Expanding our view of the spine system

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Dear Editor,

This letter does not address specifically any particular article, but rather the larger body of work that exists in the spine literature. There exists a critical barrier for improving our understanding of the spine system, which stems from our characterization of stability and our application of reductionist methods. These limitations highlight the need for a new approach to study the spine.

Clearly for any system, including the spine, to fulfill its intended goal or function requires the system to be stable. For the spine, stable behavior allows it to bear loads, permits controlled movement, while avoiding injury and pain. Although there is some debate whether spine instability occurs in the classic sense, there is no debate that the spine must be stable to function.

It is a well-established theory that systems require feedback control for stability. With feedback control, information about the state of the system is used to generate stabilizing control input. This is true for simple systems, such as a ball on a hill, which rely on “passive” control or very sophisticated systems such as airplanes and rockets. The spine system fits into the latter group given its complexity. But what information about the system is required for stability? To answer this question, we can perform a simple experiment using a task known as stick balancing. Like the spine, a stick in the palm of the hand represents an inverted pendulum, which requires some form of control to maintain stability.

In Fig. 1, there are two stick balancing scenarios. In the first scenario (A), the stick is positioned to the left of the hand with zero velocity. To stabilize the stick would require the hand to move to the left, to bring the center of mass of the stick under the center of pressure acting on the palm. In the second case (B), the stick has the same starting position, but this time, it is moving to the right. For the second scenario, which direction should the hand move to catch the stick? It is unclear and depends on how fast the stick is moving. If it is moving extremely fast, the hand may have to move to the right and not the left to catch the stick. This experiments show that our controller (central nervous system) uses both position and velocity-related feedback to stabilize the stick. Moreover, it becomes quite clear that position-related feedback alone is insufficient for describing the state of the system and stabilizing it. This is true for the stick balancing system, as it is also for the spine system.

Our current biomechanical definition of spine stability is based on the elastostatic approach first derived by Bermark [1]. “Elasto” stems from the elastic properties of the system, such as trunk muscles stiffness, which helps stabilize the spine. “Static” refers to the fact that the spine system is frozen in time, meaning it is stationary. Hypothetical perturbations are applied to the spine in its current configuration to determine if it is stable. From this approach, it became apparent that muscles and the stiffness they provide are essential to maintain spine stability [1–4]. Not surprisingly, muscle stiffness became linked with stability.

There are a few limitations with the elastostatic approach. If we apply the elastostatic approach to the stick balancing example, it would predict that the system would be unstable. But we know if we apply forces to the base of the stick in the correct fashion, the stick can be stabilized.

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Fig. 1 **a** Stick is positioned to the left of the hand with zero velocity. **b** Stick positioned to the left of the hand, but moving to the right

In instances when control is important, the elastostatic approach fails to capture the dynamics of the task and may lead to incorrect predictions of whether the system is stable or unstable. Therefore, to investigate issues related to neuromuscular control, this approach does not provide much insight. Moreover, this approach, which represents a static characterization of stability, places too much emphasis on stiffness, which represents position-related feedback, and ignores the damping properties of the system, which represents velocity-related feedback. To demonstrate how little attention damping receives, we recently performed a PubMed search using the following terms: (1) stiffness AND stability AND spine, (2) stiffness AND instability AND spine, (3) damping AND stability AND spine, and (4) damping AND instability AND spine. Search 1 and 2 dealing with stiffness yielded 355 articles; whereas, search 3 and 4 dealing with damping yielded a meager 6 hits. It is apparent that damping characteristics are not associated with spine stability. This is true for in vitro testing of the osteoligamentous spine, in which the primary focus is on stiffness or its reciprocal, flexibility, as well as in vivo testing of spine neuromuscular control, which is typically concerned with assessing trunk stiffness.

As we are well aware, radiographic spine abnormalities are not always associated with spine pain or injury. Furthermore, motor control impairments may not always be present in symptomatic individuals. For the most part, the way we currently study the spine system is through a reductionist approach, in which components of the system are isolated. Using this approach, we assess such things as the effect of degenerative changes on spine mechanics or

we investigate differences in motor control in people with and without low back pain. However, this approach often fails to connect the dots to show specifically how these documented changes or differences affect the behavior of the complete spine system. We need to move away from “documenting” differences to “understanding” the effect these differences have on the spine system. To do this is quite challenging and requires a different approach. Fortunately, there is a branch of science developed specifically to study and understand complex systems in this way.

In the twentieth century, modern society and technology became so complex that traditional reductionist methods of analyzing and resolving problems were no longer sufficient. Out of necessity, Systems Science was developed to study interdependence and provided the framework to explore general properties of systems, such as stability, optimality, and robustness. Given the complexity of the human spine, the systems approach is ideally suited for studying spine function, and could provide the basis for integrating experimental data to provide a coherent picture. With this approach, various forms of impairment or combinations of impairment (i.e., degenerative disc disease coupled with muscle wasting) could be assessed to quantify their effects on the spine system, and with this, allow us to move away from simply documenting differences between people with and without low back pain. There has been some progress in this area, but it has been quite limited. To break through the barrier of understanding of spine function, particularly in understanding spine dynamic, the adoption of the systems approach is warranted, which has been shown to be invaluable in studying other complex systems.

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