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Forefoot and rearfoot contributions to the lunge position in individuals with and without insertional Achilles tendinopathy

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ABSTRACT

Background: Clinicians use the lunge position to assess and treat restricted ankle dorsiflexion. However, the individual forefoot and rearfoot contributions to dorsiflexion and the potential for abnormal compensations are unclear. The purposes of this case–control study were to 1) compare single- (representing a clinical lunge position measure) versus multi-segment contributions to dorsiflexion, and 2) determine if differences are present in patients with tendinopathy.
Methods: 32 individuals (16 with insertional Achilles tendinopathy and 16 age- and gender-matched controls) participated. Using three-dimensional motion analysis, the single-segment model was defined as tibial inclination relative to the whole foot. The multi-segment model consisted of rearfoot (tibia relative to calcaneus) and forefoot (1st metatarsal relative to calcaneus) motion. Two-way (kinematic model and group) analyses of variance were used to assess differences in knee bent and straight positions. Associations between models were tested with Pearson correlations.
Findings: Single-segment modeling resulted in ankle DF values 5° greater than multi-segment modeling that isolated rearfoot dorsiflexion for knee bent and straight positions ($P < 0.01$). Compared to controls, the tendinopathy group had 10° less dorsiflexion with the knee bent ($P < 0.01$). For the tendinopathy group, greater dorsiflexion was strongly associated with greater rearfoot ($r = 0.95$, $P < 0.01$) and forefoot ($r = 0.81$, $P < 0.01$) dorsiflexion. For controls, dorsiflexion was strongly associated with rearfoot ($r = 0.87$, $P < 0.01$) but not forefoot dorsiflexion ($r = 0.23$, $P = 0.39$).
Interpretation: Clinically used single-segment models of ankle dorsiflexion overestimate rearfoot dorsiflexion. Participants with insertional Achilles tendinopathy may compensate for restricted and/or painful ankle dorsiflexion by increased lowering of the medial longitudinal arch (forefoot dorsiflexion) with the lunge position.

1. Introduction

Current evidence identifies limitations in ankle dorsiflexion (DF) as one of the key impairments linked to the chronicity of pain and dysfunction in many lower limb pathologies including Achilles tendinopathy (Kaufman et al., 1999; Wilder and Sethi, 2004), plantar fasciitis (Patel and DiGiovanni, 2011; Riddle et al., 2003), midfoot arthritis (DiGiovanni et al., 2002), stress fractures (Wilder and Sethi, 2004), shin splints (Neely, 1998; Wilder and Sethi, 2004), and patellofemoral pain syndrome (Lun et al., 2004). While there is minimal research on ankle range of motion in patients with insertional form of Achilles tendinopathy (IAT), there is evidence indicating that limited ankle DF occurs in this population (Kedia et al., 2014; Nawoczenski et al., 2015). Intervention strategies for IAT commonly use the lunge position with the knee bent and straight as stretch to improve ankle DF as well as other weight-bearing positions into maximal ankle DF, such as eccentric heel lowering (Fahlstrom et al., 2003; Kedia et al., 2014; Rompe et al., 2009).

The weight-bearing lunge position is often used to assess ankle DF range of motion that may be necessary to complete functional tasks, such as stair climbing (Bennell et al., 1998) or squatting (Macrum et al., 2012). It is an evaluative tool that requires minimal equipment to administer. The clinical evaluation of ankle DF using the lunge position reflects the composite motion of the foot and ankle (Bennell et al., 1998; Chisholm et al., 2012; Gatt and Chockalingam, 2011; Jones et al., 2005; Munteanu et al., 2009), and measurements frequently assess tibial inclination relative to the foot. While it is known that motion occurs in the multiple joints of the foot and ankle, it is unclear if the relative contributions of forefoot dorsiflexion and rearfoot eversion are clinically significant when compared to rearfoot dorsiflexion during the lunge with the knee bent and knee straight.

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A recent three-dimensional in vivo kinematic analysis of ankle rotation has shown calcaneal plantarflexion, or anterior calcaneal rotation, to occur during a squatting task in healthy adults (Chizewski and Chiu, 2012). This motion may contribute to greater anterior tibial inclination from the vertical position (Chizewski and Chiu, 2012). Additionally, a recent study of standing wall stretches for gastrocnemius tightness demonstrate arch height changes (navicular drop) that occur in the midfoot if the arch is not supported during the weight-bearing lunge stretch (Jung et al., 2009). These findings suggest that the talocrural joint is just one contributor to 'ankle DF' in a lunge position. Examination of multi-segment sagittal plane rotations that include both forefoot and rearfoot rotations may provide greater insight into mechanics that cannot be reliably assessed using a single measure. Additionally, if greater ankle DF in the lunge position is associated with greater forefoot/1st metatarsal dorsiflexion, then modifications in the use of the lunge position for evaluation and treatment may be needed to protect the soft tissues supporting the medial longitudinal arch.

To date, there has been limited detail regarding in vivo multi-segment contributions to a weight-bearing lunge position. Additionally, comparison to a homogenous patient group with chronic IAT may provide additional insight into compensation strategies associated with restricted and/or painful ankle DF. The purposes of the current study are to 1) compare and contrast single- versus multi-segment (forefoot and rearfoot) sagittal plane contributions to ankle DF in a knee bent and knee straight weight-bearing lunge positions, and to 2) determine if differences are present in patients with chronic IAT when compared to matched controls. The first hypothesis was that the single segment model would overestimate ankle DF when compared to multi-segment (rearfoot DF and forefoot DF) contributions to ankle DF in both knee bent and straight positions. The second hypothesis was that the IAT group would demonstrate less rearfoot DF and greater forefoot DF than the control group during the lunge position.

2. Methods

2.1. Participants

Thirty-two individuals participated in this case–control study. The sample included 16 people with unilateral insertional Achilles tendinopathy (IAT) and 16 age- and gender-matched controls. Over a 10 month period, participants with IAT were recruited from the practices of foot and ankle surgeons and control participants were recruited from local community centers. Control participants were within 4 years of their gender-matched case, and there were no differences in demographics between groups (Table 1). The symptomatic side of the IAT participant was matched with the same limb side (right/left) of the control. The groups reported similar physical activity levels on the International Physical Activity Questionnaire (IPAQ- long-form) (Craig et al., 2003).

Table 1
Demographics of participants with insertional Achilles tendinopathy (IAT) and age- and gender-matched controls.

	IAT n = 16	Controls n = 16	*P* value
Age, y	58.1 (8.5)	57.5 (8.4)	.85
Sex, F:M	9:7	9:7	1.00
Height, m	1.7 (0.1)	1.7 (0.1)	.68
Weight, kg	87.9 (16.7)	82.0 (13.8)	.28
BMI, kg/m^2	30.4 (5.7)	28.8 (4.9)	.41
Activity level, MET-minutes/week[a]	3633 (559 to 8414)	3193 (1566 to 15,079)	.53

Abbreviation: metabolic equivalent (MET).
Values are mean (SD) and groups compared with independent samples *t*-test unless otherwise indicated.
[a] Values are median (interquartile range) and groups compared with independent samples Mann–Whitney *U* test.

Participants with IAT were diagnosed with chronic unilateral IAT (symptoms >3 months) by fellowship-trained orthopedic foot and ankle surgeons. Participants were included if they met the criteria for diagnosis or 1) tenderness to palpation within 2 cm of the tendon insertion, and 2) pain aggravated by physical activity. The median duration of symptoms in the IAT group was 8 months (range: 3 months to 15 years). Ultrasound imaging of tendon structure and mechanical properties in this sample were consistent with the diagnosis of unilateral IAT (Chimenti et al., 2014a). Participants were excluded if they had isolated retrocalcaneal bursitis, asymptomatic Haglund's deformity, a previous foot or ankle surgery, bilateral IAT or had other conditions that may affect ankle range of motion (e.g. pregnancy, neurological condition). A total sample size of 32 was needed to have 80% power to detect a 5° difference in single-segment DF between groups. All subjects were informed of the study procedures and signed a consent form approved by our institutions' human subject research review boards.

2.2. Kinematic model

A 3-segment model, including the first metatarsal, calcaneus and tibia, was used to capture foot and ankle motion. To track each segment, sets of 3 infrared light emitting diodes (IREDs), on a thermoplastic molded platform were taped to the skin overlying each segment of interest (Fig. 1). In addition, 1 IRED was placed at the base of the 5th metatarsal. Skin-mounted markers, compared to bone-mounted markers, have an error of 2.6° for the calcaneus (Nester et al., 2007) and 2.3° for the first metatarsal (Umberger et al., 1999) in the sagittal plane. Digitized points were used to define the longitudinal axis of the segment, and then 2 additional orthogonal axes were created from a 3rd digitized point defining a plane using Motion Monitor software (Version 8.64, Innsport Training, Chicago, IL, US). The longitudinal axis (Y) of the leg was defined from the fibular head to the lateral malleolus. The anterior–posterior axis (X) of the calcaneus was defined by points on the floor from the middle of the heel to the end of the second toe. The longitudinal (X) axis of the foot was defined from the posterior

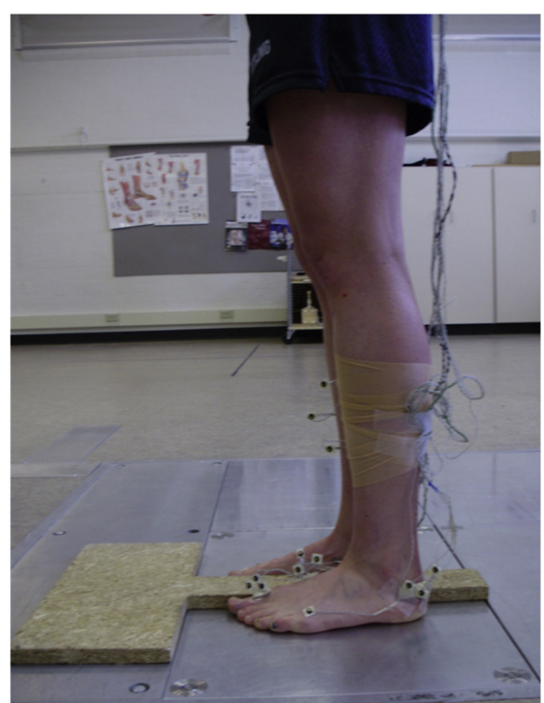

Fig. 1. Kinematic model of the foot and ankle included the first metatarsal, calcaneus and tibia.