Gait Stability Differences During Single Limb Support between Patient Ankle Arthritis and Health Participants

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INTRODUCTION: End-stage ankle arthritis (AA) is estimated at 50,000 new cases per year and is associated with a degree of physical impairment equivalent to end-stage kidney disease and heart failure. [1,2] Patients with end-stage ankle arthritis have slower walking speeds, decreased ankle sagittal plane range of motion, and generate lower ground reaction forces to compensate for the affected limb. [3] Falls are the leading cause of fatal and nonfatal injuries for people 65 years of age and older and lead to significant complications [4]. Furthermore, those with lower limb osteoarthritis have between 53%-85% greater risk of falling [5]. Margin of Stability (MoS) is a dynamic measurement of balance that can be used as a surrogate for fall risk [6]. MoS is calculated by assessing the minimum distance between the velocity adjusted center of mass (COM) and the edge of the base of support (BoS). A decrease in MoS has been associated with increased fall risk in patients with various pathologies including stroke, amputations, spinal cord injury, and other neurological disorders [7]. Prior work has focused on assessing peak differences in MoS across the stance phase of gait. The purpose of this project was to examine differences in the MoS during single limb stance between limbs (affected (AFF), unaffected (UNAFF)) in patients with AA and healthy control (HC) participants (dominant (D), non-dominant (ND)). We hypothesized that AA would have significantly greater fall risk (lower MoS) when compared to HC and that the affected limb (AFF) in patients with AA would demonstrate lower MoS when compared to the unaffected (UAFF) limb.

METHODS: Three-dimensional motion capture and force plate data were collected during self-selected speed level walking in 30 patients with end-stage AA and 30 matched HC. The body center of mass (COM) was estimated as in Whittle [8]. The extrapolated COM and MoS were determined within the foot coordinate system during single limb support (SLS) on each limb [6, 9]. Single limb support was defined as the time from contralateral toe-off to contralateral heel strike and the mediolateral (MoS_{ML}) and anteroposterior (MoS_{AP}) MoS were calculated at each time point to generate a MoS time-series that was normalized to single support. A two-dimensional statistical parameter mapping (SPM) repeated measures analysis of variance (ANOVA) was completed to examine time-series MoS interactions and main effects for group (AA, HC) and limb (AFF/UNAFF or D/ND) ($\alpha = 0.05$) [10,11].

RESULTS: There were no differences between the AA and HC cohorts for age (AA: 57.0±5.4 years, HC: 55.2±10.3 years, $p=0.41$) or Sex (AA: 14 male, 16 female, HC: 15 male, 15 female). The AA group had a higher BMI (AA: 30.3±5.1, HC: 26.1±6.4, $p<0.001$) and slower gait speed (AA: 1.40±0.24, HC: 0.85±0.24, $p<0.001$). Single support time was significantly longer in AA UNAFF limb compared to all other limbs (AA UNAFF: 0.461±0.062, AA AFF: 0.390±0.045, HC D: 0.400±0.045, HC ND: 0.402±0.047, $p<0.001$). During the second half of SLS there was a group by limb interaction ($p=0.028$) for the MoS_{AP} and a group by limb the AA group ($p<0.001$) for the MoS_{ML} throughout SLS (Figure 1). Based on pairwise comparisons, the MOS_{AP} was different between the AFF and UNAFF limbs in patients with AA from 85%-100% of SLS ($p=0.039$) and between both limbs in HC and the AFF limb in the AA group throughout SLS ($p<0.001$). Pairwise comparisons for the MoS_{ML} (Figure 1) indicated the AFF and UNAFF limbs in the AA group were different throughout SLS ($p<0.001$) and the ND limb of HC was different from the AFF limb in in the AA group during early SLS (0%-61%) ($p=0.012$).

DISCUSSION: The results of this study indicate that MoS_{AP} and MoS_{ML} are different between patients with AA and healthy control participants during single limb support. The MoS_{AP} is greater on both limbs in patients with AA and the MoS_{ML} is greater on affected limb in patients with AA indicating a more stable gait pattern in each of these conditions. This phase of the gait cycle is important given that only one foot is in contact with the ground and all adjustments must be made by that limb to prevent falls or in the case of these results it may be that the patient decreases SLS on the AFF side and the UNAFF limb is used to compensate. Therefore, it appears that patients with AA are adopting a more conservative and stable gait on the AFF limb to decrease their risk of falling. Future research should consider the impact of surgical interventions (arthroplasty and arthrodesis) on time-series MoS and assess fall risk during different gait conditions such as walking on uneven ground, at different speeds and while changing directions.

SIGNIFICANCE/CLINICAL RELEVANCE: Falls are a common, dangerous, and expensive sequela for patients with end-stage ankle arthritis. The impact of AA on fall risk are not well known and this study begins to identify compensatory patterns, including reduced gait speed, increased single support time on the unaffected limb, that likely provide a more stable gait pattern and increase both MoS_{AP} and MoS_{ML}.

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IMAGES AND TABLES:

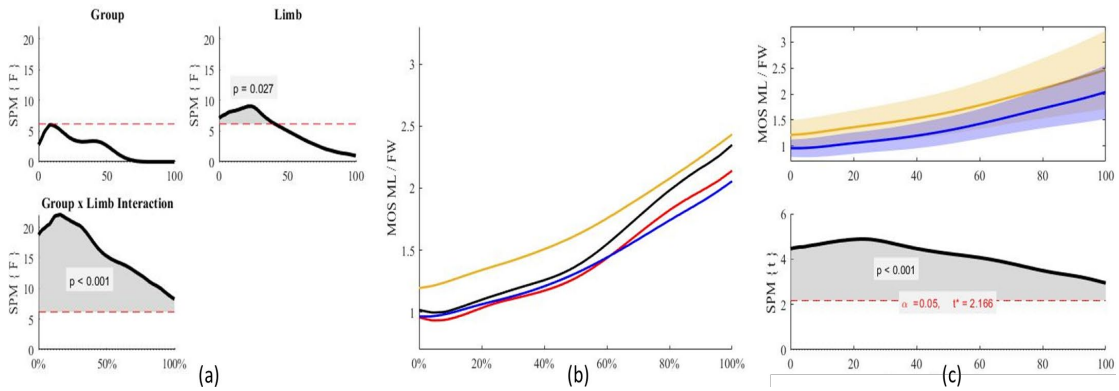

Figure 1. Two-way ANOVA SPM results (a), means for each group and limb (b), and selected pairwise comparison for MoS_{ML} (c). Red indicates HC D, black indicates HC ND, blue AA UNAFF, and yellow AA AFF.