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Enabling health potential: exploring nonlinear and complex results of osteopathic manual medicine through complex systems theory

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Abstract: Osteopathic medicine is a holistic, patient-specific approach. Explaining the impact of osteopathic manipulative medicine (OMM) has been problematic because many of its effects are nonlinear. Complex systems theory (CST) is explored as a mechanism of understanding the interplay of the body's anatomy and physiology, an illness process, and the effects of OMM. Tensegrity is discussed as an example of an emergent property of the body's systems that affects not only biomechanics but also pathophysiology. Previous explanations of osteopathic philosophy are reviewed. The Host + Disease=Illness paradigm is a way to think through the impact of host and disease factors on an illness state, and how targeted interventions may affect the illness. The Osteopathic 5 Models are another way to view the body's complexity. The area of greatest restriction (AGR) screen can be understood to direct OMM in a way that respects complexity and enables asymmetric and nonlocal results to realize health potential. The impact of this framework is in coherently explaining the impact of osteopathic philosophy and OMM and exploring new approaches to research.

Keywords: manipulation, osteopathic; osteopathic medicine; systems biology; systems theory.

Osteopathic medical education often echoes holistic practice sayings from its founder, Andrew Taylor Still, MD, DO, such as, "To find health should be the object of the doctor. Anyone can find disease." [1] However, in the practical application of medicine, how does one treat the patient and the disease? How do we enable patients' health potentials to emerge in complicated, nonlinear clinical problems?

Complex systems theory (CST) is an approach to analyzing complex systems that have interconnected, nonlinear, and dynamic mechanisms that are difficult to analyze in a reductionist manner. The physiology of human beings is complex and has been analyzed utilizing many parameters: consider the contrast of a static heart rate measurement to the more complex and dynamic analysis of heart rate variability. Utilizing CST as a lens to understand the dynamics of an individual's physiology and body mechanics is helpful because it may lead to different approaches to treatment. Instead of understanding that the treatment of disease as linear, in which one intervention leads to a certain result, it may alternatively be thought of as nonlinear and asymmetric, in which a simple intervention could lead to a complex change throughout the whole body.

Osteopathic medicine was developed in the United States by the previously mentioned Andrew Taylor Still, MD, DO, in the late 1800s as an improved approach to the contemporary medical practice of the time. It considers the whole patient when addressing a particular complaint and includes the musculoskeletal system as a way of assessing function of the entire body. Early osteopaths had many of the same insights regarding the interdependence of bodily subsystems, resilience, and the holistic approach to the body that CST analyzes [2]. Unfortunately, there was no overarching paradigm at the time from which they could work. Later osteopathic physicians, such as Cain, [3] and researchers such as IM Korr, PhD, also viewed osteopathic medicine as interacting with the complexity of the human system as a whole in a way that is consistent with CST. The modern concept of tensegrity deals with the complexity of the neuromusculoskeletal system and fits the osteopathic understanding of whole body thinking.

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Osteopathic medicine considers the Host factors of the patient, as well as the Disease, as they apply to an emergent Illness state. The Osteopathic 5 Models are another way to begin to integrate holistic thinking into a particular patient's case [4]. Treatment approaches can include osteopathic manipulative medicine (OMM) in addition to medications, procedures, and surgeries [4]. OMM is one of the ways that osteopathic medicine is unique from allopathic medicine. More than just a series of physical techniques, it is a way of interacting with the patient's system as a whole. OMM is thought to work through the neuromusculoskeletal system to affect the whole body in a nonreductionist and nonlinear way.

The area of greatest restriction (AGR) approach refers to a system of assessing and treating somatic dysfunctions in an order of greatest to least restricted areas [4]. AGR evaluates for the most significant altered palpatory and mechanical changes, including the most restricted range of motion, while the patient is standing and seated [5, 6]. Typically the region of greatest motion loss is treated first, because it is most likely the location of a key somatic dysfunction. AGR honors the mechanical complexity of tensegrity as well as the interactions of various musculoskeletal structures. Utilizing both standing and seated evaluations, AGR is a dynamic method of organizing an osteopathic treatment based on discovering the most restricted region and treating the most restricted dysfunction within that region.

In this paper, CST is explored as a paradigm to understand how the body works, how it breaks down biomechanically and physiologically, how disease states can be viewed from a systems perspective, and how OMM may interact with the complex adaptive system of the body to change entrenched neurologic patterns and improve patients' potential for health. Utilizing the CST paradigm helps to give a 21st century context to osteopathic philosophy. With regards to OMM in particular, CST aids in understanding how osteopathic manipulation can affect the whole body and its different systems.

Clinical summary

Complex systems theory as applied to the human body

Reductionist thinking is a simplification of a complex system in order to better understand the parts. It also implies more linear causation than actually occurs. In human physiology, the reductionist approach assesses the body as a machine that can be reduced to smaller parts to ultimately reveal function and mechanism of action. The implicit assumption is that, by improving the function of the various systems and subsystems, the organism as a whole will improve. Clearly, much has been learned from this approach, and many modern medical treatments and procedures have resulted from reductionism. However, the reductionist philosophy has limitations because it does not explain behaviors of the system that are the result of complex interactions of multiple subsystems. In clinical practice, improving the function of individual systems does not always result in improvement of the person as a whole.

The physiology of human beings is interconnected through multiple positive and negative feedback systems that occur within and between different organ systems and utilizing different mechanisms, such as hormones, cytokines, and neuromuscular input. In medical education, the body is divided into organ systems, and its interconnections are discussed in the periphery. This may work as a pedagogical model and is helpful with certain aspects of research and in the development of interventional approaches; however, when it comes to actually dealing with real people with chronic diseases, it is incomplete [7, 8]. Korr [9] discusses the limitations of the reductionist viewpoint in medicine: viewing the body as the sum of its parts, not considering the effects of subjective experience, endorsing linear causation, and ignoring the unique personhood of the ill patient.

Complex systems, such as finance, ecology, and weather, all have similar characteristics [10–12]. Complexity in the human body is seen in the different levels of body structures and how they coordinate from local to regional to generalized actions. The higher degree of complexity in the system, the more resilient it is, in which resilience is the ability for the system to compensate for fluctuations [12]. Qualities of complex adaptive systems include complex and self-organizing collective behavior, resilience, signaling and information processing, adaptation to experiences, and emergent characteristics [12]. These are further discussed below.

A common example of complex and self-organizing collective behavior is how a slime mold fuses together separate slime mold entities to become a self-organized entity [11]. This entity then acts collectively and adapts to benefit the whole organism, without the benefit of a central nervous system. Similarly, human embryology also features complex and self-organizing collective behavior, in which the whole is greater than the sum of the parts.

Resilience refers to the ability of a functional system to respond to disturbances, or unpredictable situations, and return to a neutral position [13]. Variability in a system increases its resilience, as seen in human physiology research. Heart rate variability, which assesses the degree of high-functioning coupling of the autonomic nervous system, has been shown to correlate with the whole system's health [14]. A higher rate of variability in the heart rate (i.e., more fluctuations in the heart rate measurements) indicates more adaptability and health; a lower rate of variability indicates less likelihood of recovery from a disease state [15–17].

Examples of signaling and information processing are the concepts of coupling, decoupling, and recoupling. Coupling is the interconnection between different systems, which enables a "highly adaptive, resilient organism." [18] This interconnection can degrade, in decoupling, and reintegrate, in recoupling [13]. Decoupling is reflected in a loss of complexity and therefore a loss in resilience. Aging is an example of a process that decouples a variety of systems; for example, it decreases the complexity, or variation, in heart rate variability, gait stride length, and respiratory dynamics [14, 18]. Somatic dysfunction may be another example that decouples the system and decreases resiliency [19]. Recoupling of systems helps to restore complexity, variation, and resilience. Exercise can be a recoupling mechanism in elderly patients, and beta blockers can be a recoupling agent in patients with congestive heart failure [18]. OMM may be another mechanism that recouples systems, affecting whole body physiology through the neuromusculoskeletal system and biomechanical tensegrity [19].

Emergent characteristics arise from the relationships between subsystems and are not predictable from the characteristics of each system [20]. An example is that the functions of the brain and consciousness itself are not predictable based on the sum of the individual neurons [21].

Another example of emergent property is tensegrity, which is a self-stabilizing structure with compression elements (e.g., bones) that are suspended by a body-wide network under tension (e.g., continuous fascial networks) that distributes force in a nonlinear manner. Properties of these tensegrity structures include defiance of gravity, efficiency, storage of kinetic energy and tolerance of more strain than would be expected with classical mechanics [22, 23]. The tensegrity structure itself enables coordination of movement, which decreases the input needed by the neurologic system [22, 23]. Ingber et al. [24] discussed research that shows that in a larger organism, physical forces affect the cytoskeleton of cells and thereby affect cellular mechanisms in a more efficient manner than through chemistry alone. Affecting the mechanical tension of the cell through the cytoskeleton can affect cellular functions such as biochemistry, physiology, and genetic expression [25]. This understanding of the impact of biomechanical tension on biochemistry and genetic expression supports the osteopathic tenet that structure and function are interrelated.

Complex system dynamics in health, predisease, and disease

The dynamics of a complex system is illustrated by alternative stable states [13]. Stable states represent high resistance to change. Both positive "hills" and negative "potential wells" are stable states, which is illustrated as a hypothetical situation in Figure 1. Health or illness can be a self-stabilizing stable state, which explains why musculoskeletal compensation patterns are established and are then hard to change. Tipping points, or critical transition points, are points in which the system is pushed out of its previous stable state into another stable state.

In this diagram, the x axis represents time and the y axis represents the health of the overall system. On the left side of the diagram, variability to the system is represented by perturbations that could be caused by stressors, somatic dysfunction, and other negative Host factors. Positive host factors, such as exercise, a healthy amount of sleep, and genetics, restore the normal level of health. However, if there is an injury for which the body cannot compensate, this can result in decompensation of the system, as Still found in an early patient with presumptive pneumonia who improved after manipulation of her rib cage [26].

There is also an interim state between health and disease, which could be described as the predisease state, Point B [13]. In fact, OMM is very effective in this liminal state in which somatic dysfunction is palpable but not necessarily causing disease [27]. If the somatic dysfunction persists, it will gradually affect the whole system until a disease state occurs. If the somatic dysfunction can be corrected and that state maintained through manipulation, exercises, and nutrition, the patient may move closer to their health potential. In 1929, McConnell [28] stressed the importance of understanding the impact of structural dysfunction on the physiology of the individual; if unaddressed, this can lead to more symptomatic disease and a decompensation of the system.

The body as a complex adaptive system, with two osteopathic paradigms

The body can be viewed as a complex adaptive system, which is another way of stating that the body is a unit, a

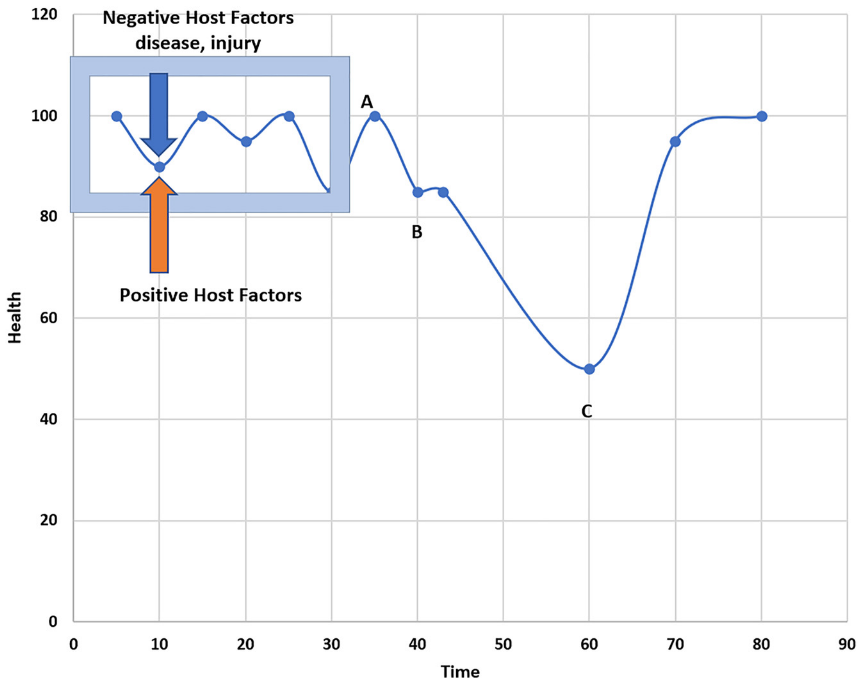

Figure 1: The alternative stable states model of human health in a hypothetical case. If a person starts at off 100% health, negative host factors, disease, or injury can affect the state of his or her health. At that point, positive host factors or adjustments on the part of the person (drinking more water, sleeping more, or taking medications) can be sufficient to help them return to a state of normal health. The box illustrates a range of randomness that the patient's system can tolerate without decompensating. At Point A, the patient has received an injury, such as a blow to the ribs. The system attempts to compensate for this somatic dysfunction through Point B, which is a predisease state, and then decompensates into an illness state. At Point C, a properly applied intervention, such as OMM, is sufficient to help them return close to a state of normal health, which can increase back to normality given enough time and without any other incident.

tenet of osteopathic medicine. A complex adaptive system is one that has multiple systems nested within each other, such as endocrine, respiratory, and neurological, and that can adapt through experience [29].

However, simply stating that the body is a unit does not fully capture its complicated interconnections. The musculoskeletal system is a system that communicates with all other systems. This means that if one is well versed in palpation, anatomy, physiology, and pathophysiology, the body's functioning can be interpreted through the most accessible system, the musculoskeletal system, as stated by Korr [30] in 1990.

This paper presents two examples of how to utilize the idea of complex adaptive systems to explain the osteopathic paradigm.

Illness as a complex interaction of host and disease factors

The Host + Disease=Illness paradigm of Edward G. Stiles, DO, FAAODist (EGS), is helpful in understanding the uniqueness of the osteopathic approach (Table 1) [3, 31]. Illness results from the impact of both host and disease factors. Appreciating the complexity of these factors and their interactions is necessary to understand and treat illness. Host factors that contribute to overall health are capable of overcoming the effect of disease factors, so that illness does not result. On the other hand, disease factors can overwhelm host factors and lead to illness. Osteopathic training provides important diagnostic and treatment tools to aid in potentiating the host components, with the goal of preventing or lessening the manifestation of illness.

Table 1: The Host + Disease=Illness paradigm [3]. This is a model to explain how host and disease factors interact to create an illness state.

	Host factors in illness	Disease factors in illness
HOST + Disease=ILLNESS	Significant	Less significant
Host + DISEASE=ILLNESS	Less significant	Significant
HOST + DISEASE=ILLNESS	Moderate	Moderate

Host factors could be things like poor nutrition or sleep habits, or smoking. Somatic dysfunction, which impacts the musculoskeletal, vascular, lymphatic, visceral, and neurologic systems, is another host factor that can be considered in both the etiology and treatment of a given Illness state [3]. Disease factors could be elements like the virulence or pathogenicity of the disease. Illness is the unique emergent experience of the state of physiologic dysfunction in a given patient. In addition to having a conceptual framework of integrating Host factors into a state of Illness, this paradigm also delineates how OMM can be helpful in a given state of Illness, through treating Host factors.

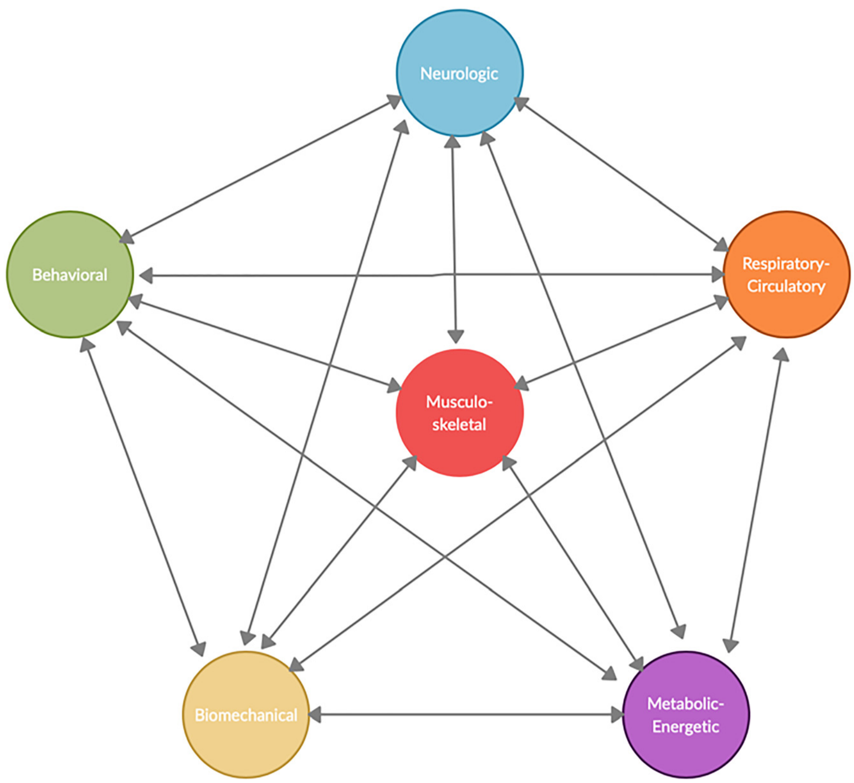

Figure 2: The Osteopathic 5 Models diagram, with the musculoskeletal system centrally integrated. This model acknowledges complex interactions between body systems.

In the first instance, Host factors are more contributory to the Illness state, whereas the disease itself is less significant. An example of this would be a hospitalized patient with acute asthma who did not respond to the standard sympathomimetic drugs such as albuterol. If the patient's symptoms significantly improved after treatment of the upper cervicals with OMM, one can deduce that parasympathetic innervation was more crucial to this patient's physiological picture than the sympathetic innervation, which was why the sympathomimetic drugs were not working. This clinical rationale can improve targeted drug management.

In the second instance, Disease factors are more significant, whereas the Host factors are not as contributory but may have lowered resistance enough to allow the Disease to be expressed. An example could be a seemingly healthy patient who develops a cough because of a virulent pathogen. In this case, treatment will be most helpful if directed toward the disease process. Supportive treatment to improve Host function will be helpful for recovery but not as critical as in the first scenario.

In the third example, both Host and Disease Factors contribute approximately equally to the Illness state. Treatment in this scenario should be directed at both the Host and Disease factors to obtain the best results. If a patient is hospitalized with pneumonia and has somatic dysfunctions that contribute to this clinical situation, such as rib cage dysfunctions, usual medical care and OMM for the significant somatic dysfunctions should be applied to obtain better results faster.

The Host + Disease=Illness paradigm is deceptively linear, but it implies a series of feedback loops in its understanding and management of an Illness state. Effective OMM addresses Host factors through a variety of mechanisms that can improve overall health. Considering how to affect Host and Disease factors may also be a way to approach complex clinical problems that do not have clear treatments.

Osteopathic 5 models

The Osteopathic 5 Models can be utilized as an example of understanding the body as a complex and interconnected system. The 5 Models are Neurologic, Biomechanical, Respiratory-Circulatory, Metabolic-Energetic, and Behavioral [4], which are all mediated through the musculoskeletal system (Figure 2). In this model of the body, affecting one system will affect all of the others. Because of the complex interaction of the musculoskeletal system with other systems, somatic dysfunction findings can help guide treatment choices and offer an efficient approach to intervention.

Discussion

For aspiring "ten-fingered osteopaths," the question may be: How do you design a treatment plan that is coherent and may be expected to change the neurologic patterning that maintains a maladaptive stable state?

AGR is an example of a screening process that can move through the body's compensatory mechanisms and re-establish a new, and hopefully healthier, pattern. EGS further developed the AGR screening method by Fred L. Mitchell Sr, DO, FAAO, in an attempt to obtain similar results as his mentor.

The mechanism for making changes to compensatory systems potentially lies in the repatterning, or recoupling [19], of the neurologic system and changing the tensegrity mechanics of the neuromusculoskeletal system. Manipulation works via the musculoskeletal system, which changes afferent input to the spinal cord and cortex and efferent local reflexes, which affect muscular coordination and contractions [32, 33]. If the most significant dysfunctions to the proper operating of the system are addressed, an asymmetric and nonlinear response can be evoked in the system as a whole through its effect on the tensegrity structure. In other words, treating a rib dysfunction that is the most significant restriction in a system may impact the thoracic spine, heart, and lungs, in addition to the rib itself.

AGR is one way to determine the most significant dysfunction that the tensegrity system of the neuromusculoskeletal system is trying to protect [34]. Other ways of sequencing are treating the most significant counterstrain tender point in an area, or with visceral listening techniques as taught by Barral and Mercier [35]. Instead of a Newtonian linear cause and effect, properly applied OMM can have a nonlinear effect that is patient-specific [34].

Conclusions

Osteopathic medicine has an inherent potential for working with the complex biopsychosocial individuality of patients, as illustrated with the Host + Disease=Illness model, to improve their potential for health. OMM utilizes a diagnosis of the neuromusculoskeletal system to ascertain the most problematic dysfunctions, which represent a dynamic, patient-specific response to gravity and injury. AGR is a method to assess layers of compensation patterns and addressing these key dysfunctions with manipulation affects the patient's whole complex system, applying to any or all of the 5 Models. Utilizing the language of CST may help with the translation of osteopathic concepts to allopathic medicine and other scientific fields.

One of the barriers in OMM research has been demonstrating the nonlinear and asymmetric effects of OMM. Research questions could be posed utilizing the larger framework of CST instead of the standard linear approach of what techniques are most helpful for a given clinical situation. Some example questions could be: Does OMM act as a recoupling mechanism? How does treatment sequencing, such as AGR, affect the functioning of the whole patient? Does effectively treating patients who have somatic dysfunction with OMM help improve resiliency, as assessed by heart rate variability?

Perhaps a more important consideration is how the clinical encounter can be affected by a physician who is fully attuned to the complexity of the patient. The importance of this consideration was stressed by Still and his early students and is a hallmark of the osteopathic approach. Although medicine traditionally focuses on reductionist views of the body, osteopathic medicine can offer a way to integrate multiple aspects of a person in order to individualize medical care.

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