PRENATAL MOTOR DEVELOPMENT AFFECTS OBSERVED MOTOR BEHAVIOR FOR DIFFERENT INCUBATION PERIODS IN DOMESTIC CHICK

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INTRODUCTION

The length of incubation and thus, the time to hatch, significantly vary in chick embryos (*Gallus gallus*) with light exposure conditions. Continuous incubation in the dark throughout embryogenesis (24D) delays hatching by 1-2 days (~5-10% of total gestation), as compared to incubation in daily periodic light (12 hours of light, 12L) or continuous bright light (24L). Do such light-induced changes during prenatal development impact postnatal motor skill? Our null hypothesis is that, regardless of incubation conditions, chicks adapt and hatch equally ready to cope with the postnatal environment. In agreement with this, a recent study of global gait parameters found no differences in body weight, leg length or locomotor competence across these 3 conditions [1]. However, unconstrained overground locomotion is a highly variable behavior, and the global gait parameters may not have been sufficiently sensitive to detect group differences, if they existed. Thus, in this study we investigate postural control of sway during quiet stance, by examining center of pressure (COP) dynamics, as a more sensitive measure of motor skill [2]. Our results identify significant differences across incubation conditions for several postural metrics, suggesting that length of incubation impacts motor behavior on the day of hatching.

METHODS

To investigate COP dynamics during quiet stance, we trained chicks on the day of hatching to stand on a custom-designed force plate (Fig. 1), positioned on a 6-axis force transducer (ATI Nano17, Apex, NC). Hatchlings stood quietly on the force plate for 30 s per trial for a minimum of 3 trials (N=30 chicks, 10 chicks per light condition). All procedures were approved by the USC IACUC.

We extracted the 2-dimensional COP data (Fig.2) and analyzed parameters commonly investigated in postural control studies: mean sway velocity (MV), mean sway angle (SW), and mean distance from COP centroid (MD) [2]:

$$MV = \sum_{n=1}^{N-1} \left| X[n+1] - X[n] \right| / T$$

$$SW = 1/2T \sum_{n=1}^{N-1} \left| X_1[n+1] X_2[n] - X_1[n] X_2[n+1] \right|$$

$$MD = 1/N \sum_{n=1}^{N} \left[X_1[n]^2 + X_2[n]^2 \right]^{1/2}$$

where T is the trial length and X[n] are the 2-dimensional coordinates at the n-th sample. Moreover, we computed the variance percentage explained by the anterior-posterior/medio-lateral (AP/ML) directions as well as the ratio of these variances. Next, we separated deterministic components, possibly related to a control strategy, from stochastic components, i.e. the noisiness of the system and looked for differences across conditions [3]. For this purpose, we fitted a 2nd order function V(x) to the data's state space [$X, \dot{X}$] according to

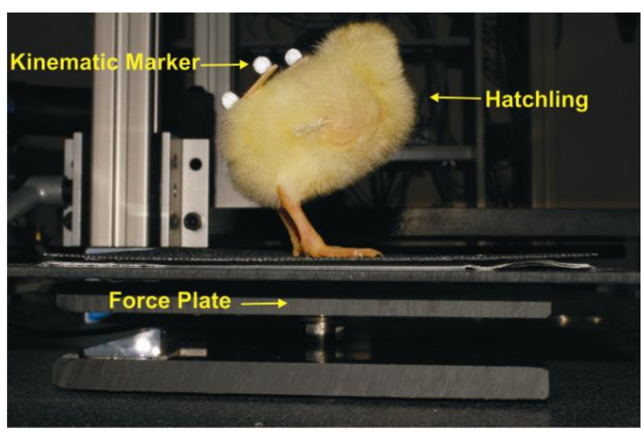

Figure 1: Experimental setup. A hatchling performing a quiet stance trial on the force plate.

the potential function formulation F = -dV/dx, i.e., the force applied to a particle is proportional to the value of a potential function V(x) [4]. Finally, we fitted a 2^{nd} order function to the data's state-dependent variance VAR(X|X = x) in a sufficiently large neighborhood of a sample data point x [2]. The potential function V(x) quantifies the tendency of a stable system to return to a stable fix point, in this case the COP centroid, for a given displacement, dx. On the other hand, the conditional variance quantifies the state-dependent variability of the COP dynamics.

RESULTS AND DISCUSSION

Postural control of sway, as measured by COP dynamics, differed significantly across the 3 incubation conditions with respect to sway velocity, sway area and average distances from the mean COP. All measures were largest for chicks experiencing the longest incubation period (24D condition) and smallest for chicks experiencing the shortest incubation period (24L condition). Also, the proportions of COP variance along the AP and ML directions were largest in the 24D group, while the ratios of these proportions were similar across conditions. This suggests that largest sway area positively varied with length of incubation. However, a similarly shaped COP ellipse was found across all chicks. Other metrics such as total number of turns during postural sway, total length of COP path and mean frequency of sway in AP direction did not vary with length of incubation induced by light conditions.

Regarding the deterministic vs. stochastic analysis, we found that chicks with the largest state-dependent accelerations were associated with longer incubation condition (24D). The findings indicate hatchlings in this group executed larger corrective efforts against COP divergence. Further, we found that these chicks also exhibited the largest state-dependent variability, suggesting a relatively stronger random or noise component.

CONCLUSIONS

In contrast to the findings of our earlier gait study, we find that quiet stance in chicks is affected by length of incubation, evidence that leads us to reject the null hypothesis. We see higher sway velocity,

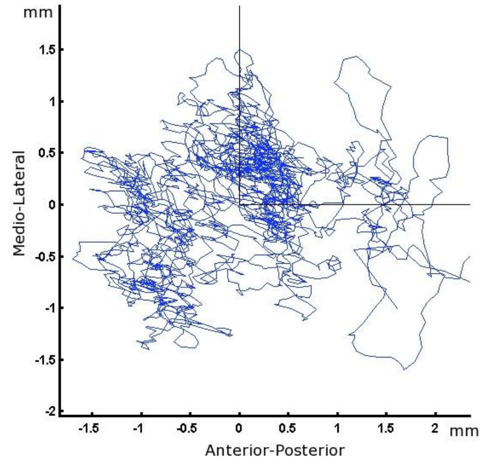

Figure 2: COP displacement in ML and AP directions for postural sway in a 24L hatchling.

larger sway area and longer average distances from mean COP in chicks with the longest incubation period (24D). These animals developed a noisier postural system, while exhibiting the strongest tendency to return to a stable fixed-point, possibly to cope with the increased noise level. Larger sway measures are typically associated with inferior postural control following nervous system lesions [5]. Thus, whether or not these differences reflect developmental adaptations in sensorimotor function requires further investigation. Moreover, our results suggest the next set of experiments in which the application of external perturbations during quiet stance tests postural stability. This would be a direct test of whether or not sensorimotor function is impacted by incubation period.

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