

# SEGMENTAL KINEMATIC ANALYSIS USING A TRIDIMENSIONAL RECONSTRUCTION OF RAT HINDLIMB: COMPARISON BETWEEN 2D AND 3D JOINT ANGLES

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## INTRODUCTION

Functional recovery is one of the primary goals of therapeutic intervention in neuromuscular research. Animal models have been widely used to assess motor and sensory functions after induced lesion. Several spatial and kinematic parameters have been reported as sensitive outcome variables to quantify functional recovery: ankle angle, ankle-stance angle, stance/swing ratio, step length ratio, angle of the ankle joint at terminal stance, angle of the ankle joint at midswing, tail height, tail deviation and midline deviation. Eversion, dragging and exorotation of the foot during stance phase is referred by Meek [1] as an important aspect of walking quality. The rotation of the injured paw instead of dragging, contracture of toes, inversion of the feet and plantar flexion of the toes have been described as the main qualitative of abnormalities observed in foot placement during locomotion. Nevertheless there are few published studies where tridimensional kinematics is used to describe rat's locomotor function [2,3]. What is, this approach is based on the vector dot product, which only enables us the computation of planar angles [4], moreover only sagittal plane angular data has been reported. In order to better understand the effects of induced lesions in rat's locomotor function, a more anatomical and functional approach should be considered. The purpose of the present study is: (1) to perform a segmental kinematic analysis using a tridimensional reconstruction of the rat hindlimb, regarding the morphology and the movement of each segment, (2) to calculate hip, knee, ankle and metatarsophalangeal planar angles (sagittal, frontal and transverse planes) and (3) to compare both 3D (Cardan sequence x-y-z) and 2D angles for the peaks of flexion, extension, IC (initial contact), TO

(toe-off), midstance, midswing, stance amplitude and swing amplitude in the sagittal plane of motion.

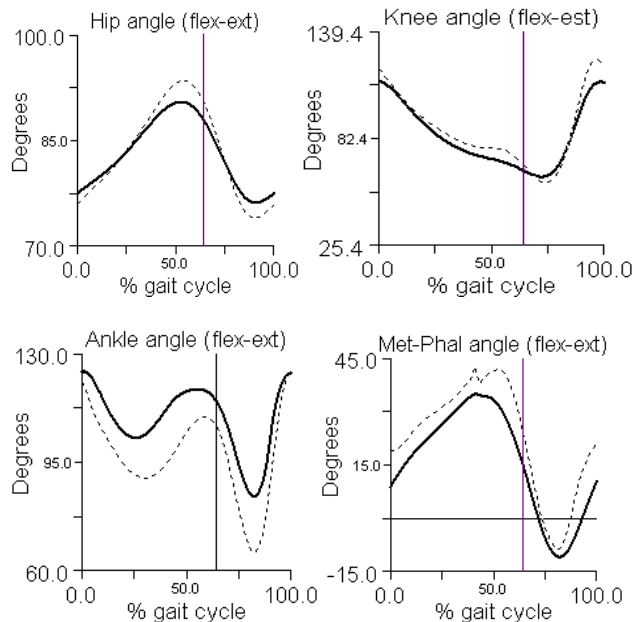
## METHODS

Eight adult male Sasco Sprague Dawley rats (Harlan, Barcelona, Spain) with approximately 250g and 0,23m of length were used in this study. Motion capture was collected with an optoelectronic system of 6 cameras Qualisys (Oqus-300) operating at a framerate of 200Hz. Animals walked on a Perspex track with length, width and height of respectively 120, 12 and 15 cm. 7 reflective markers with 2mm diameter were attached to 7 bony prominences on the right side of the rat: 4<sup>th</sup> finger, 5<sup>th</sup> metatarsal head, lateral malleolus, lateral knee joint, great trochanter, anterior superior iliac spine and ischial tuberosity. Three non collinear markers were attached to segments foot, shank and thigh. Seven virtual markers (placed medially to the attached ones) were generated by means of anthropometric and CT scans data, to obtain the correct joint diameter. Five body segments were reconstructed: pelvis, right thigh, right shank, right foot and right finger using Visual 3D software for biomechanics modeling. A total of 42 gait cycles kinematics from 7 rats were obtained. Gait parameters were normalized to the gait cycle. Three-dimensional biomechanical analyses were carried out and hip, knee, ankle and metatarsophalangeal joint angular displacements were calculated.

## RESULTS AND DISCUSSION

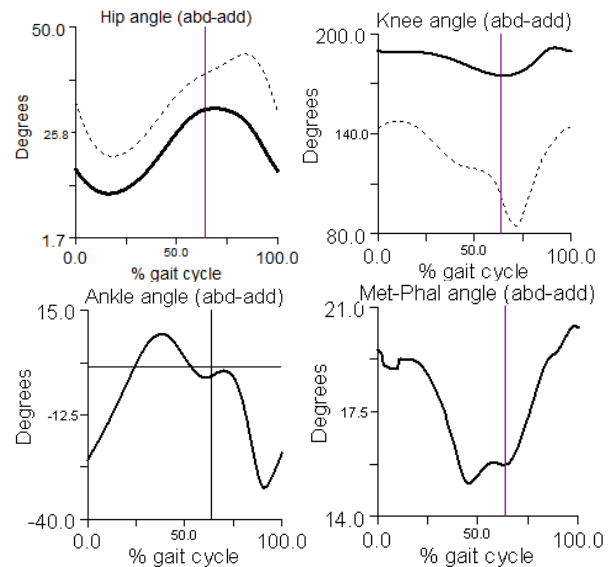
There were no significant differences when comparing averaged 2D and 3D angular displacements for the flexion/extension actions in the hip and ankle joint parameters (Fig.1). However,

extension peak and swing amplitude in the knee joint are significantly different between 2D and 3D approaches, with a knee extension peak of 110° and 123° for the 3D and 2D methods, respectively. Knee angular amplitude in the swing phase was 69° and 50° for the 3D and 2D methods, respectively. Also, MF joint shows statistically significant differences in the extension peak (40° and 51° for 3D and 2D, respectively) and angular displacement at IC instant (9° and 18° for the 2D and 3D, respectively).



**Figure 1:** Averaged 3D angular displacement (solid line) of lower limb joints around the medio-lateral axis of rotation. Averaged 2D planar angle (sagittal plane) (dotted line). Vertical line corresponds to toe-off instant.

Regarding 3D joint angular displacement around the anterior-posterior axis (Fig.2), hip adduction peak occurs at 17% of gait cycle with an angle of 9.7°, while the abduction peak occurs at 70%, with an angle of 30°. IC, midstance, midswing and TO occur with the hip at 18°, 16°, 28° and 13° of angular displacement, respectively. Stance amplitude is 13° and swing amplitude is 28°. Knee abduction/adduction 3D curve reveals a pattern that suggests a more functional behavior, when compared with 2D curve. Ankle and MF joints show an eversion peak of 9° at 39% of gait cycle and an inversion peak of 15° at 50% of gait cycle, respectively. Regarding segments axial rotation, foot segment has an external rotation peak of -20°, occurring at 54% of gait cycle.



**Figure 2:** Averaged 3D angular displacement (solid line) of lower limb joints around the anterior-posterior axis of rotation. Averaged 2D planar angle (frontal plane) (dotted line). Vertical line corresponds to toe-off instant.

## CONCLUSIONS

Angular displacement not just in sagittal plane but also in frontal and transverse planes of motion seems to have an important functional meaning, due to the existence of a gait pattern where eversion of the foot and exorotation occur. Clinical conditions also refer toe angular deviations, so including toe segment in rat kinematics is extremely important. Moreover, adding segment's axial rotation to kinematic data will allow the recognition of several dysfunctional events in gait patterns. Comparing 2D with 3D computing methods, it should be considered that rat joints are not always aligned in the same plane of motion, so computing planar angles can under/overestimate joint angular displacement. Nevertheless, the contribution of the Euler/Cardan rotations for the joint angular displacement cannot be neglected, in order to clarify which kinematics gait parameters are specially connected to functional recovery.

## REFERENCES

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