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Article type : Original Article

Title: Differences in foot muscle morphology and foot kinematics between symptomatic and asymptomatic pronated feet

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This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/sms.13512
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Running title: Foot muscle and kinematics of pronated feet

Differences in foot muscle morphology and foot kinematics between symptomatic and asymptomatic pronated feet

ABSTRACT

Purpose: This study aimed to determine the differences in foot muscle morphology and 3D multi-segmental foot kinematics during walking between symptomatic and asymptomatic individuals with pronated feet (pronators) in a physically active population.

Methods: A total of 30 young physically active adults with pronated feet participated in this study, with 15 of them having recurring overuse injuries in the lower extremity in the 6 months prior to the test. A pronated foot was identified as having a foot posture index score between 6 and 12. An ultrasound system was used to measure the cross-sectional area and thickness of foot muscles of interest, including peroneus muscles, flexor digitorum longus and brevis, and abductor hallucis. Foot kinematic data during walking was collected using a 3D motion capture system incorporating the Oxford Foot Model.

Results: The symptomatic pronators demonstrated smaller cross-sectional area of flexor digitorum longus and abductor hallucis, and thinner peroneus muscles and abductor hallucis than their asymptomatic counterparts. The symptomatic pronators also displayed higher forefoot peak abduction during the stance phase of walking

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Conclusion: There are differences in both extrinsic and intrinsic foot muscle morphology between symptomatic and asymptomatic pronators in a physically active adult population. Strengthening foot muscles may contribute to injury prevention in pronators. Large forefoot abduction instead of large rearfoot eversion during walking might be the indicator of pain in physically active pronators. Findings of this study may have implications on the underlying mechanisms of overuse injuries in individuals with pronated feet.

Key words: foot posture, recreational runners, intrinsic foot muscle, forefoot abduction, multi-segment foot model.

Introduction

A pronated foot posture is characterized as having a lower arch, an abducted forefoot and an everted rearfoot in static assessments. As non-neutral foot alignment may influence dynamic foot function, it is hypothesized that such a foot posture may contribute to the development of several musculo-skeletal conditions which result in pain, e.g., plantar fasciitis, medial tibial stress syndrome and patellofemoral pain syndrome[1, 2]. However, individuals with a pronated foot posture (referred to as pronators in the text) do not necessarily develop related symptoms. It remains unclear why some pronators are symptomatic while others are free of injuries, despite having the same static foot posture and participating in similar physical activities. It is well known that static foot measures only have limited ability to predict foot dynamics[3]. The alignment disadvantage of asymptomatic pronated feet may be compensated by optimal foot core dynamics, such as having sufficient muscle strength to control joint motions. Understanding the foot muscular characteristics and kinematics during walking, which is the most frequently undertaken daily activity, of symptomatic and asymptomatic pronators is of great importance.

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The concept of the foot core system suggests that the foot has multiple interacting subsystems of passive, active and neural components, and that functional variability exists between these subsystems[4]. As components of the active subsystem of the foot core, foot muscles may play an important role in compensating for the malalignment of a pronated foot, such as increasing the resistance of medial longitudinal arch (MLA) deformation during loaded activities. The intrinsic foot muscles, which have been overlooked in the past few decades, function to stabilize the MLA and modulate the rate of pronation during walking. Kelly and co-workers suggested that the three largest intrinsic foot muscles, i.e. abductor hallucis (AbH), flexor digitorum brevis (FDB) and quadratus plantae, have the capacity to control foot posture[5]. Electrical stimulation of these muscles can generate sufficient force to counter the deformation of the MLA caused by external load, as well as causing significant forefoot adduction and rearfoot inversion[5]. By using intramuscular electromyography, they further confirmed that these intrinsic foot muscles actively regulate arch deformation during dynamic activities[6]. These intrinsic foot muscles also contribute to stiffening the distal foot to aid propulsion during bipedal locomotion[7]. However, the role of these muscles in pronated feet is yet to be established. In our previous study, we found larger cross-sectional area (CSA) and thickness of foot muscles in asymptomatic pronators compared to their counterparts with a neutral foot posture[8]. As a larger muscle is related to higher strength capacity[9, 10], this seems to suggest a compensatory mechanism in asymptomatic pronators. However, this finding cannot be extrapolated to a potential association between symptomatic pronators and weakness or dysfunction of foot muscles, as the comparison was made between asymptomatic pronators and neutral foot controls.

Based on early kinematic studies using a one segment foot model, excessive rearfoot eversion has been identified as the key component of excessive foot pronation, and associated with the development of overuse injuries[11]. As a consequence, controlling excessive frontal

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plane rearfoot motion has become the target of many interventions, such as taping and foot orthoses, in symptomatic pronators[12]. However, more recent studies using multi-segmental foot models show controversial findings on rearfoot eversion during walking in pronators, while suggesting that forefoot kinematics is relatively more functionally meaningful in pronators[8, 13, 14]. For instance, our previous study indicated that pronators who displayed excessive rearfoot eversion during walking compared to neutral foot controls were symptom free although participating in running activities[8]. These results indicate that excessive rearfoot eversion may not necessarily correlate with the presence of symptoms, and that the transverse plane forefoot motion might be a more sensitive indicator to distinguish symptomatic from asymptomatic pronators.

To date, most studies conducted on pronators include individuals with a neutral foot posture as references, and current interventions and treatments for symptomatic pronators aim at correcting to more closely resemble a neutral foot, such as a neutral rearfoot position. Identifying differences between symptomatic and asymptomatic pronators is crucial to clarify the contributing mechanisms to the pathology in pronators. Therefore, this study aimed to determine the differences in foot muscle morphology and 3D multi-segmental foot kinematics during walking between symptomatic and asymptomatic pronators. As some pronators may be free of overuse injuries simply due to inadequate exposure to loading, such as a sedentary lifestyle, a physically active population was investigated. We hypothesized that symptomatic pronators would have smaller intrinsic and extrinsic foot muscles which contribute to MLA maintenance, such as AbH, FDB and flexor digitorum longus (FDL), than asymptomatic pronators. As for foot kinematics, we hypothesized that the symptomatic group would display larger forefoot abduction compared to the asymptomatic group, and that both groups would have comparable rearfoot eversion independent of symptom presence. Findings

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of this study might provide a better insight into the aetiology of excessive pronation related injuries and in future treatment strategies for symptomatic pronators.

Methods

Participants

A total of 30 young physically active adults (11 females and 19 males) participated in this study. Ethics approval was granted by the Medical Ethics Committee of KU Leuven and written informed consent was obtained from each participant. To have a homogeneous group, this study recruited recreational runners only. All participants ran regularly with a running volume of at least 15 km per week for at least 6 months prior to the test. Foot posture was assessed using the 6-item Foot Posture Index (FPI)[15]. At least one foot of the participant was classified as pronated, with an FPI score between 6 and 12. The foot with the larger FPI score was used for further measurements and data analysis. If the FPI score of both feet were the same, the right foot was measured. Participants were considered symptomatic if they were diagnosed by a medical practitioner with recurring overuse injuries in the past six months prior to testing. Fifteen participants were symptomatic, with the following symptoms: medial tibial stress syndrome (8 out of 15), patellofemoral pain (6 out of 15), plantar fasciitis (1 out of 15), recurrent ankle trauma (3 out of 15). Some of them had multiple symptoms.

Protocol

An ultrasound system (a Telemed Echoblaster 128 CEXT system, UAB Telemed, Vilnius, Lithuania) with a 10 MHz linear wideband array transducer (model: HL9.0/60/128Z) was used to capture images of foot muscles, including peroneus muscles (PER), FDL, FDB and AbH. Measurements were taken while the foot was in an unloaded position. All images were obtained by a trained assessor using a protocol described by Crofts et al[16]. To capture

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the thickness of the muscle, the probe was placed along the direction of the muscle fibre, and for the CSA, the probe was rotated 90° at the muscle's thickest part.

A three-dimensional motion capture system (Vicon MX, Vicon Motion System Ltd., Oxford, England) with 10 cameras was used with a sampling frequency of 150 Hz. Reflective markers were attached to the skin according to the marker set of the Plug-in gait model and the left/right Oxford Foot Model. The Oxford Foot Model is a multi-segmental foot model with three foot segments, i.e. rearfoot, forefoot and hallux, and it has been shown to provide consistent inter-segmental foot motions throughout the gait cycle for both normal and abnormal feet[17, 18]. One force plate (AMTI, Watertown, US) with a sampling frequency of 900 Hz was used to detect gait events. Participants were required to perform barefoot walking at their preferred speed and five measurements were recorded when the whole stance phase of the foot of interest was on the force plate.

Data processing

All ultrasound images were processed in the Image J software (National Institute for Health, Bethesda, MD, USA) to measure the muscle thickness and CSA by an assessor blinded to the participant's group. Kinematic data were low pass filtered at 6 Hz using a fourth order Butterworth filter. Foot kinematic data were processed in Vicon Nexus 2.4. The following angles were chosen for further analysis: forefoot relative to rearfoot motion: dorsiflexion/plantarflexion, adduction/abduction and inversion/eversion; and rearfoot relative to tibia motion: dorsiflexion/plantarflexion, internal/external rotation, and inversion/eversion. The peak angles during stance phase of walking were chosen for further analysis, as they are associated with the maximum stretch on foot structures. For each trial, gait events were detected using the vertical ground reaction force to determine initial heel contact and toe-off with a threshold of 50 N. The kinematic data of one participant in the asymptomatic group

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was excluded due to a technical issue (marker drop-off) which prevented data processing and analysis.

Except for the age and running volume, all measures were normally distributed. A Kruskall-Wallis H test was performed for the comparison of age and running volume between two groups. The difference of participants' demographic characteristics, muscle morphology and foot kinematics between symptomatic and asymptomatic groups were analysed using a one-way ANOVA. P-values less than 0.05 were considered statistically significant. To test whether the effects were clinically meaningful, effect sizes (Cohen's d) for the differences in muscle morphology and foot kinematics were calculated between groups. The effect size was reported and reviewed according to Cohen's effect scale as small (0.2 - 0.5), medium (> 0.5 and ≤ 0.8), and large (> 0.8)[19]. The 95% confidence intervals (95%CI) for the mean difference and the Cohen's d were presented in the result section. All statistical analyses were performed using the SPSS version 22 (SPSS Science, Chicago, Illinois).

Results

Participant demographics are shown in Table 1. There was no significant difference in age, height, weight, BMI, FPI and training volume between two groups.

Foot muscle morphology

Morphological differences in PER, FDL and AbH between the two groups were found (Table 2). The thickness of the PER and ABH in symptomatic individuals were 12% and 14 % respectively smaller than that in asymptomatic individuals, with a large effect size. The CSA of the FDL and ABH in symptomatic individuals were 27% and 19% respectively smaller than that in asymptomatic individuals, with a large effect size.

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Foot kinematics

Differences in forefoot relative to hindfoot motion and hindfoot relative to tibia motion during stance phase of walking are presented in Table 3 and Figure 1. The symptomatic group showed a larger peak forefoot abduction than the asymptomatic group, with a large effect size. Both groups showed comparable peak angles in all three planes of rearfoot relative to tibia motion during the stance phase of walking.

Discussion

Protective interventions for symptomatic pronators may benefit from a knowledge of the inter-segmental foot kinematics and both intrinsic and extrinsic foot muscular characteristics of these individuals. To identify the characteristics of symptomatic pronators, this study compared the foot muscle morphology and foot kinematics during walking between symptomatic and asymptomatic pronators in a physically active population. Our findings showed that the symptomatic group demonstrated smaller foot muscles and larger forefoot peak abduction during walking, compared to their asymptomatic counterparts. This study suggests that a pronated foot (classified by static assessments) by itself is not a cause of injury, but that some pronators with large enough muscle and normal forefoot abduction are injury-free despite regularly participating physical activities.

Intrinsic foot muscles

Although intrinsic foot muscular compensation has long been proposed to facilitate normal foot dynamic function in pronators[20], experimental investigations on this topic is lacking, which makes it difficult to compare our findings to other studies. During walking, the MLA lowers to absorb impact in the first half of the stance phase, and stiffens to recoil

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energy and function as a rigid lever for propulsion in the late stance. Maintaining a functional MLA is therefore crucial for gait efficiency and injury prevention. It has been reported that a 4-week exercise training program aiming at strengthening the intrinsic foot muscles was effective in improving resistance to MLA deformation, resulting in a lower navicular drop and better balance performance[21]. We hypothesized that symptomatic group had smaller AbH and FDB, as these muscles function to regulate MLA deformation[22, 23], and assist dynamic foot stability during weight bearing activities[24]. Our results showed that the CSA and thickness of AbH in the symptomatic group was smaller than those of the asymptomatic group with large effect sizes. The average CSA of FDB was slightly smaller in the symptomatic group, but this difference was not significant. From an anatomical perspective, the AbH may play a more important role in supporting the MLA than the FDB, as the former is the most medially located plantar intrinsic foot muscle and the latter runs in the middle of the plantar foot. This may explain why the two groups only displayed difference in the AbH size in a relatively small sample size of the current study. Furthermore, the action of AbH to flex the first ray and invert the calcaneus could aid in forefoot locking and midtarsal joint locking mechanisms[25, 26]. This muscle also contributes to the stabilization and supination of the midtarsal joint during propulsion[27]. Therefore, strengthening intrinsic foot muscles, especially AbH, might be beneficial for symptomatic individuals who has compromised dynamic foot function.

Extrinsic foot muscles

We also found a thinner PER and smaller FDL in symptomatic pronators. Morphological differences in extrinsic foot muscles between pronated and normal have been documented previously. These studies reported inconsistent findings regarding to the CSA and thickness of PER of pronators[8, 28, 29]. The PER functions to plantarflex and evert the foot

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as well as to support the transverse arch. Moreover, the peroneus longus everts the first ray during stance phase of walking, exerting a stabilizing influence on the first ray[30]. Therefore, thinner PER in the symptomatic group may have implications on the locking of the first ray. As an ankle inverter muscle, the eccentric activity of FDL is necessary for an efficient propulsion during walking[31]. It has been reported that asymptomatic pronators display larger FDL than neutral foot controls[8, 28]. In the current study, the larger FDL found in the asymptomatic group further suggested that pronators may benefit from having a stronger FDL. In summary, as larger muscles are indicative of a higher capacity of muscular strength, asymptomatic pronators may have adequate foot muscle control and endurance that help compensate for their insufficient passive structures.

Forefoot kinematics

The only foot kinematic difference found in the current study was a larger forefoot peak abduction in the symptomatic group, which occurred at the propulsion phase of walking. This is consistent with the results of a recent study on children, which found that forefoot abduction during walking was larger in children with symptomatic flatfeet than those with asymptomatic flatfeet using the same multi-segment foot model[32]. An excessively abducted forefoot may produce repeated strains on medial soft tissue structures resulting in micro-tears, inflammation and eventual pain, as reported by a study that low-arched runners more frequently suffer medial soft tissue injuries[33]. Previous studies suggested excessive transverse plane forefoot motion in both symptomatic and asymptomatic pronators, compared to neutral foot controls[13, 18]. In these studies, however, the influences of participants' physical activity level were not taken into account. In a physically active population, e.g. recreational runners, the training effect of running may stimulate the muscles to grow, leading to stronger muscles. Consequently, these individuals may have better control of foot motions, such as forefoot

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abduction. This is partly supported by our previous study, which recruited a similar population as this study, and demonstrated a lack of transverse plane forefoot motion difference between asymptomatic pronators and neutral foot controls[8]. We assume the asymptomatic individuals might be those who have developed sufficient muscles to control transverse plane motions, while the symptomatic ones might be those who have failed to develop strong muscles to control foot motions. Therefore, we propose that the transverse plane forefoot motion might be a clinically relevant indicator of symptomatic pronators. Controlling excessive forefoot abduction might reduce the overuse injury risk in individuals with pronated feet, presumably by minimizing the repeated micro-trauma to medial soft tissues.

Rearfoot kinematics

A noteworthy lack of kinematic difference between two groups was in frontal plane rearfoot motion, which is often the target of orthotic intervention in pronators. Although rearfoot peak eversion has been used as a risk predictor for overuse injuries[34], current evidence for a link between excessive rearfoot eversion and overuse injuries is weak. Furthermore, previous studies investigating clinically effective orthoses show none to slight reduction in rearfoot eversion during walking[35, 36], which is indicative of the inability of the sole use of this parameter to explain reported clinical effects of orthoses. Compared to the rearfoot kinematics of neutral foot controls in a similar population from our previous study[8], both symptomatic and asymptomatic pronators demonstrate excessive rearfoot peak eversion (in this case, rearfoot eversion being about 6 degrees larger than neutral controls). This indicates that excessive rearfoot eversion may be related to pronators in general, and may not be linked directly to the incidence of overuse injuries. This raises doubts over primarily aiming at controlling the frontal plane rearfoot motion in interventions for pronators. Further

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investigations into clinical paradigms, are therefore, required to improve management of symptoms related to a pronated foot posture.

This current study showed that symptomatic pronators had smaller foot muscles and larger forefoot abduction during walking than their asymptomatic counterparts. These findings may have a potential to be generalized to symptomatic individuals in general. Further investigations are, therefore, required to evaluate the foot muscular characteristics and forefoot kinematics in symptomatic individuals independent of their foot posture and their sports participation.

Link between foot muscles and kinematics

In the current study, the muscular morphological differences between the symptomatic and asymptomatic groups might partially explain their kinematic differences during walking. As muscle size contributes to muscular force production, the CSA and thickness of intrinsic and extrinsic foot muscles may have implications on dynamic foot performance. Larger AbH and FDL can provide larger forces to adduct the forefoot, which may account for the reduced forefoot peak abduction in asymptomatic pronators during walking compared to symptomatic pronators. Furthermore, the PER is active in midstance and late stance of a gait cycle[37], which corresponds with the timing of peak forefoot abduction.

Limitations

There are several limitations to the current study that should be considered. The number of females was not equal across the two groups, with one more female in the symptomatic group. The mean value of training volume in the symptomatic group was lower than in the asymptomatic group. However, this difference was not statistically significant,

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and we did not find a correlation between training volume and the sizes of muscles of interest. We used skin-mounted markers for kinematic measurements, which is prone to skin movement artefact. The foot model used in this study does not has a midfoot segment and considers the forefoot as one segment instead of separating it into the medial and lateral forefoot segments. This may miss the independent movements between these segments. Furthermore, all kinematic measurements were performed while walking barefoot, as such the results cannot be extended to shod conditions. The causes of overuse injuries in pronators are multifactorial, and therefore, it is difficult to draw conclusions concerning the association between injury risk, foot muscle morphology and foot kinematics of pronators. Lastly, due to the nature of this cross-sectional study, the differences between symptomatic and asymptomatic pronators found by this study should be interpreted with caution.

In summary, symptomatic pronators demonstrated smaller foot muscles and larger forefoot peak abduction during walking compared to asymptomatic pronators in a physically active adult population. Strengthening foot muscles, such as AbH, PER and FDL, may contribute to injury prevention in pronators. Further longitudinal studies on foot muscle training effects in symptomatic pronators are required. Excessive forefoot abduction during walking might be the indicator of pain in physically active pronators. Contrary to some previous research, symptomatic pronators did not show larger rearfoot peak eversion during walking than asymptomatic pronators. The findings of this study may have implications for the underlying mechanisms of overuse injuries in pronators.

Perspective

Our study has important clinical implications for understanding the aetiology and developing the prevention and treatment of overuse injuries associated with a pronated foot posture. Recent studies indicate that intrinsic foot muscles play an important role in foot

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dynamic function[5-7]. Our results suggested that these muscles are also associated with symptom development in people with a pronated foot posture. Further studies are needed to examine the influence of strengthening intrinsic foot muscles on preventing injuries in pronated feet. By investigating detailed foot kinematics during walking, our results suggest that forefoot transverse motion rather than rearfoot frontal motion is related to symptoms in pronated feet. Foot orthotics have been used widely to prevent and treat overuse injuries. However, a randomized-controlled trial showed that using foot orthotics had minimal effect on preventing overuse injuries[37].It should be noted that the design of the foot orthotics used in their study focused on supporting the midfoot and rearfoot, while our study indicates that forefoot motion may be more related to symptom development. Using foot orthotics that target to control forefoot abduction and improve foot muscle function, may enhance the prevention and treatment role of orthotics, which requires further investigation.

Acknowledgements

The authors would like to thank Sam van Opstal for his assistance in data collection.

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Table 1

Participants' characteristics

Variable	Symptomatic		Asymptomatic	
	Mean ± SD	Range	Mean ±SD	Range
Number (female/male)	15 (6/9)	N/A	15 (5/10)	N/A
Age	23.3 ± 5.1	19 - 34	25 ± 5.3	21 - 42
Height (cm)	176.0 ± 10.0	160 - 191	175.8 ± 10.1	155 - 192
Weight (kg)	70.3 ± 10.1	51.0 - 85.5	70.2 ± 9.4	56.0 - 89.4
BMI	22.6 ± 1.6	19.9 - 25.3	22.7 ± 1.9	19.6 - 25.5
FPI	7.7 ± 1.7	6 - 11	7.1 ± 1.1	6 - 10
Training volume (km/week)	19.5 ± 6.6	15 - 40	25.7 ± 10.9	15 - 50
Walking velocity (km/h)	4.6 ± 0.4	3.7 - 5.1	4.7 ± 0.4	4.0 - 5.4

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Table 2

Mean ± SD of the CSA and thickness of selected extrinsic and intrinsic foot muscles of symptomatic and asymptomatic pronators

Muscles	Symptomatic pronators	Asymptomatic pronators	Mean Difference [95 % CI]	Cohen's d [95% CI]
PER CSA (mm^2)	337.1 ± 61.8	385.9 ± 74.2	48.8 [-2.3, 99.9]	0.71 [-0.02, 1.45]
PER thickness (mm)	12.1 ± 1.4*	13.6 ± 1.2	1.5 [0.5, 2.5]	1.15 [0.38, 1.92]
FDL-CSA (mm^2)	161.8 ± 34.8*	204.8 ± 38.4	43 [15.6, 70.4]	1.17 [0.40, 1.95]
FDL thickness (mm)	11.7 ± 1.6	12.4 ± 2.0	0.7 [-0.7, 2.0]	0.39 [-0.34,1.11]
AbH CSA (mm^2)	228.5 ± 48.4*	271.1 ± 35.2	42.6 [10.9, 74.2]	1.01 [0.25,1.77]
AbH thickness (mm)	11.0 ± 1.3*	12.5 ± 0.7	1.5 [0.7, 2.3]	1.44 [0.63, 2.24]
FDB CSA (mm^2)	233.3 ± 64.5	244.4 ± 46.2	11.1 [-30, 53.0]	0.20 [-0.52, 0.92]
FDB thickness (mm)	10.1 ± 1.5	10.4 ± 1.7	0.3 [-0.9, 1.5]	0.19 [-0.53, 0.90]

*p<0.05, *PER* peroneus muscles, *FDL* flexor digitorum longus, *AbH* abductor hallucis, *FDB* flexor digitorum brevis, *CSA* cross-sectional area.

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Table 3. Comparison of foot kinematics during stance phase of walking between symptomatic and asymptomatic pronators (deg)

Joint	Plane	Variables	Symptomatic pronators	Asymptomatic pronators	Mean difference [95% CI]	Cohen's d [95% CI]
Forefoot relative to rearfoot	Sagittal	Peak plantarflexion	-5.1 ± 4.9	-6.3 ± 6.2	-1.2 [-5.5, 3.1]	0.21 [-0.52, 0.95]
		Peak dorsiflexion	5.9 ± 3.8	3.5 ± 5.1	-2.4 [-5.9, 1.0]	0.53 [-0.21, 1.27]
		ROM	11.1 ± 2.5	9.8 ± 2.1	-1.2 [-3, 0.6]	0.56 [-0.17, 1.29]
	Transverse	Peak adduction	- 3.4 ± 5.3	0.0 ± 3.5	3.3 [-0.1, 6.8]	0.76 [0.00, 1.51]
		Peak abduction	- 10.0 ± 5.2*	-6.2 ± 3.9	3.8 [0.2, 7.3]	0.83 [0.07, 1.59]
		ROM	6.6 ± 1.7	6.2 ± 2.3	-1.2 [-3, 0.6]	0.2 [-0.52, 0.92]
	Frontal	Peak inversion	9.8 ± 6.6	10.4 ± 7.2	0.6 [-4.7, 5.8]	0.09 [-0.64, 0.82]
		Peak eversion	4.1 ± 6.5	3.7 ± 7.9	-0.4 [-5.9, 5.1]	0.06 [-0.67, 0.78]
		ROM	5.6 ± 1.9	6.6 ± 2.4	1 [-0.7, 2.7]	0.46 [-0.26, 1.19]
Rearfoot relative to tibia	Sagittal	Peak plantarflexion	-9.0 ± 5.1	-5.9 ± 5.3	3.1 [-0.8, 7.1]	0.60 [-0.15, 1.34]
		Peak dorsiflexion	11.2 ± 6.2	13.9 ± 5.5	2.7 [-1.7, 7.2]	0.46 [-0.28, 1.20]
		ROM	20.3 ± 3.7	19.8 ± 3.4	-0.4 [-3.1, 2.3]	0.14 [-0.58, 0.86]
	Transverse	Peak internal rotation	17.0 ± 20.6	13.6 ± 16.1	-3.4 [-17.6, 10.7]	0.18 [-0.55, 0.91]
		Peak external rotation	0.3 ± 20.1	-1.9 ± 16.1	-2.2 [-16.1, 11.8]	0.12 [-0.61, 0.85]
		ROM	12.2 ± 4.1	11.9 ± 3.3	-0.2 [-3.1, 2.6]	0.08 [-0.64, 0.8]
	Frontal	Peak inversion	5.7 ± 5.7	6.3 ± 5.3	0.6 [-3.6, 4.8]	0.11 [-0.62, 0.84]
		Peak eversion	-6.5 ± 5.1	-5.6 ± 6.0	0.8 [-3.4, 5.1]	0.16 [-0.57, 0.89]
		ROM	16.7 ± 3.1	15.5 ± 2.7	-1.2 [-3.5, 1]	0.41 [-0.31, 1.14]

ROM: range of motion.

The values of dorsiflexion, adduction, supination, inversion and internal rotation are displayed in positive values.

*p<0.05.

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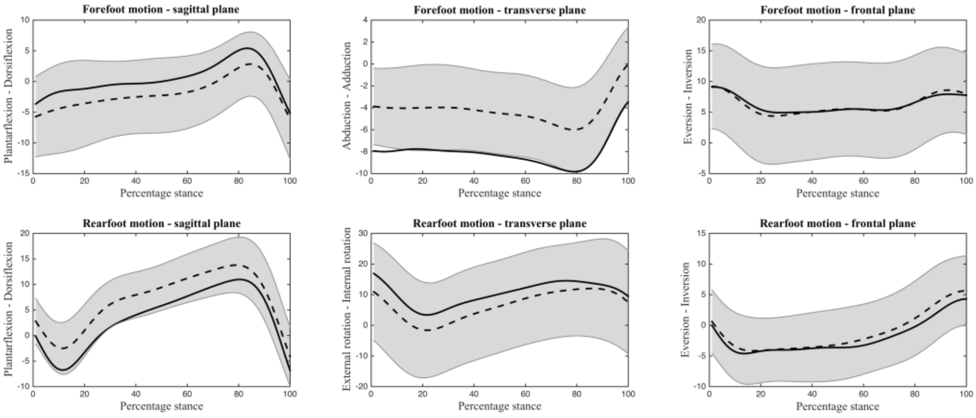

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