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CatWalk: the next step in gait analysis

By Guido C. Koopmans

Quantitative gait analysis is useful in objective assessment of walking ability as well as identifying the underlying causes for walking abnormalities in patients with cerebral palsy, Parkinson disease, stroke, head or spinal cord injury, and other neuromuscular problems. The results of gait analysis have shown to be useful in determining the best course of treatment in these patients.

Over the years many different methods are developed to analyze gait in laboratory animals. Most of these methods focus on overground locomotion and range from scoring spontaneous open field locomotion [1] to more sophisticated methods using contact electrode recordings [2], footprint analysis [3], kinetics [4], 2D and 3D kinematics [5], and CatWalk™ [6]. The latter, a computer-assisted automated quantitative gait analysis system, allows rapid and objective quantification of a large number of gait parameters, both static and dynamic. Especially the dynamic parameters (e.g. swing duration, stance duration, and inter-limb coordination) were difficult to analyze prior to the availability of CatWalk.

This user report focuses on CatWalk as a method to analyze and quantify locomotion in a model of spinal cord injury (SCI). The parameters measured by CatWalk, in particular measures for coordination, are used to test the behavioral implications of voluntary locomotor training induced by enriched housing facilities.

Experiment

A spinal cord contusion injury at low-thoracic spinal cord level was performed in adult male rats (Wistar strain). After injury, all animals were housed individually for three weeks. Thereafter, the animals were kept either in an enriched environment (EE) [7] or remained housed individually in normal (N) type III macrolon cages. The animals stayed in their housing facilities (EE or N) for a period of eight weeks. CatWalk data were obtained before injury and at 21, 49, and 77 days after injury. The habituation, pre-training, and testing procedure are described previously [8]. Briefly, one week prior to testing, the animals were habituated and trained to cross the walkway. Walkway crossing was stimulated by rewarding the animals after each run with small food pellets. For reliable assessment of locomotor performance, three uninterrupted runs per animal per time point were analyzed and we thereby focused on the following CatWalk parameters:

1. *Regularity Index (RI):* The RI defines coordination as the exclusive use of normal step sequence patterns (NSSP) during uninterrupted locomotion. The regularity index (RI) grades the degree of coordination as follows: RI = (NSSP x 4/PP) x 100%, wherein PP represents the total number of paw placements.
2. *Phase Lag:* Phase lag quantifies interlimb coordination by measuring timing relationships between footfalls; the time of initial contact of one of the paws is related (expressed as %) to the stride cycle of another paw; for details see [9, 10]. Phase lag can be calculated (1) between limbs on the same girdle (girdle pair), (2) between limbs on the same side (lateral pair), and (3) between the opposite front- and hind limb (diagonal pair).
3. *Phase lag variability:* Phase lags are calculated for every single stride cycle and normally 5-6 stride cycles are needed to cross the walkway from which the variability (standard deviation of the mean) is calculated. In the present experiment we focused on phase lag variability in girdle and lateral pairs.
4. *Phase lag mismatch %:* When a step does not fit the constraints set for computation of the phase lag a mismatch (error) is scored. The number of mismatches are related to the total number of steps and expressed as mismatch %. We focused on phase lag mismatch % in girdle and lateral pairs.

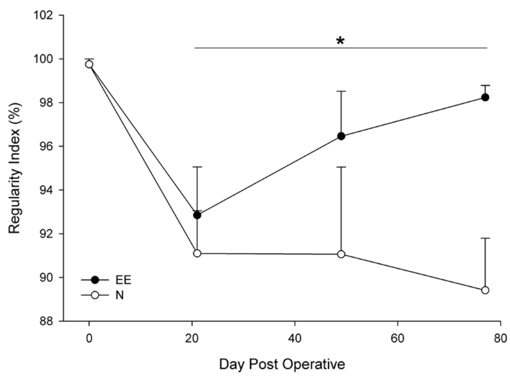

Figure 1. *The regularity index (RI) was high before injury (DPO-0; RI (%) 99.75 ± 0.25, mean ± sem). Three weeks after injury, at the beginning of the treatment perio, the mean RI was decreased (DPO-21, EE 93.9 ± 2.2 and N 91.6 ± 2.7, mean ± sem). During the following two months of treatment the RI recovered close to pre-operative levels in the EE animals, whereas the RI did not recover at all in the N animals.*

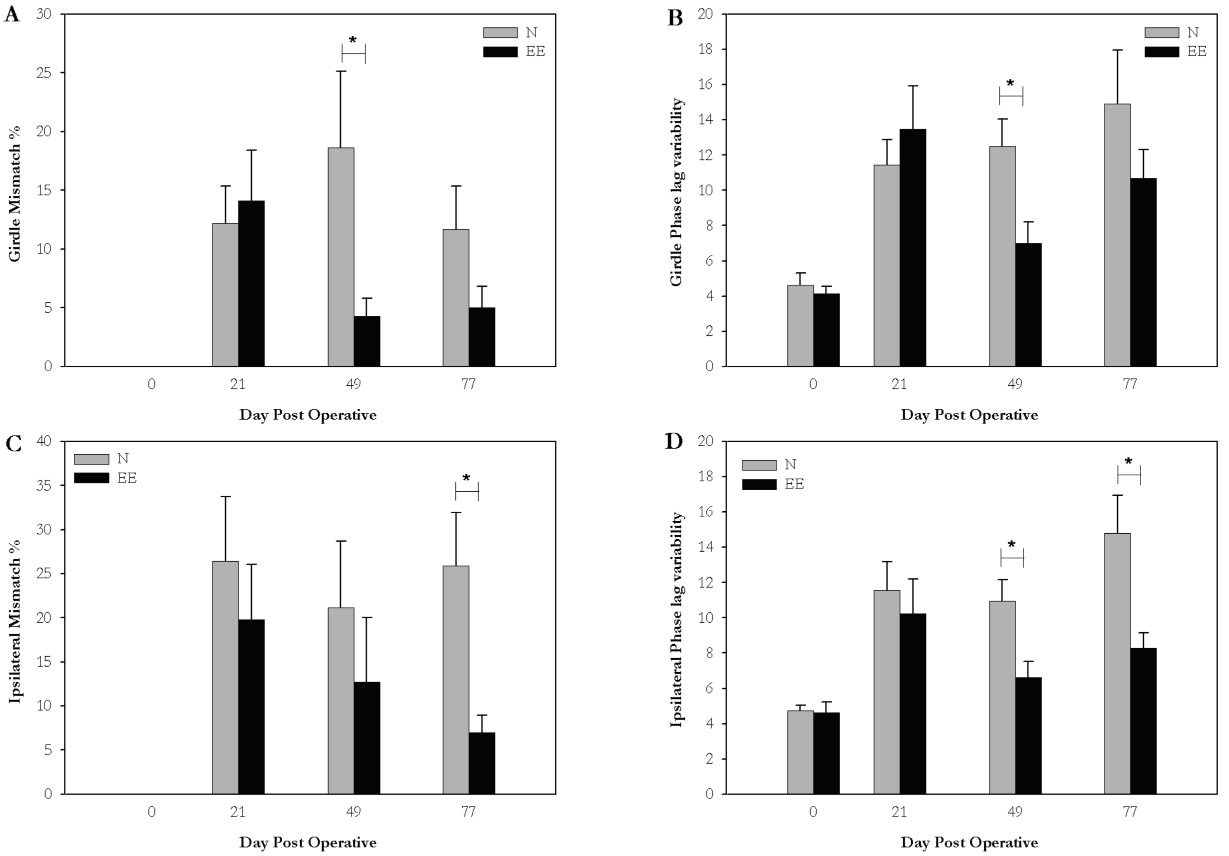

Figure 2. *Interlimb coordination as assessed by the phase lag related parameters: mismatch % and phase lag variability. The girdle (A) and ipsilateral mismatch % (C) showed that before injury all paw placements fitted the constraints set for computation of the phase lag. Injury of the spinal cord resulted in an increase of both the girdle and ipsilateral mismatch % at DPO-21. Thereafter, the number of mismatches decreased in EE housed animals and remained the same in N housed animals. The girdle (B) and ipsilateral phase lag variability (D) was low at pre-operative testing but increased 3 weeks post-operative. At DPO-49, the girdle variability in normal housed animals remained increased but significantly decreased in enriched housed animals. The ipsilateral variability in EE housed animals was shown to be complete recovered to preoperative values at DPO-49. At the end of the experiment, significant differences remained on the ipsilateral variability whereas this was not observed for the girdle variability. All values are expressed as Mean + SEM, * $p < 0.05$.*

Most important findings & conclusions

The RI clearly showed a positive effect of enriched housing after spinal cord injury as can be seen in figure 1. Next to the RI, the parameters phase lag mismatch % and phase lag variability were able to pin-point important functional improvements with respect to interlimb coordination as induced by enriched housing (see figure 2). The parameter phase lag did not reveal differences between the two groups. The RI has shown to be a useful parameter to analyze treatment-induced recovery of interlimb coordination. Moreover, the recent implementation of the phase lag computation in CatWalk allows objective and semi-automated quantification of interlimb coordination based on the time-relationships between footfalls in a large number of subjects. As a consequence this enabled the development and use of the phase lag variability and the phase lag mismatch % as extra outcome measures to assess interlimb coordination and the recovery hereof.

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