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Point of View

An Integrated Approach to Musculoskeletal Performance, Disease, and Recovery

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Optimizing rehabilitation outcomes, including preventing pathology and its progression, relies on a comprehensive knowledge of the condition's etiology. Put simply, physical therapists cannot optimally prevent or treat what they do not understand. Understanding the etiology of musculoskeletal syndromes and diseases is challenging because these conditions likely result from the interaction between multiple complex factors, including time, underlying biology and physiology, and task demands on the system. Furthermore, behavioral and social determinants of health likely play important roles. Research seeking to understand the etiology of a musculoskeletal condition requires a robust and comprehensive conceptual framework that explicitly identifies key variables, relationships, and outcome measures. The validity of this framework ultimately determines the utility and clinical impact of the research and therefore deserves frequent and careful scrutiny. This Point of View will explore the predominant conceptual framework that has guided research into the etiology of rotator cuff pathology and propose a framework that can help guide future research in an effort to optimally prevent and treat rotator cuff pathology. Although this Point of View explores the proposed framework within the context of rotator cuff pathology, it can be generalized and applied across musculoskeletal rehabilitation and research.

Traditional Conceptual Framework

For more than 40 years, studies investigating the etiology of rotator cuff pathology have been largely based on variations of a single conceptual framework. This framework focuses on the role of theorized mechanisms of rotator cuff pathology: *intrinsic* mechanisms are theorized to contribute to injury through tendon degeneration and include factors such as tendon biology, material properties, and genetics,[1–3] whereas *extrinsic* mechanisms are theorized to contribute to injury through tendon compression during motion and include factors such as anatomy, kinematics, muscle strength, and joint laxity.[1–4] In addition to intrinsic and extrinsic mechanisms, overuse is also proposed to play a role in rotator cuff pathology either as an independent mechanism or one that is mediated by intrinsic or extrinsic factors.[1,2,5,6] In essence, this framework identifies factors internal to or external to the injured tissue, in this case, the rotator cuff tendon.[7]

Although the traditional framework has created a common language to guide research and clinical practice, it does not adequately emphasize the multifactorial nature of rotator cuff pathology. Consequently, the complex etiology has not been emphasized in investigative approaches or adequately translated to clinical practice. Further, the inherent challenges associated with investigating interacting factors and tendon degeneration in humans likely contributed to an overemphasis on extrinsic mechanisms—particularly subacromial compression—as the predominant cause of rotator cuff pathology.[8,9] However, both non-surgical and surgical interventions for "subacromial impingement" often result in only an average improvement of approximately 50% in patient-reported outcomes (eg, Shoulder Pain and Disability Index, pain visual analog scale) relative to the metrics' highest functional level.[10–13] Ultimately, improving clinical outcomes requires matching disease pathogenesis and progression with targeted treatment strategies.

Any conceptual framework that seeks to guide the investigation of the etiology of musculoskeletal syndromes and diseases should acknowledge the potential for interactions between mechanisms and the importance of individual-specific tolerances for tissue stress (mechanical or metabolic) that change over time. For example, an individual with reduced subacromial space could theoretically still have a healthy tendon if the incidence and severity of rotator cuff compression remain below the individual's current tolerance to withstand tissue stress. Likewise, an individual who does not experience rotator cuff compression or high levels of tissue stress may still develop pathology if their genetic, biological, and/or physiological factors do not support

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Table. Descriptions and Examples of Task Demand and Body System Factors in the Proposed Integrated Conceptual Framework to Musculoskeletal Performance, Disease, and Recovery

Factor	Definition	Examples	Relationship to Tissue Pathology
Task demand factors			
Load	The physical stress on a system during a task	Resistance, velocity, large moment arms	Increased load, frequency, and duration requires increased tissue resilience to prevent overuse
Frequency	The number of repetitions the task is performed	Repetitive movement	
Duration	The length of time the task is performed	Duty cycle	
Body system factors			
Genetics	Genetic code and epigenetic modifications of that code that relate to the efficiency of transcription	DNA, epigentics, age	Influences the biological and physiological potential of a tissue
Biology and physiology	The structure and function of cells and tissue	Progenitors and their mileu, immunology, vascularity, age, etc	Influences the current state of the tissue
Morphology	The shape and form of anatomical structures	Tissue cross-sectional area, glenoid dysplasia, critical shoulder angle, acromial shape, etc	Influences the magnitude of mechanical load on tissue
Movement strategy	The kinematics and kinetics employed in response to task demands	Muscle strength, flexibility, neuromuscular control, etc	Influences the magnitude of mechanical and metabolic load on tissue
Tissue fitness	History-dependent interaction between tissue biology and the load on the tissue	Muscle strength, flexibility, joint laxity, neuromuscular control, nutrition, training history, recovery time, etc	Influences tissue endurance limit and resiliency

otherwise "normal" loads. Although these examples are simplistic, they highlight the importance of investigating rotator cuff pathology, and indeed any pathology, within a framework that acknowledges its multi-factorial nature. To do so, a more comprehensive conceptual framework is needed.

Proposed Conceptual Framework

The proposed framework takes a systems approach that inherently emphasizes the multi-factorial and time-sensitive nature of rotator cuff pathology. The framework emphasizes factors that are related to the body system, task demands, or the interaction between these components. Specifically, body system factors refer to the individual's shoulder anatomy and all supporting physiological influences (eg, muscular, nervous, skeletal) and defines the underlying capacity (mechanical and metabolic) of tissues to bear load and their capacity (magnitude and timing) to adapt and heal (Table). Task demand factors are imposed on the body system to achieve a movement goal and/or level of performance (eg, load, frequency, and duration) (Table). Given that task demands are layered onto the body system, they do not function independently but interact and vary substantially over time. Therefore, understanding the capacity of the internal system to accommodate the external demands at any given point in time, or over time, is the pivotal piece of knowledge in understanding performance, disease, and treatment.

Within the proposed conceptual framework, body system and task demand factors interact with each other to define a "critical threshold" that differentiates shoulder activity (nonpathological) from acute or overuse injury (pathological). In other words, an individual's exposure to task demands is weighted against the level of resiliency afforded by their body system to determine whether their rotator cuff health remains stable or declines into a state of pathology (Figure). For example, if exposure to task demands is within the capacity of the body system at the time of task performance, then the individual is below the critical threshold and the rotator cuff health remains stable or improves (eg, remodeling, hypertrophy). However, if exposure to task demands exceeds the capacity of the body system to respond at the time of task performance, then the individual surpasses the critical threshold and injury (micro or macro) occurs. At this point, the body system requires time to adapt and/or repair itself before further exposure to external demands. The amount of time required and ultimate capacity for repair depend on the individual's internal biology and the anticipated demands in subsequent tasks. If the task demands are unchanged and the recovery is incomplete, the individual will eventually be in a state of overuse injury. Without effective intervention (eg, rest, rehabilitation, activity modification), overuse may lead to the initiation and/or progression of tissue pathology.

The critical threshold in the proposed conceptual framework has several important characteristics that may aid in understanding the complex interactions between body system and task demand factors. First, the critical threshold emphasizes the relative magnitudes of each factor, not absolute values. For example, some individuals may have a mechanically and/or physiologically robust body system that allows them to tolerate higher exposure to task demands that would have led to overuse and pathology in another individual with a less robust body system (Figure). This relative nature of the critical threshold may help explain why not all individuals with high task exposure (eg, manual workers) have rotator cuff pathology and why individuals with seemingly low exposure may still develop pathology.[14,15] Second, the critical threshold and the system-focused nature of the conceptual framework directly acknowledge the potential for multiple mechanisms of rotator cuff injury to occur simultaneously. Furthermore, it allows for currently unknown or under-appreciated mechanisms to be readily implemented into the framework.

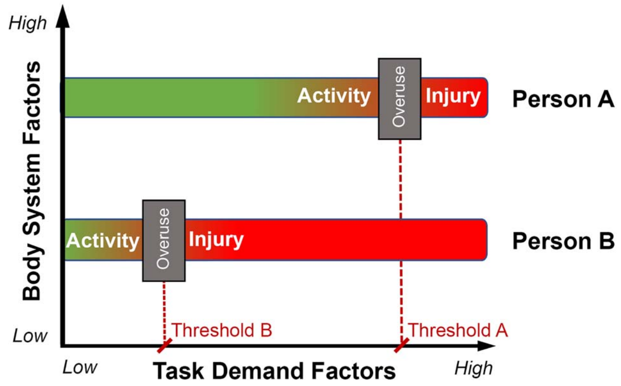

Figure. Schematic illustrating the integrated approach to musculoskeletal performance, disease, and recovery. The x-axis represents task demand factors, which are imposed on the body system to achieve a movement goal and/or level of performance. The y-axis represents body system factors, which define the tissue's capacity (mechanical and metabolic) to bear load and its capacity (magnitude and timing) to adapt and heal, and include factors such as genetics, the biology and physiology of the neuromusculotendinous unit, and neuromuscular control. In this example, Person A has higher (ie, more resilient) body system factors compared with Person B. Consequently, Person A's tissue has a higher tolerance threshold and can withstand a higher level of task demand factors (via activity) before overuse occurs and injury results. Without effective intervention (eg, rest, rehabilitation, activity modification), overuse may lead to the initiation and/or progression of tissue pathology.

Another important characteristic of the proposed conceptual framework is that the theoretical critical threshold is not a fixed entity but is capable of both upward and downward adjustments, which consequently impact the rotator cuff's potential for injury and recovery. Specifically, upward adjustments (eg, appropriate training) raise the threshold and improve the body system's ability to tolerate task demands. In engineering terms, this would be called a "safety factor." Conversely, downward adjustments (eg, aging) lower the threshold and reduce the body system's capacity to manage task demands, making overuse—and therefore pathology—more likely to occur. Furthermore, downward adjustments may impair the rotator cuff's recovery potential and delay healing time. Evidence for downward adjustments can be seen in the higher prevalence for rotator cuff pathology associated with age,[16,17] comorbidities (eg, diabetes),[18,19] and substance use (eg, smoking),[16,19,20] and the tendency of these factors to impair prognosis.[21–23] Less understood are the factors that may raise the critical threshold and subsequently protect an individual from pathology, reduce recovery time, and/or promote healing. Furthermore, the critical tolerance within an individual currently remains an indeterminate entity. However, the body system's dynamic nature suggests the critical threshold may be modifiable. Efforts to quantify this threshold within an individual and to determine how it may be modified (ie, upwardly adjusted) may provide critical information to inform the timing and intensity of prevention, mitigation, and treatment strategies.

Call to Action

The proposed conceptual framework not only encourages a paradigm shift in how we think about musculoskeletal injury and disease but also highlights opportunities for future research and clinical practice that must be pursued if clinician-scientists are to effectively address these problems. A pivotal gap in research and practice is quantifying the "state" of tissues—essentially their biomechanical capacity (mechanical and metabolic) to bear load and their capacity (magnitude and timing) to adapt and heal. For example, the development of low-cost, high-precision imaging techniques capable of providing a longitudinal assessment of the body system—and thus providing insight into an individual's critical threshold and recovery potential—would revolutionize the prevention and conservative treatment of musculoskeletal conditions. Furthermore, understanding the extent to which task demands are influenced by exercise and functional, athletic, and work-related activities would help clinicians, coaches, and ergonomists monitor shoulder activity. Without this information, it is nearly impossible to manage loads during tasks (eg, assign ergonomic loading limits) or to titrate loads during training and/or recovery (conservative or surgical).

In musculoskeletal injury, a precision approach to preventing and treating pathology would involve optimizing the minimum number of body system and task demand parameters needed to predict injury risk, healing capacity, and healing time in the presence of normal and abnormal physiology. This is a tall order; however, a starting point would be to measure something about the capacity of the body systems to manage task demands or to adapt and repair. To minimize the exposure to task demands, researchers should optimize strategies for workplace modification, optimize individualized training plans for overhead athletes, and identify the factors that influence kinematics, motor control, and fatigue to prevent or minimize rotator cuff tendon mechanical loads. To maximize the capacity of the body systems to manage task demands and to adapt and heal, we will want to know about tissue strength, inflammation, and ongoing regenerative responses.

Summary

Contemporary approaches to understanding and treating musculoskeletal performance, injury, disease, and recovery require an understanding, and ability to measure key time-varying body-system and task-demand factors that impact patient function. This framework, of course, ultimately fits into a larger framework that incorporates the overall individual and how they interact with society. Periodically revisiting these frameworks allows us to refocus research efforts and expand our clinical armamentarium to include high-value clinical measurements and new intervention approaches. In the example case of rotator cuff disease, there is an immediate need to quantify the health and recovery potential of tissues as prerequisites for prescribing training, recovery, and work-load limits.

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