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GAIT COMPENSATIONS IN RATS AFTER A TEMPORARY NERVE PALSY

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SUMMARY

The aim of this work was to define a method for measuring the gait of rats in order to characterise their locomotion and provide a reliable measure for joint pathology and recovery. The gait of healthy rats was assessed during normal locomotion, shortly after temporary nerve block to the left hind limb and again after full recovery. Average gait parameters for female Sprague-Dawley rats (SD) were determined using an optical motion tracking system (Vicon, Oxford, UK) and the DigiGait™ imaging system (Mouse Specifics, Boston MA).

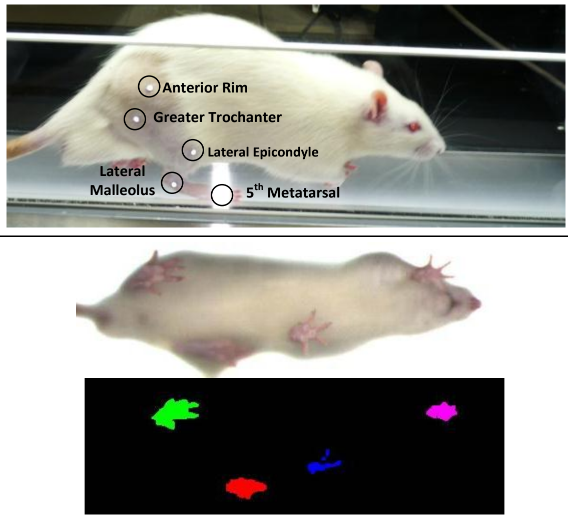
Gait dynamic analysis and joint kinematics were found to be a reliable approach for the quantification of the gait of healthy and injured rats and joint kinematics was shown to be more sensitive in identifying subtle deficits in movement associated with nerve injuries.

INTRODUCTION

About 12.9% of extremity injuries sustained after a blast are associated with peripheral nerve injury, often distant to the site of direct impact and without visual physical damage to the affected limb [1]. Even though animal models have been commonly used for investigating neurological diseases, studies looking at blast related nerve injuries are limited. Since most of the neurological diseases are accompanied by gait changes, understanding rat locomotion can provide an objective measure for nerve dysfunction and recovery [2, 3]. The aim of this study was to define a method for measuring the gait dynamics and kinematics of the hind-limbs of rats during normal gait, impaired gait due to a nerve palsy, and recovery.

METHODS

The locomotion of four adult female Sprague-Dawley (SD) rats was studied during treadmill walking at different speeds between 10 to 30 cm/sec. The DigiGait™ system captured the ventral aspect of the animals whilst walking, using a high-speed digital video camera, mounted below a transparent treadmill belt. Simultaneously, three-dimensional kinematics were acquired using an optical motion tracking system at 200 Hz, imaging 3 mm diameter reflective markers attached on the skin over prominent bony landmarks (Figure 1).



(a)

(b)

Figure 1: (a) Lateral and (b) ventral view of a rat on the treadmill (the retro-reflective markers on ankle, knee, hip and pelvis are visible in (a)).

The gait of the rats was assessed during normal locomotion, 30 min after a transient sciatic nerve block was induced by injection of local anesthetic (0.2 ml of 0.5% Lidocaine) just caudal to the greater trochanter of the left hip and 90 min post injection. Statistical differences between the gait parameters and angular data were assessed using a repeated measures analysis of variance (ANOVA) test with the Bonferroni correction. Inter-limb joint angle coordination was assessed using the symmetry error [4] that characterised left–right symmetry for the entire gait cycle.

RESULTS AND DISCUSSION

During normal gait, dynamic parameters and joint angles were within the range reported for rats for treadmill walking [5, 6 and 7]. As the speed of the treadmill belt increased, there was a decrease in the stance phase duration ($p<0.01$), whilst the swing time remained almost constant. Stride length was also found to increase with speed (Table 1). Kinematic waveforms were similar across the different speeds (Figure 2a); however, as the speed increased joint angle graphs were shifted to the right, showing prolonged swing phase and shortened stance phase.

Temporary sciatic nerve block in the left hind-limb had significant effects on both stance and swing joint angles in the affected limb (Figure 2b). Most rats were able to run only at speeds of 10 and 15 cm/sec and when compared to normal gait, the range of motion of the left ankle and knee joints significantly decreased. At the same time, the range of motion of the contralateral ankle joint increased. Gait dynamics revealed that the stance phase duration of the left limb significantly decreased (p<0.05) whereas that of right limb increased. Furthermore, the injured rats avoided placing their affected foot onto the belt leading to a noticeable reduction (p<0.05) of the maximum paw area on the treadmill over time (Max dA/dT). Videos of the rats' sagittal and lateral views confirmed that the rats tended to drag their left hind limb for most of the gait cycle.

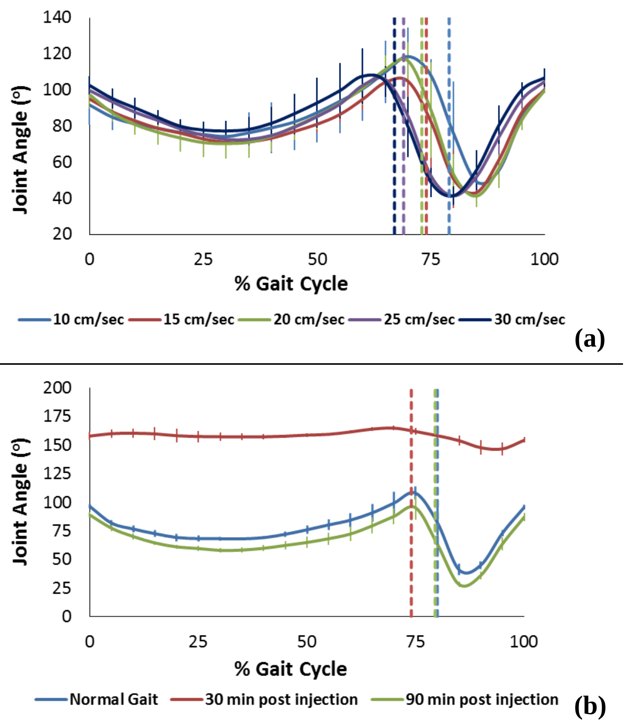


Figure 2: Mean flexion (-ve) / extension (+ve) angles and standard deviations for the left ankle during treadmill locomotion of one rat; (a) during normal gait at different speeds and (b) during impaired gait and recovery. The vertical dashed line marks the stance-swing transition.

The symmetry error between the ankle joints was $7^0 \pm 2^0$ during normal gait, but increased to $57^0 \pm 7^0$ at 30 min post injection revealing an un-coordinated gait. At 90 min post injection the symmetry error reduced to $3^0 \pm 3^0$, suggesting that the rats had fully recovered and adopted a coordinated gait. Gait dynamics (Table 1) further supported this argument, as there were no statistical differences between the parameters before the injection and after 90 min. The mean range of motion for all the joints after the animals had recovered was similar to those recorded during normal gait; however, in the ankle joint there was a noticeable decrease in the peak extension and flexion angles during the stance and swing phases respectively (p<0.05), suggesting that minor walking deficits were still present.

CONCLUSIONS

This study presents a quantitative analysis of rat locomotion, using the DigiGait™ imaging system and the optical motion tracking system from Vicon. Gait dynamic and kinematic parameters during normal gait fall within ranges reported in literature. Both methods provide valuable information about the compensation methods of rats after a nerve injury and are able to detect recovery. In particular, joint kinematics appear to be more sensitive in identifying subtle changes in movement [6], however this needs to be further investigated to confirm the feasibility and greater detail of this approach.

ACKNOWLEDGEMENTS

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Table 1: Gait dynamics of the left hind foot of the female rats. Data expressed as mean ± SD were collected during normal gait, 30 min after the injection of local anesthetic near the greater trochanter of the left hip and 90 min post injection.

	Speed (cm/sec)	Swing (sec)	Stance (sec)	Stride Length (cm)	Max dA/dT (cm^2/sec)
Normal Gait	10	0.14 (0.03)	0.65 (0.14)	7.90 (1.36)	210.09 (52.51)
	15	0.14 (0.02)	0.50 (0.09)	9.50 (1.58)	202.74 (40.51)
	20	0.13 (0.01)	0.39 (0.03)	10.58 (0.66)	208.34 (40.30)
	25	0.13 (0.01)	0.32 (0.02)	11.30 (0.34)	178.71 (28.68)
	30	0.13 (0.01)	0.29 (0.02)	12.58 (0.42)	190.30 (30.76)
30 min post injection	10	0.14 (0.02)	0.36 (0.08)	5.48 (1.03)	73.99 (10.30)
	15	0.16 (0.04)	0.31 (0.03)	7.07 (1.13)	74.25 (11.55)
90 min post injection	10	0.16 (0.04)	0.68 (0.22)	8.37 (2.56)	233.79 (37.77)
	15	0.16 (0.01)	0.51 (0.04)	10.00 (0.71)	209.84 (37.72)
	20	0.15 (0.02)	0.38 (0.04	10.67 (0.61)	271.77 (36.53)
	25	0.15 (0.01)	0.41 (0.02)	13.85 (0.35)	189.64 (28.88)