement has been found to have a validity of ICC 0.13 – 0.32 when comparing the clinical and the radiological Q-angle, an intratester reliability of ICC 0.22 – 0.91 and an intertester reliability of ICC 0.20 – 0.83.[44] This should be considered a limitation to the study.

There is a great need for identification of risk factors and causal pathways leading to injuries in runners. Future studies within this area of research should be designed as prospective follow-up studies including large samples of runners. The training volume, duration, pace and frequency should be measured objectively with GPS or similar feasible methods.

CONCLUSION

Static foot posture quantified by FPI and Q-angle do not seem to affect the risk of injury among novice runners taking up a running regime wearing a conventional neutral running shoe. The results from this pilot study should be interpreted with caution due to a small sample size.

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