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**Post-sprain versus post-fracture post-traumatic ankle osteoarthritis:  
impact on foot and ankle kinematics and kinetics**

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### **HIGHLIGHTS**

- Ankle osteoarthritis affects mainly foot mechanics about dorsi/plantarflexion axes
- Ankle osteoarthritis affects the kinetics of the neighbouring foot joints
- Post-fracture ankle osteoarthritis exhibit lower power absorption at MTP1 joint

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## ABSTRACT

**Background:** Common etiologies for post-traumatic ankle osteoarthritis are ankle fractures and chronic ankle instability. As the nature of trauma is different for these two etiologies, it might be expected that the two subtypes of post-traumatic ankle osteoarthritis would display different foot mechanics during gait.

**Research question:** The objective of this exploratory cross-sectional study was to compare the foot kinematics and kinetics of patients suffering from post-fracture ankle osteoarthritis with those of patients suffering from post-sprain ankle osteoarthritis.

**Methods:** Twenty-nine subjects with end-stage post-traumatic ankle osteoarthritis and fifteen asymptomatic control subjects participated in this study. All patients suffered from post-traumatic ankle osteoarthritis secondary to ankle-related fracture (Group 1; n=15) or to chronic ankle instability (Group 2; n=14). A four-segment kinematic and kinetic foot model was used to calculate intrinsic foot joint kinematics and kinetics during gait. Vector field statistical analysis MANOVA was used to assess differences between groups for the entire three-component intrinsic foot joint angles and moments.

**Results:** MANOVA showed significant differences between the groups. Post-hoc analyses suggested that the differences between post-fracture ankle osteoarthritis group and controls were caused by a combination of less adducted Shank-Calcaneus position and less plantarflexion at this joint. Post-hoc analyses also suggested that both pathological groups exhibited a decreased plantarflexion moment for Shank-Calcaneus, Chopart, Lisfranc joints compared to controls. Analyses of both pathological groups versus controls for power suggested lower Shank-Calcaneus and Lisfranc power generation during pre-swing phase.

**Significance:** No significant differences were found between the two pathological groups in this exploratory study. Alterations in foot kinematics and kinetics were mainly found about the dorsi-/plantarflexion axis during the pre-swing phase of the stance phase for both pathological

groups compared to controls. Observed differences were not limited to the painful ankle joint, but seem also to have affected the kinetics of the neighbouring foot joints.

**Keywords:** Ankle; Osteoarthritis; Kinetics; Kinematics; Gait; Intrinsic foot joints

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## 1. Introduction

Ankle osteoarthritis is a progressive and degenerative joint disease affecting approximately 1% of the world's adult population [1]. Recent publications have demonstrated that the degree of physical impairment from ankle osteoarthritis is at least as severe as that from congestive heart failure and hip osteoarthritis using the SF-36 [2,3]. Numerous clinical and epidemiologic studies of patients suffering from ankle osteoarthritis have identified previous trauma as the most common aetiology [4,5]. Post-traumatic ankle osteoarthritis most frequently occurs secondary to ankle-related fractures and to chronic ankle instability [5]. Evidence suggests that post-fracture ankle osteoarthritis (PF OA) results either from irreversible cartilage damage which occurs at the time of the fracture, or from chronic cartilage overloading which occurs as a result of post-fracture articular incongruity during weightbearing activities. The evidence also suggests that post-sprain ankle osteoarthritis (PS OA) results from pathological cartilage overloading due to chronic joint instability [6].

Significant biomechanical alterations of the entire foot and lower limb have been reported in patients suffering from PF OA [7,8]. Their gait is asymmetrical and characterized by a decreased walking speed, decreased stride length and reduced mobility of the ankle joint complex [9]. They also seem to adopt an antalgic walking strategy to prevent shear loading through the painful joint [9]. Despite this knowledge, no study has so far compared the gait mechanics of patients suffering from PF OA to those of patients suffering from PS OA. Moreover, ankle joint kinetics reported in patients suffering from post-traumatic ankle osteoarthritis have in the past been calculated using a rigid foot modelling approach, which is known to overestimate the amount of ankle joint power, potentially leading to clinical misinterpretations [10,11]. The development of a more full understanding of the difference in the gait mechanics, including those of both the ankle joint and intrinsic joints of the foot, of these two subgroups of patients is therefore required. Currently, to the authors' knowledge, no

research has been conducted using patients suffering from the two types of post-traumatic ankle osteoarthritis using a four-segment foot model. The use of a four-segment foot model would allow the exploration of whether the more distal located foot joints compensate differently between these two types of post-traumatic ankle osteoarthritis. This approach may show kinetic patterns to occur that a rigid foot model would mask, and give additional information regarding forefoot function by assessing Chopart and Lisfranc joint complex kinetics.

The overall objective of this exploratory cross-sectional study was to compare the foot kinematics and kinetics of patients suffering from PFOA with those of patients suffering from PSOA during the stance phase of gait. As the nature of the causative trauma is different, one might expect that the two types of post-traumatic ankle osteoarthritis would display different foot mechanics during gait. In addition, each pathological group was individually compared to an asymptomatic group of peer-matched control subjects.

## **2. Methods**

### ***2.1. Participants***

A convenience sample of twenty-nine subjects with end-stage post-traumatic ankle osteoarthritis (Takakura stage 3 to 4 (4 being complete obliteration of the joint space)) and fifteen asymptomatic subjects (CTRL) participated in this study (Table 1). This convenience sample size was based on similar clinical biomechanical research [9,10,12]. All patients suffered from post-traumatic ankle osteoarthritis secondary to ankle-related fracture (PFOA; n=15 subjects; 9 males and 6 females) or to chronic ankle instability (PSOA; n=14 subjects; 9 males and 5 females). Exclusion criteria for both post-traumatic groups were (1) being younger than 18 years, (2) systemic or neurological diseases, (3) any medical problem other than post-traumatic ankle osteoarthritis that could possibly affect gait. The inclusion criteria for the pathological groups were post-traumatic end-stage ankle osteoarthritis with an indication for

either ankle fusion or total ankle replacement. The severity of ankle osteoarthritis was scored using the Canadian Orthopaedic Foot & Ankle Society classification system (Table 1)[13]. Control subjects (10 males and 5 females) were peer-matched with both PF and PS OA groups according to their demographics. Exclusion criteria for the control subjects were any medical problems that could possibly affect normal gait. The local ethical committee approved the study (B200-2017-061) and all participants signed an informed consent form.

## ***2.2.Data collection***

Participants were first fitted with sixteen 8mm retro-reflective markers on the foot and shank in accordance with the multi-segment Rizzoli foot model [14]. The measurement protocol was started by asking participants to walk at a self-selected speed along a 10m walkway in which a pressure plate (Footscan®, dimensions 0.58 m x 0.42 m, 4096 sensors, 2.8 sensors per cm<sup>2</sup>, RsScan, Paal, Belgium) was mounted upon an AMTI force plate (Watertown, US). The force plate was custom-made to fit the surface dimensions of the plantar pressure plate. The advantage of this set-up was the continuous calibration of the pressure plate with the force plate using a 3D interface box (RsScan, Paal, Belgium). A passive optoelectronic motion analysis system (Qualysis, Göteborg, Sweden) comprised of 8 Miquis cameras tracked the kinematic data of the participants while walking over the instrumented walkway. The global acquisition frequency was 200Hz. Data was collected from five valid trials for each participant. A trial was considered valid when the foot under investigation made a clear contact with the pressure plate without visible gait adjustments. Walking speed was also required to remain relatively constant across all trials of a recording session.

### 2.3. Data analysis

Inter-segment center definitions of the four segment foot model were based on an adapted version of Rizzoli multi-segment foot model developed by Deschamps et al. (2017) (IOR-4Segment-model 1) (Figure 1)[15]. The ankle joint center was defined as the midpoint between the malleoli markers, and motion at this joint was considered between the calcaneus and the shank (hereafter referred as Shank-Calcaneus). To define the calcaneus-midfoot joint center, an additional virtual cuboid marker was created and defined as being at 2/3 of the distal distance between the peroneal tubercle and the base of the fifth metatarsal. The calcaneus-midfoot joint center was defined as the midpoint between the cuboid and the navicular bone (hereafter referred as Chopart joint). The midfoot-metatarsus center (hereafter referred as Lisfranc joint complex) was defined as being on the base of the second metatarsal. The first metatarsophalangeal joint center (MTP1) was defined as being at intersection of the projection of the first metatarsal head marker vertically at mid distance and the floor [15]. Inter-segment 3D rotations were calculated according to IOR-4Segment-model 1 of Deschamps et al. (2017) following ISB recommendations [15]. End-stage ankle osteoarthritis rarely occurs in isolation, more often presenting concomitant ankle and hindfoot deformities [16,17]. As the (mis)alignment of the distal foot joints may affect the function of the ankle and hindfoot, no offset values for all joint rotations (obtained from a static trial) were calculated and subtracted from the corresponding values over the walking stance to preserve the anatomical foot and ankle characteristics associated with ankle osteoarthritis.

Joint forces ( $\mathbf{F}$ ) and moments ( $\mathbf{M}$ ) were calculated in the Joint Coordinate System using a bottom-up inverse dynamic method [18,19]. Kinematic and force data were filtered using a low-pass zero-lag, 4<sup>th</sup> order, Butterworth filter, with a cut-off frequency of 10 Hz. Inertia and weight parameters of each foot segment were not accounted for considering that the inertia effects were negligible during stance in comparison to the external forces [20,21]. The force

plate data were distributed over each foot segment using a validated proportionality scheme [22,23]. The estimation of the subarea of each foot segment was achieved for each time frame by projecting the markers' position vertically onto the sensor matrix of the pressure platform. The resulting center of pressure (CoP) of each estimated subarea was then used as the CoP for the corresponding foot segment in the inverse dynamics calculations. An in-house written Matlab© program (Mathworks Inc., Natick, US) was used for inter-segment kinematic and kinetic computations. Internal joint moments and powers were normalized by subject-mass, and all one-dimensional data were time-normalized to 100% of the stance phase.

#### ***2.4. Statistical analysis***

First, a Shapiro-Wilk test was used to check for data normality. A one-way ANOVA test and Kruskal-Wallis test were used to identify statistically significant differences between groups for demographic and spatio-temporal data. In cases where significant differences were observed, a Post hoc Tukey honestly significant difference test was used to indicate which groups were different. All statistical tests were conducted using SPSS (V25, IBM Corp, Chicago, US).

Foot kinematics and kinetics were statistically compared using one-dimensional (1D) statistical parametric mapping (SPM) (open-source code; v.M.0.4.5; www.spm1d.org) [24–26]. SPM regards the whole 1D continuous vector trajectory that changes in time as the unit of observation, and time dependence is incorporated directly in the statistical testing. This method is based on the Random Field Theory which makes probabilistic conclusions based on the random behavior of that 1D observational unit [24]. This approach was validated for 1D data [27]. Between-group statistical analyses were conducted in three steps. Firstly, one-way MANOVA ( $SPM\{\chi^2\}$ ) was used to assess kinematic and kinetic differences between the three groups (PSOA, PFOA and CTRL) (Figure 2A). The hypothesis testing objective was to find

the critical  $\chi^2$  value that smooth, one dimensional multivariate Gaussian data would reach in alpha percent of an infinite number of experiments involving smooth, 1D data. If the experimentally SPM $\{\chi^2\}$  trajectory crosses the critical value, the null hypothesis is rejected (Figure 2A). Individual probability values were then calculated for each supra-threshold cluster that could have resulted from an equally smooth random process [24–26]. Secondly, if significant differences were found, post hoc analyses two sample Hotelling's  $T^2$  on group pairs were performed to assess the time varying three-component angles and moments of the ankle, Shank-Calcaneus, Chopart, Lisfranc and MTP1 joints (Figure 2B). By considering three-component angles and moments (dorsi/plantarflexion, adduction/abduction, inversion/eversion waverforms), as well as collinearities between them are all modelled statistically. Thirdly, if significant differences between respective groups were found, secondary post hoc analyses two-sample t-tests (SPM $\{t\}$ ) for each individual component (dorsi/plantarflexion, adduction/abduction, inversion/eversion) were performed (Figures 3-5). As power is a scalar output, one-way between subjects ANOVA (SPM $\{F\}$ ) was calculated separately. If statistical significance was reached in the SPM $\{F\}$ , then post-hoc two-sample t-test (SPM $\{t\}$ ) was performed to determine the between-group differences (using the same processes as described above). The alpha = 0.017 was used to reduce the likelihood of a type 1 error.

### 3. Results

#### 3.1. Demographic and spatio-temporal data (Table 1)

No significant differences between the groups were found for age, weight, height or BMI. No significant differences were found between PF OA and PS OA groups for walking speed or stride length. However, both post-traumatic ankle OA groups showed significantly shorter stride lengths ( $P < 0.001$ ) and slower walking speeds than the control group ( $P < 0.001$ ).

### 3.2.SPM analysis

#### 3.2.1. Foot joint angles

The one-way MANOVA test showed significant differences for the Shank-Calcaneus joint between the three groups over approximately 8.5-14% ( $P = 0.016$ ) and 93-100% ( $P = 0.016$ ) of the stance phase (Figure 2A). Post-hoc analyses Hotelling's  $T^2$  suggested that this difference was caused between PF OA and CTRL groups (4-65.5% and 91-100% of the stance phase) (Figure 2B). Post-hoc analyses two sample t-tests for individual components of PF OA vs CTRL group suggested that the differences were caused by combination of adduction/abduction and dorsi-/plantarflexion: less adducted Shank-Calcaneus position compared to CTRL (0-65.5% and 88-100% of the stance phase) and less plantarflexion at this joint during pre-swing ( $P = 0.016$ ; 93-100% of the stance phase) (Figure 3).

#### 3.2.2. Joint moments

The one-way MANOVA tests showed main effects between the three groups for all foot joint moments (Shank-Calcaneus ( $p = 0.006$ ; 75-80% of the stance phase); Chopart ( $P < 0.001$ ; 68-84% of the stance phase), Lisfranc ( $P < 0.001$ ; 62.5-85% of the stance phase)) except for the MTP1 joint. Post-hoc analyses Hotelling's  $T^2$  suggested that this difference was caused between both pathological groups and CTRL groups. Post-hoc analyses two sample t-tests for individual components of both pathological groups vs CTRL group suggested that both pathological groups exhibited a decreased plantarflexion moment for Shank-Calcaneus, Chopart, Lisfranc joints between 58.5 and 85.5% of the stance phase of gait compared to CTRL (Figure 4). In contrast to the PS OA group, the results also suggested that PF OA had a decreased abduction moment at the Lisfranc joint between 72 and 84.5% of the stance phase compared to CTRL (Figure 4).

### 3.2.3. Power

The results showed significant SPM{F} main effects for all three groups for all power variables moments (Shank-Calcaneus ( $P < 0.001$ ; 74.5-92% of the stance phase), Lisfranc ( $P < 0.001$ ; 75-85% of the stance phase); MTP1 ( $P < 0.001$ ; 74-82.5% of the stance phase)) except for the Chopart joint. Post-hoc analyses two sample t-tests for power variables suggested that the differences observed at heel off were caused by lower Shank-Calcaneus and Lisfranc power generation for both pathological groups compared to CTRL (Figure 5). A more noteworthy difference in power pattern was observed for the PF OA group highlighting lower power absorption at the MTP1 compared to CTRL (Figure 5).

## 4. Discussion

To our knowledge, this was the first exploratory study to compare the foot kinematics and kinetics of PF OA and PS OA patients. This study did not find any differences in joint angles and moments between the pathological groups. We believe that there may be two possible explanations for this lack of differences. Firstly, patients suffering from end-stage ankle osteoarthritis adopt an antalgic walking strategy to prevent shear loading through their painful ankle joint [9]. This may suggest that the results of this study could be attributed to the fact that both pathological groups had adopted a similar walking pattern to avoid pain in their arthritic ankle. Secondly, patients with ankle osteoarthritis often present concomitant foot and ankle deformities, which may affect the intrinsic foot joint mechanics during gait [16,17]. It is therefore plausible to suggest that both pathological groups may have had similar intra- and extra-articular foot and ankle deformities, the effects of which masked the more subtle differences resulting from the primary pathologies. Future biomechanical studies should therefore include the assessment of intra- and extra-articular foot and ankle deformities, the addition of which may provide further insight into the mechanical deficits associated with ankle osteoarthritis.



One of the objectives of this exploratory study was also to compare the foot mechanics of patients suffering from post-traumatic ankle osteoarthritis to those of a group of asymptomatic subjects. Overall, the gait alterations identified were comparable with corresponding results from previous studies. The gait of our post-traumatic patients was characterized by a decreased walking speed, decreased stride length and reduced Shank-Calcaneus kinematics (PF OA group) and kinetics (both pathological groups) in comparison with the CTRL group [1,8,12]. A reduction of the range of motion (ROM) about the dorsi/plantarflexion and adduction/abduction axes at the Shank-Calcaneus joint, particularly during pre-swing was observed in PF OA group compared to CTRL. These findings are in accordance with those from previous studies [8,9,12]. In contrast to the results of Valderrabano et al. (2007), no significant reduction in ROM was observed about the inversion/eversion axes. However, both post-traumatic ankle osteoarthritis groups tended to have a more inverted Shank-Calcaneus joint position during loading response and early midstance compared to CTRL.

It is of interest to note that the 1D-analysis did not reveal any significant differences for the Chopart joint in this exploratory study. However, both pathological groups seem to exhibit a more adducted position of the Chopart joint during the same period of gait. It is reasonable to assume that the inverted hindfoot position, in association with a more adducted position of the Chopart joint, may be explained by a co-contraction phenomenon between the tibialis anterior and gastrocnemius muscle, both foot and ankle adductor and invertor muscles, in an attempt to keep the ankle joint stable from heel strike to midstance [28].

Multi-segment kinetic foot models have recently been shown to be sensitive enough to detect differences between the gait of healthy subjects and the gait of patients with ankle osteoarthritis [10,20]. This study has provided a first attempt towards gaining further insight into the kinetic behavior of the Chopart joint and Lisfranc joint complex by using a four-segment foot model. The results showed that both post-traumatic ankle osteoarthritis groups

displayed significantly less plantarflexion moment for the main intrinsic joints of the foot during propulsion compared to the control group. Valderrabano et al. (2007) suggested that the reduction of moments in post-traumatic ankle osteoarthritis may be a consequence of the associated atrophy and weakness of the lower leg muscles or a protective gait strategy to reduce loading in the painful joint [9].

Direct comparison between the two ankle osteoarthritis groups revealed in this exploratory study no differences in joint power. However, when the two groups were individually compared to CTRL, the results suggested that PS OA reduces power generation only at the Shank-Calcaneus and Lisfranc joints, whereas PF OA results in reductions in joint power at the Shank-Calcaneus, Lisfranc and MTP1 joints. This could be explained by the nature of trauma in the PF OA group, as the soft-tissue envelope around the fractured ankle may have become scarred and inelastic due to fibrosis after osteosynthesis surgery, affecting the functioning of the extrinsic foot muscle tendons, and thus the function of the joints distal to the ankle joint. Previous studies have provided further evidence of lower leg muscle dysfunction in patients suffering from end-stage post-traumatic ankle osteoarthritis resulting from secondary arthritic muscle atrophy, arthrogenous muscle inhibition or a combination of the two [28,29].

## **5. Limitations**

Since walking speed affects foot kinetics, caution should be exercised when interpreting the differences in joint moments and power between our pathological groups and the control group as their walking speed differed [30]. Therefore, future studies investigating foot joint kinetics should address this limitation by comparing symptomatic subjects with speed-matched control subjects. Another limitation was the partitioning of the total ground reaction forces acting on the calcaneus segment based on a proportionality scheme which combined pressure

and force plate data together with marker placement data. Even though this proportionality scheme was validated, the reported joint moments and power should be regarded as estimates [15]. Although the sample size was based on similar studies [9,10,12], it was not possible to compute a priori statistical power. This was because no minimum detectable change values between post-sprain and post-fracture post-traumatic ankle osteoarthritis have been reported in the literature for Chopart, Lisfranc and MTP1 joints. The lack of differences between the two populations could therefore be an effect of the sample size, and future studies need to be undertaken to confirm the findings of this exploratory study.

## **6. Conclusion**

This paper provides the first exploration and comparison of multi-segment foot kinematics and kinetics between subjects suffering from PF OA and PS OA. Our preliminary findings indicate that no significant differences were here found between the two pathological groups. Alterations in foot kinematics and kinetics were mainly found about the dorsi-/plantarflexion axis during the pre-swing phase of the stance phase for both pathological groups compared to CTRL. Observed differences were not limited to the painful ankle joint, but seem to also affect the kinetics of the distal foot joints.

## **CONTRIBUTIONS**

PAD conceived the original idea of the study, contributed to gait data collection, analysis and interpretation, drafted the manuscript and approved its final version.

TL conceived the original idea of the study, contributed to patient's enrollment and examination, provided critical revision of the manuscript and approved its final version.

BDB contributed to patient's enrollment and examination, provided critical revision of the manuscript and approved its final version.

JLB conceived the original idea of the study, contributed to patient's enrollment and examination, provided critical revision of the manuscript and approved its final version.

AN contributed to gait data collection, analysis and interpretation, performed statistical analysis, provided critical revision of the manuscript and approved its final version.

RD contributed to gait data analysis and interpretation, provided critical revision of the manuscript and approved its final version.

LC contributed to gait data analysis and interpretation, provided critical revision of the manuscript and approved its final version.

IB contributed to gait data analysis and interpretation, provided critical revision of the manuscript and approved its final version.

## **COMPETING INTEREST STATEMENT**

The authors do not have any significant conflicts of interest relevant to this manuscript.

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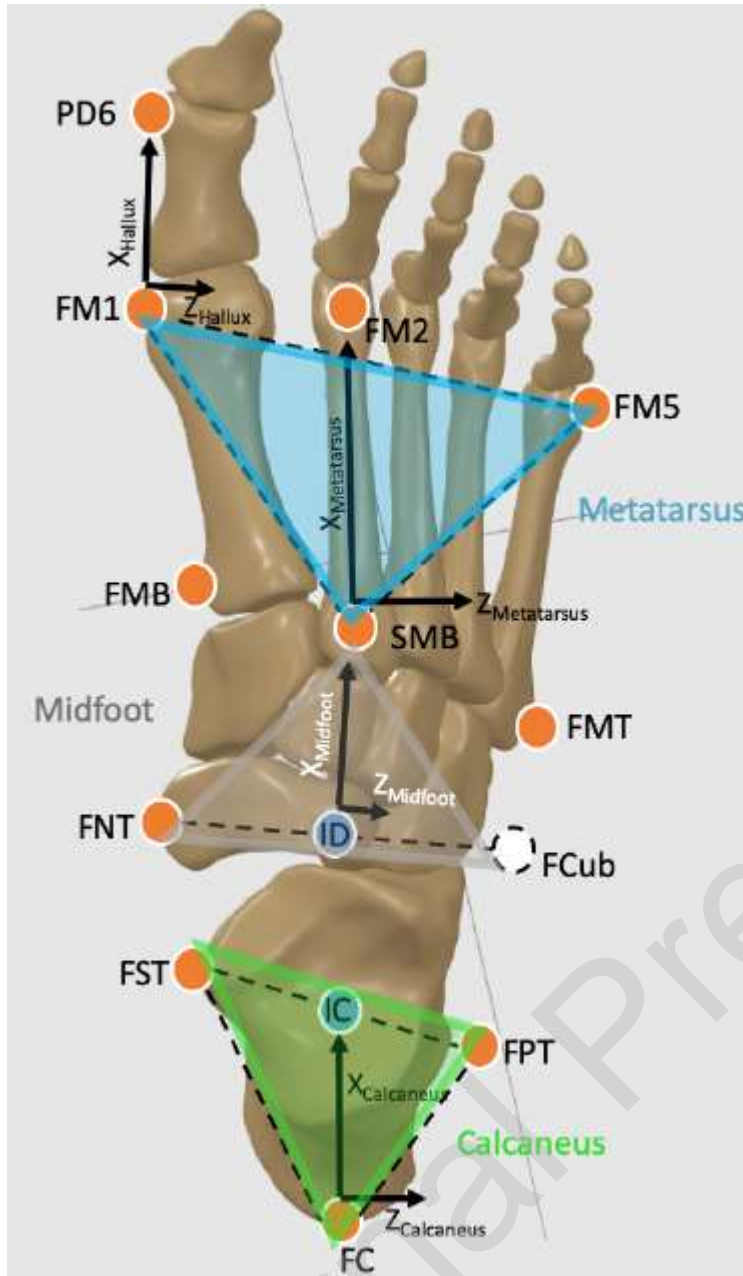
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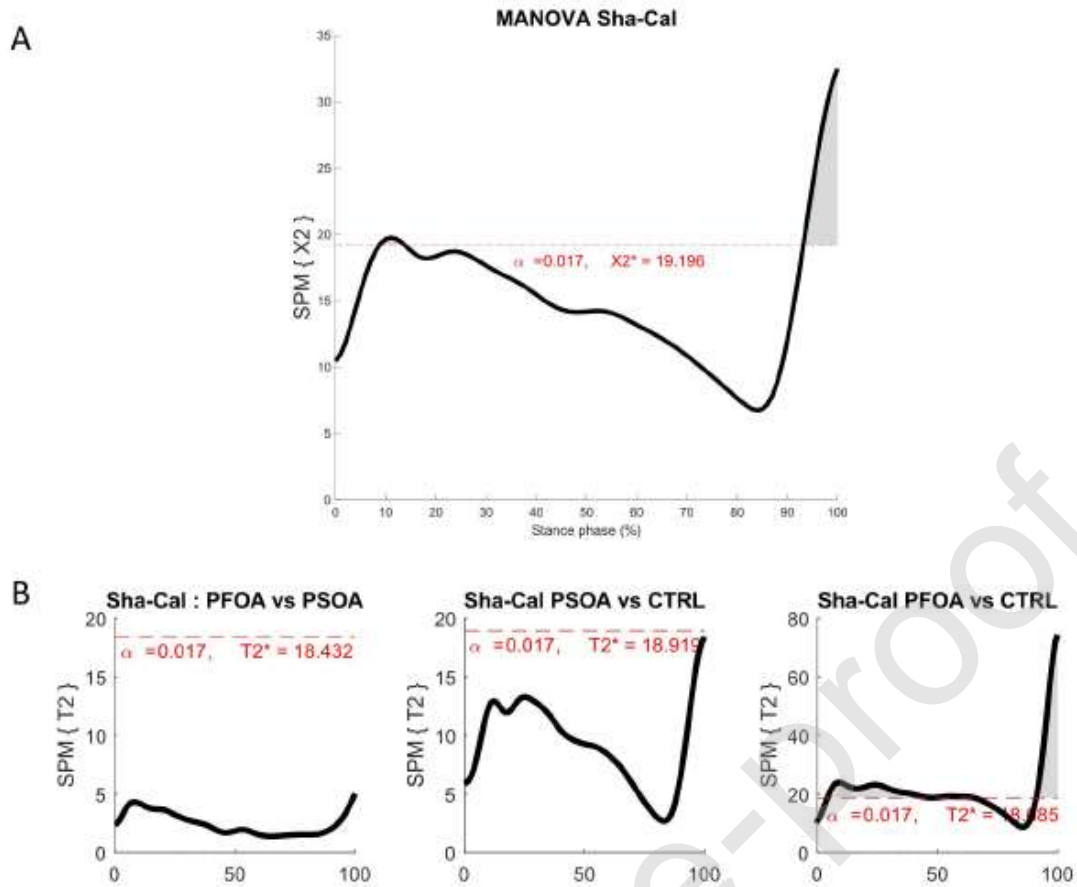
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**CAPTIONS**

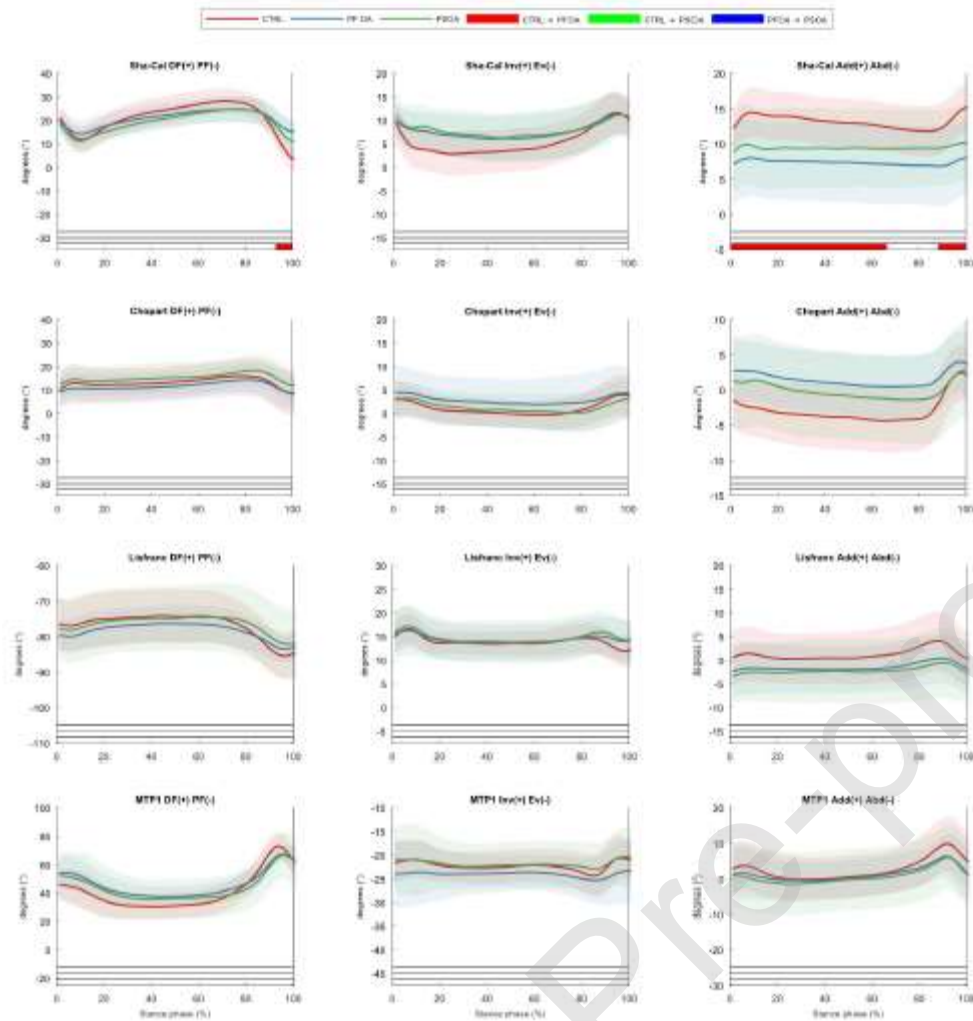
**Figure 1:** Inter-segment center definitions were defined according to an adapted version of Rizzoli foot model (Leardini et al. 2007) developed by Deschamps et al. (2017) (IOR-4Segment-model 1). Markers name: upper ridge of the posterior surface of the calcaneus (FC); peroneal tubercle (FPT); sustentaculum tali (FST); virtual cuboid marker (FCub), tuberosity of the navicular bone (FNT); first, second and fifth metatarsal base (FMB, SMB, FMT); first, second and fifth metatarsal head (FM1,FM2, FM5); PD6: distal dorso-medial aspect of the head of the proximal phalanx of the hallux; First Metatarso-phalangeal joint center (FM1); Midfoot-Metatarsus center (SMB); Calcaneus-Midfoot center (ID)



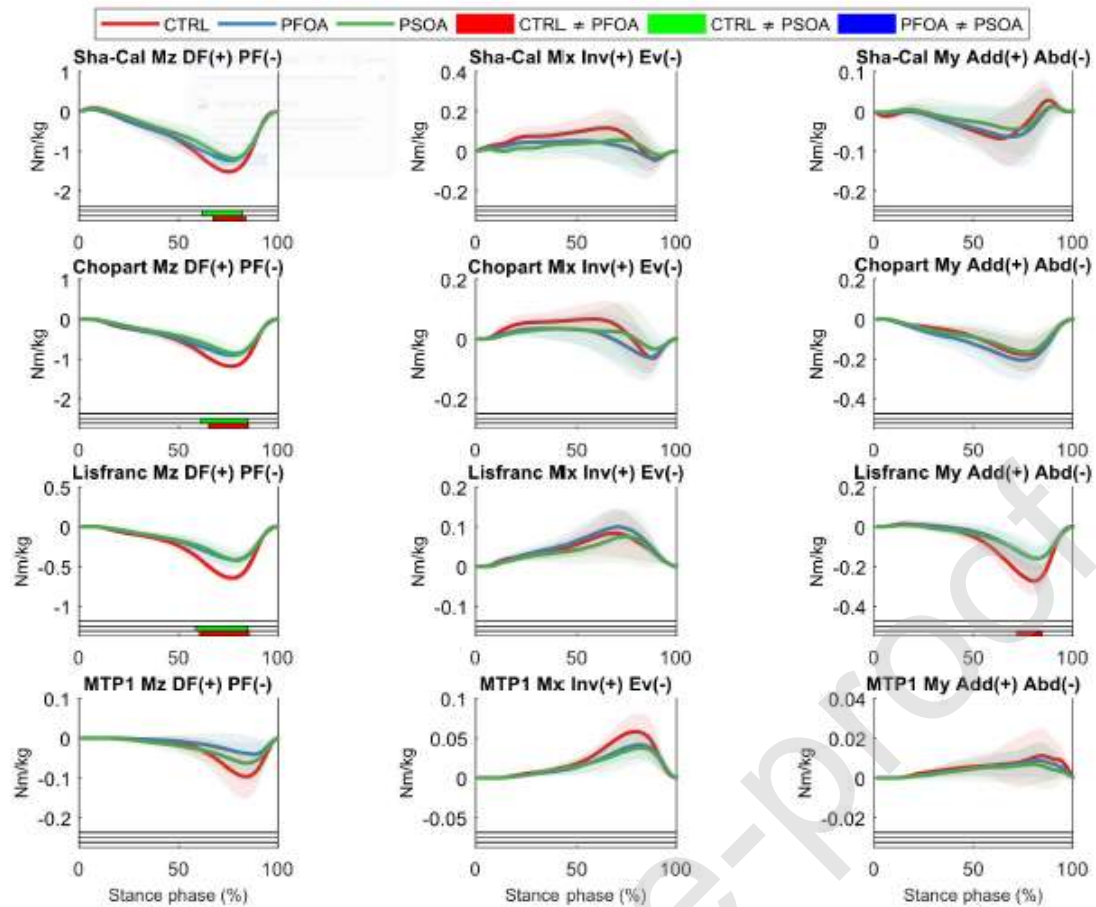
**Figure 2:** A) MANOVA ( $SPM\{\chi^2\}$ ) results depicting group differences. The critical threshold (red dashed line) was 19.196. Two regions (supra-threshold clusters – shaded) of the  $\chi^2$  trajectory exceeded the critical threshold. MANOVA ( $SPM\{\chi^2\}$ ) therefore shows a significant group difference ( $P < 0.0169$ ). B) Post-hoc Hotelling's  $T^2$  test suggested that this difference was mainly between PF OA and CTRL groups.



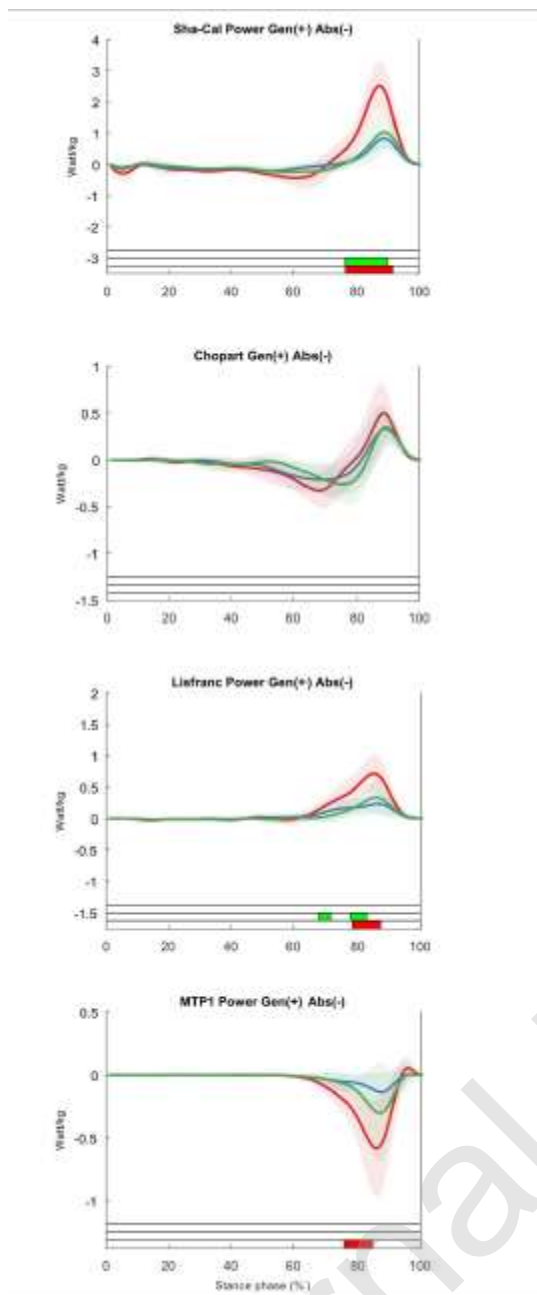
**Figure 3:** Joint angle waveforms representation with  $\pm 1$  standard deviation cloud for the intrinsic foot joints between the three groups during the stance phase of gait: Sha-Cal: Shank-Calcaneus; Chopart; Lisfranc; MTP1: 1st Metatarso-Phalangeal joint. PS OA group (green), CTRL group (red) and PF OA (blue); DF: dorsiflexion ; PF: plantarflexion; Add: Adduction ; Abd :Abduction ; Inv: Inversion ; Ev: Eversion. Statistical between-group differences ( $P < 0.0169$ ) according to the post-hoc analyses two sample t-tests (SPM{t}) for individual component of the intrinsic foot joint angles are presented underneath each figure as a color box (red box: group difference between CTRL and PF OA; green box: group difference between CTRL and PS OA; blue box: group difference between PS OA and PF OA).



**Figure 4:** Joint moment waveforms representation with  $\pm 1$  standard deviation cloud for the intrinsic foot joints between the three groups during the stance phase of gait: Sha-Cal: Shank-Calcaneus; Chopart; Lisfranc; MTP1: 1st Metatarso-Phalangeal joint. PS OA group (green), CTRL group (red) and PF OA (blue); DF: dorsiflexion ; PF: plantarflexion; Add: Adduction ; Abd :Abduction ; Inv: Inversion ; Ev: Eversion. Statistical between-group differences ( $P < 0.0169$ ) according to the post-hoc analyses two sample t-tests (SPM{t}) for individual component of the intrinsic foot joint moments are presented underneath each figure as a color box (red box: group difference between CTRL and PF OA; green box: group difference between CTRL and PS OA; blue box: group difference between PS OA and PF OA).



**Figure 5:** Power waveforms representation with  $\pm 1$  standard deviation cloud for the intrinsic foot joints between the three groups during the stance phase of gait: Sha-Cal: Shank-Calcaneus; Chopart; Lisfranc; MTP1: 1st Metatarso-Phalangeal joint. PS OA group (green), CTRL group (red) and PF OA (blue); Gen (+): Generation ; Abs (-): Absorption. Statistical between-group differences ( $P < 0.0169$ ) according to the post-hoc analyses two sample t-tests (SPM{t}) for the power variables are presented underneath each figure as a color box (red box: group difference between CTRL and PF OA; green box: group difference between CTRL and PS OA; blue box: group difference between PS OA and PF OA).



**Table 1:** Demographic and spatio-temporal data between 1) post-sprain ankle osteoarthritis (PS OA); 2) post-traumatic post-fracture ankle osteoarthritis (PF OA) and 3) asymptomatic control subjects (CTRL). Abbreviations: COFAS: Canadian Orthopaedic Foot & Ankle Society classification system for ankle osteoarthritis (Type 1 has isolated ankle osteoarthritis; Type 2 signifies ankle osteoarthritis associated with intra-articular ankle deformity or a tight heel cord or both, Type 3 patients have ankle osteoarthritis with deformity of the hind- or midfoot, tibia or forefoot; and Type 4 includes Type 1 to Type 3 plus subtalar or calcaneocuboid or talonavicular osteoarthritis); SD: standard deviation; BMI: body mass index; N.S.: not significant. \*Post hoc Tukey honestly test ( $P < 0.05$ ).



	PS OA (n=15 ankles)			PF OA (n=15 ankles)			CTRL (n= 15 ankles)			ANOVA (F) / Kruskal-Wallis (H)		PS OA vs PF OA	PS OA vs CTRL	PF OA vs CTRL
	Mean	SD	Min- Max	Mean	SD	Min- Max	Mean	SD	Min- Max	F / H	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
<b>Age (years)</b>	63,86	5,96	51-70	58,47	9,79	38-74	59,67	7,96	43-70	3,216 (H)	0,196	N.S.	N.S.	N.S.
<b>Height (m)</b>	1,72	0,11	1,48- 1,90	1,73	0,08	1,57- 1,85	1,72	0,07	1,63- 1,83	0,218 (H)	0,897	N.S.	N.S.	N.S.
<b>Weight (kg)</b>	82,64	12,50	59-100	84,13	15,09	64-111	77,36	15,85	53-111	0,888 (F)	0,419	N.S.	N.S.	N.S.
<b>BMI</b>	28,01	4,23	21,7- 34,60	28,01	4,21	21,38- 34,6	26	4,27	19,95- 34,64	1,109 (F)	0,34	N.S.	N.S.	N.S.
<b>Walking Speed (m/s)</b>	0,91	0,17	0,61- 1,27	0,97	0,19	0,65- 1,27	1,25	0,15	0,96- 1,46	16,498 (F)	< 0,001	0,592*	< 0,001*	< 0,001*
<b>Stride Length (% Height)</b>	0,64	0,05	0,56- 0,75	0,65	0,09	0,44- 0,75	0,78	0,06	0,66- 0,88	19,835 (F)	< 0,001	0,940*	< 0,001*	< 0,001*
<b>COFAS</b>	Type 1	4		Type 1	7		N/A							
	Type 2	5		Type 2	0									
	Type 3	5		Type 3	6									
	Type 4	1		Type 4	2									

**Table 1** : Demographic and spatio-temporal data between 1) post-sprain post-traumatic ankle osteoarthritis (PS OA); 2) post-traumatic post-fracture ankle osteoarthritis (PF OA) and 3) asymptomatic control subjects (CTRL). Abbreviations: COFAS : Canadian Orthopaedic Foot & Ankle Society classification system for ankle osteoarthritis (Type 1 has isolated ankle osteoarthritis; Type 2 signifies ankle osteoarthritis associated with intra-articular ankle deformity or a tight heel cord or both, Type 3 patients have ankle osteoarthritis with deformity of the hind- or midfoot, tibia or forefoot; and Type 4 includes Type 1 to Type 3 plus subtalar or calcaneocuboid or talonavicular osteoarthritis); SD : standard deviation; BMI : body mass index; N.S. : not significant. \*Post hoc Tukey honestly significant difference test.