Approaching intraspinal mechanosensing in avians

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Avians belong to a diverse class of vertebrates and share the ability to locomote in largely different habitats. Their bipedal locomotion mode requires exceptional perception capabilities and limb-body coordination to maintain balance when running in unstructured terrains. Sensorimotor delays of several ten milliseconds lead to large muscle response times, potentially prohibiting high-frequency locomotion where state feedback is required [1].

Sensing mechanism located proximally to the spinal cord and its pattern generating units could lead to faster muscle responses–the sensorimotor pathways would be shorter [2]. Body rotation-compensating behavior observed in spinal cord transected birds indicates that local sensory control mechanisms exist [3]. Later, the lumbosacral organ (LSO) was described as a potential intraspinal mechanosensor [4–7]. The LSO structure consists of a glycogen body wedged between both spinal cord hemispheres, a pronounced network of denticulate ligaments supporting the hemispheres and the glycogen body, an enlarged spinal canal filled with cerebrospinal fluid, and accessory lobes which are potentially mechanoreceptive sensors. The accessory lobes protrude from the spinal cord hemispheres into the spinal canal near the denticulate ligaments. The lumbosacral organ's functionality is currently not fully understood. Previous hypotheses suggested a sensing mechanism based on the excitation of accessory lobes by intraspinal fluid-flow or ligament strain [5, 8].

We recently suggested that lumbosacral soft tissue could be entrained by the bird's body oscillations similar to a mass-spring-damper. The soft tissue movements would strain the denticulate ligaments, which in turn could be sensed by the nearby accessory lobes [7]. However, the lumbosacral organ is deeply embedded within the bony lumbosacral structure, making it difficult to in-vivo study its functionality.

As an alternative approach, we started developing a biophysical model (Figure 1B). The biophysical model is inspired by the 3D morphometrics of the lumbosacral organ of a common quail *(Coturnix coturnix)*, extracted by digital and classical dissections [7]. We simplified the model's geometry with a parametric design and scaled it to be fabricated and instrumented using soft-robotic tools. We also custom-designed a locomotion simulator to apply controlled locomotion oscillations and record the model's response. We can now start testing combinations of morphological features and external loads. We expect to quantify how morphological features alter the entrainment of the lumbosacral organ under external loads.

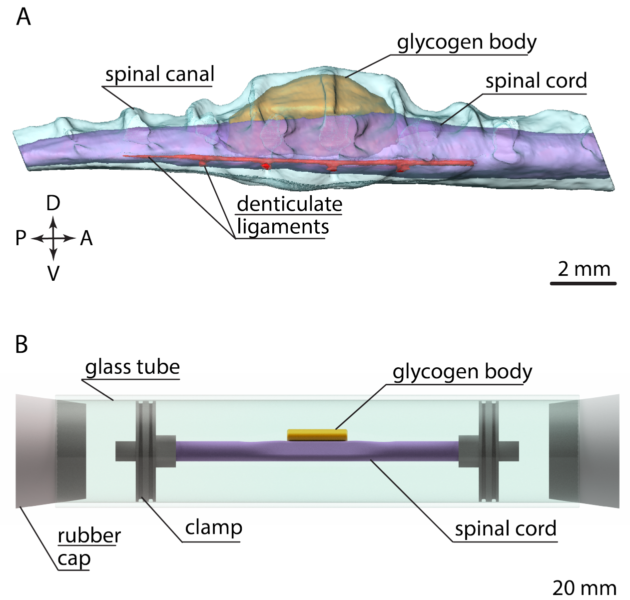

Fig. 1. (**A**) Lateral view of the 3D lumbosacral organ model with the spinal cord, the glycogen body, the denticulate ligaments, and the spinal canal filled with cerebrospinal fluid. The model was created from the digital dissection of a common quail. (**B**) Biophysical model with a simplified spinal cord and glycogen body. Both are mounted into a glass tube filled with water.

References

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