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Biotensegrity and myofascial chains: A global approach to an integrated kinetic chain

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ABSTRACT

Human movement is a complex orchestration of events involving many different body systems. Understanding how these systems interact during musculoskeletal movements can directly inform a variety of research fields including: injury etiology, injury prevention and therapeutic exercise prescription. Traditionally scientists have examined human movement through a reductionist lens whereby movements are broken down and observed in isolation. The process of reductionism fails to capture the interconnected complexities and the dynamic interactions found within complex systems such as human movement. An emerging idea is that human movement may be better understood using a holistic philosophy. In this regard, the properties of a given system cannot be determined or explained by its components alone, rather, it is the complexity of the system as a whole, that determines how the individual component parts behave. This paper hypothesizes that human movement can be better understood through holism; and provides available observational evidence in musculoskeletal science, which help to frame human movement as a globally interconnected complex system. Central to this, is biotensegrity, a concept where the bones of the skeletal system are postulated to be held together by the resting muscle tone of numerous viscoelastic muscular chains in a tension dependent manner. The design of a biotensegrity system suggests that when human movement occurs, the entire musculoskeletal system constantly adjusts during this movement causing global patterns to occur. This idea further supported by recent anatomical evidence suggesting that the muscles of the human body can no longer by viewed as independent anatomical structures that simply connect one bone to another bone. Rather, the body consists of numerous muscles connected in series, and end to end, which span the entire musculoskeletal system, creating long polyarticular viscoelastic myofascial muscle chains. Although theoretical, the concept of the human body being connected by these muscular chains, within a biotensegrity design, could be a potential underpinning theory for analyzing human movement in a more holistic manner. Indeed, preliminary research has now used the concept of myofascial pathways to enhance musculoskeletal examination, and provides a vivid example of how range of motion at a peripheral joint, is dependent upon the positioning of the entire body, offering supportive evidence that the body's kinetic chain is globally interconnected. Theoretical models that introduce a complex systems approach should be welcomed by the movement science field in an attempt to help explain clinical questions that have been resistant to a linear model.

Introduction & background

Aristotle, in his *Metaphysica*, was believed to have said, "the whole is greater than the sum of its parts", an ancient phrase that has come to represent the philosophical position of holism. The central tenet is that the properties of a given system cannot be determined or explained by its components alone, rather it is the complexity of the system as a whole, that determines how the individual parts behave [1,2]. The opposing view, reductionism, prefers to break the whole into its isolated parts, attempting to simplify the process to more fully understand the whole [1,3]. The "parts versus whole" debate has led to some divisions amongst clinicians, scientists and researchers. In human movement science, the preferred philosophical approach is often one of reductionism. As such, most movement patterns, regardless of their complexity, are analyzed through a linear framework of isolated muscle groups, based on singular muscle attachments and isolated joint actions.

Within the field of human movement science, notable movement

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Fig. 1. Dynamic Knee Valgus: "medial collapse" of the lower limb. (1) contralateral pelvic drop, (2) femoral internal rotation, (3) knee valgus, (4) tibia internal rotation, and (5) foot pronation.

dysfunctions exist that may benefit from both a whole and parts perspective. One such dysfunction is dynamic knee valgus. Dynamic knee valgus is generally regarded as an aberrant biomechanical pattern, occurring across three planes of movement consisting of internal rotation and adduction of the femur and concomitant contralateral pelvic drop (Fig. 1). The combination of these faulty movements leads to an uncontrolled medial displacement of the knee which contributes to common lower extremity injuries such as patellofemoral pain syndrome and anterior cruciate ligament injuries [4–7]. In a bid to simplify the complexity of human movement, many scientists and clinicians rely on a reductionist framework to analyze and correct aberrant patterns such as dynamic knee valgus [1,3]. Consequently, a common supposition is that re-education of knee mechanics and lower extremity alignment [6,7] can be achieved through one or all of following mechanisms 1) local-specific strengthening (e.g. knee) 2) co-contraction exercises (e.g. quadriceps/hamstrings) and 3) targeting impairments in regions immediately proximal to the knee (e.g. hip). However, there is ongoing debate whether stabilization of the lower extremity and pelvis can be addressed in such a simple linear manner, and if increasing individual muscular strength at a specific joint carries over to measurable biomechanical outcomes during complex functional movements [8–10].

In a highly complicated human movement such as running there are multiple parts of many different human systems interacting simultaneously. Attempting to disentangle the interactions of these complex systems with a reductionist paradigm may overlook the complexity of the human system and limit our understanding. Our paper proposes that in order to effectively alter movement kinematics and forces during high-speed movements, there must be an advancement in clinical reasoning. We also propose that implementation of a more holistic framework, based on nonlinear or dynamic complex systems theory [11–13], will enhance our understanding of the neuromusculoskeletal system, foster creativity in rehabilitation prescription and ultimately improve clinical outcomes.

Muscle synergies

Synergy is derived from the Greek word synergos, meaning "to work together." The concept of synergy is an aspect of the parts vs. whole debate, meaning many parts contribute to the whole, but if the parts work together in a purposeful manner, synergies can arise. Human movement is a clear illustration of the concept of muscle synergy, whereby different groups of singular muscles work together in unison to produce coordinated movements of the whole organism [14,15]. Although the existence of muscle synergies seems logical, this remains a controversial area as much of the evidence in this field has been limited to behavior observation in humans or animals, or direct stimulation of the motor system [14,15]. Consequently, there is continued debate around the mechanisms of neural control underpinning muscle synergies [16]. The most popular hypothesis is that the central nervous system accesses a flexible but small number of neurally-established functional muscle groupings. However, others have suggested that muscle synergies may even be driven through non-neural interactions such anatomical or mechanical constraints [17]. Some authors have suggested that there might be just a few specific motor patterns generated within the CNS, with individual muscles joining in to adjust to the slight variabilities of the specific task [18,19].

One method of examining muscle synergies is through the use of electromyography (EMG), which can identify the electrical activity of the individual muscles to determine if those muscles are working together to accomplish a given task as well as the EMG wavelengths in an attempt to determine the neural origins of muscle synergies [20]. In order for EMG to identify if specific muscles are working together to accomplish a task, the task being studied must be rich enough in movement variability, allowing the nervous system adequate opportunity to demonstrate various control strategies. If the task is too constrained, the nervous system will only have a limited number of ways to address the task, as a result the same muscles will appear as if they are working in synergy, but in reality, the results are secondary to poor methodological design. Flawed research methods are often the most common criticism for the concept of muscle synergies [15,21–23]. Clearly, more explanatory and pragmatic research needs to be conducted on the concept of muscle synergies to more critically evaluate the mechanisms under which they occur.

Human movement is an integrated kinetic chain

Preventing dynamic knee valgus, or limiting its associated joint forces, is an important objective in movement science research as well as in rehabilitative interventions. Many clinicians now target strength impairments in regions immediately proximal to the knee (e.g. hip). There is logic to this approach as the femur represents the primary anatomical link between the knee and hip. Furthermore, there is evidence that this approach has positive effects on pain and function in patients with patellofemoral pain [6]. However, a key limitation is that proximal hip strengthening programs fail to change biomechanical outcomes during more complex movements like running and jumping [8,10,24]. Evidence has shown that there is not a direct or linear cause and effect link between these two variables [8], most likely because the isolated strengthening approach is too simplistic to address complex movements.