Mechanobiology in Rehabilitation Science

Nicholas Andry, a professor of medicine and surgery in Paris, established the field of orthopaedics in 1741 with the publication of his book outlining the treatment of skeletal deformities. He introduced the term “orthopaedia” from the Greek word “orthos,” meaning straight or correct and “pais,” meaning child. An illustration of a tree that appeared in his book later became the international symbol of orthopaedics. The drawing depicts a crooked young tree that is encouraged to grow straight by the application of appropriate forces. Although our knowledge of skeletal biology has grown tremendously in the more than two and half centuries since this famous drawing was first published, the concept that physical forces can influence growth and biology continues to be the central tenet in clinical approaches to musculoskeletal disorders.

Scientific observations dating back to Galileo have suggested there is a causal relationship between function and form in many tissues and organ systems. In the nineteenth century, Wilhelm Roux proposed that mechanical factors played a central role in the morphogenesis of musculoskeletal tissues. In his studies of functional morphology, he referred to the collective physicochemical processes that guide development as “Entwicklungsmechnik” or developmental mechanics. Over the past fifteen years, researchers at the VA Palo Alto Rehabilitation R & D Center have used theoretical, computational, experimental, and clinical studies to discover many of the quantitative mechanical principals that Roux postulated to exist. We have also demonstrated that the same mechanical processes that guide development can also be used to simulate and predict skeletal pathologies such as osteoarthritis and osteoporosis in the aging skeleton. Furthermore, consistent principals can be used to understand the regeneration and functional adaptation of connective tissues in skeletal healing and rehabilitation.

Tremendous advances have been made in the past few years to establish a rational scientific framework for understanding how the mechanical environment of connective regeneration, rehabilitation, and aging of the skeleton. The stage is now set for important investigations of the interactions between mechanics and biology in bones, cartilage, ligaments, tendons, and muscles. This exciting new field of investigation has been termed “mechanobiology,” which can be broadly defined as the study of the interactions between mechanical forces and biological responses in tissues.
of how mechanical or physical conditions regulate tissue and cell differentiation, growth, and function. Current and future investigations in this area promise to lead to significant advances in musculoskeletal treatment and rehabilitation.

It is important to realize that a mechanobiologic view of skeletal development, aging, pathology, and rehabilitation is entirely consistent with the recent discoveries that have been made in molecular biology. Indeed, the development of a more complete understanding of skeletal biology will require that mechanobiological phenomena be explained within a cellular and molecular biologic framework. Tissue mechanical forces can influence cell physical conditions such as pressure, cell shape, and electrochemical environment or can even directly damage cells and their surrounding extracellular matrix. Changes in these cell conditions have been shown to affect cell mitosis, biosynthesis, and gene expression. The biochemical pathways of these cell functions are a major focus of investigation and the discovery of some common pathways for the action of mechanical and chemical epigenetic factors seems inevitable.

Clinical investigations of the relationships between physical forces and skeletal treatment and rehabilitation can lead to the creation of guidelines for disease prevention and clinical care. Guidelines created only from clinical experience or outcome studies, however, may not be optimal they are generally not based upon knowledge of the specific biological processes by which local mechanical factors influence tissue biology. A research program consisting of basic, applied, and clinical studies is needed. We believe that by using this type of integrated approach, impressive progress will be made in clinical care. In the coming years we look forward to a new era of clinical treatments that draw upon pharmacological and mechanobiological principles in more comprehensive biological and physical rehabilitation approaches to musculoskeletal impairments.

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