Integrated Biomechanical Influences On ANKYLOSING SPONDYLITIS

by Alfonse T. Masi & Laurie M. Savage | *April 2009*

The characteristic spinal deformities and lesions of AS occur at anatomical sites where ligaments, tendons, or joint capsules anchor or attach to bone (1-5). The epidemiological patterns of AS can offer essential clues to possible initiating pathways of the disease. The sex- and age-specific onset patterns of AS in the population are unique (6,7). The clinical condition develops about two or three times more frequently in males than females, and that M:F sex ratio increases with greater severity of skeletal lesions and deformities. Chronic low back pain and stiffness are the typical presenting symptoms of AS. These symptoms generally start from the later adolescent years to the 40s; however, juvenile onset AS (under age 16) occurs in about 15 percent of patients (6-8). Frequently, juvenile patients present with lower extremity arthritis before back symptoms (8). Foot problems, such as tarsitis (inflammation of the tarsus, the cluster of bones between the five long bones of the foot and the leg bones), often occur in children, while hip involvement is common in pre-teens and adolescents (7,8). Juvenile onset AS tends to predict a more progressive disease course (8).

AS and adolescent idiopathic scoliosis (AIS), a lateral curvature of the spine, were hypothesized to have counter-opposing biomechanical predispositions (9). The theory was based on amounts of musculoligamentous (myofascial) tonicity, or stiffness of the spine, needed for its stabilization (9). Insufficient spinal myofascial stability has been incriminated in AIS (9), whereas excess spinal stiffness is proposed to increase the risk of developing AS (5-8). Myofascia is a network of strong connective tissue that wraps around muscle and connects to ligaments and tendons (5). Among individuals in the population, such extremes of axial myofascial tonicity, as proposed for AIS vs. AS, may be the opposite poles of this biomechanical body trait that varies in the population (polymorphism), like height or intelligence, presumably reflecting different genetic profiles (9).

Genetics increase AS disease risk

In the early 1970s, scientists discovered that AS has a strong genetic predisposition that associates with immune function. This genetic link occurs among the human leukocyte-associated (HLA) genes. People who inherit any one of the majority (but not all) of the over 40 HLA-B27 variations of this gene (isotypes) have a 40- to 100-times greater risk of developing AS than individuals without such isotypes (4-6, 10).

Unlike hemophilia or sickle cell disease, in which abnormal genes cause specific molecular pathology, the HLA-B27 genes do not cause AS, and may be described as susceptibility factors (10). Two forms of HLA-B27 do not increase the risk for AS (B*2706 and B*2709), for unknown reason (10). Among persons who do develop AS, over 90% of the influencing factors are genetically determined (heritability), rather than acquired or environmental components of risk. However, genetic influences do not have full expression to cause the disease. For example, even in HLA-B27-positive children of a parent with AS, the estimated penetrance (expression) is only about 30% or less (10).

New susceptibility genes with lesser AS risk, including ARTS1 (now ERAP1, endoplasmic reticulum aminopeptidase) and IL23R, have been identified (10). The ARTS1 (ERAP1) and HLA-B27 genes are believed to work together to determine the cell surface receptor molecular characteristics and levels that influence the body's immune response. IL23R plays a role in the immune response to infection and is implicated in inflammatory bowel disease and psoriasis, which are both related to spondylitis. Identified genes explain roughly one third of the total inheritability of the disease (10). Scientists think increased immunological activation, particularly of innate pathways, is the pathological mechanism by which the various recognized susceptibility genes may predispose individuals to AS (4,7).

A broadened conceptual framework of AS is needed

At the 1970 Heberden Oration, one of the world's premier rheumatologic pathologists, Prof. John Ball, proposed the term "inflammatory enthesopathy," which received widespread attention (1). His autopsy study of advanced AS patients revealed multiple focal microscopic inflammatory lesions where ligaments attach to the spine (enthesopathy of the spine). Importantly, he subsequently indicated the possibility that mechanisms other than inflammatory enthesopathy, like trauma in a spine "susceptible to stress," could give rise to syndesmophyte formation (2). However, that interpretation received little recognition or response in the scientific community (7).

Yet, the vital unanswered question remains as to the initiating and predisposing pathways or precipitating factors for developing AS (5,10). As in the past, the focal point of AS progression continues to be viewed as skeletal changes. Research has not yet critically addressed interactions of musculoligamentous (myofascial) components on the musculoskeletal system (5). Limited space, permits only brief mention of some integrated biomechanical influences on the unique manifestations of AS (5-9).

Research breakthroughs may be achieved by intensifying currently established immunogenetics and other pathways (3,4,10). Even so, a broadening of perspectives to include biomechanical systems analysis seems to be needed (5-9). The initiating mechanisms of AS are not yet discovered, nor do current concepts sufficiently explain its unique demographic patterns or characteristic localization of lesions (5). A broadened conceptual framework of this mysterious disease need not diminish the currently established core beliefs (3,4,10). Rather, novel theories can expand current concepts and stimulate research on new predictors of the development and sequential course of the disease (5-7). Once people who are susceptible to AS can be more accurately identified by their full range of risk factors and the initiating sequences of pathology are discovered, disease prevention can be approached and more specific therapy provided (3-5,10).

The proposed integrated biomechanical concepts are a work-in-progress (5-9). They need to be critically held up to the experiences of AS sufferers and testing by scientists (3,4,10). If the novel concepts have virtue, improved understanding and management of AS can be expected. If these new views are seriously faulty, addressing their errors will only improve understanding of the current concepts of AS.

Integrated biomechanical principles offer new insights on AS disease patterns (Table 1)

Excess biomechanical stress is a recognized mechanism of local tissue injury and immunological activation, mainly via innate, rather than adaptive pathways (3-5,7). Entheses are anatomically specialized sites to accept and transmit normal repetitive biomechanical stressing forces (3-5). Accordingly, a crucial question is whether or not excess integrated forces are imposed in AS? Assuming that such excess forces do occur, we need to ask why, how, when, where, and to what effect? While these questions cannot be definitively answered, inferences can be raised. A systems integration model of increased axial (spinal) myofascial forces in AS permits a probing interpretation of biomechanical influences in the disease.

Our proposed integrated concepts (5-9,11) expand upon accepted localized biomechanical mechanisms for enthesopathy lesions in AS (2-4), and deal with its other unique features (5). Table 1 outlines the integrated biomechanical principles that may be applied to AS (5). It assumes that excessive axial (spinal) myofascial stiffness predisposes a person to the disease (5-9,11). An understanding of these biomechanical principles can offer a new perspective in interpreting the incidence patterns of AS and the unique localization of its various lesions.

The biomechanical concept was clued by clinical observations of early disease patients who complained about prominent back stiffness and tightness-even without bothersome pain (5-7). Such patients still had essentially full range of motion, yet exhibited a slow ("straining") forward bending, as if overcoming actual physical resistance, yet denying pain. An intrinsic musculoligamentous tightness and stiffness was then suspected to be an early physical component of AS, if not a predisposing factor (5-9). Many years later, after the theory had been considerably refined, it was discovered that in 1951 Dr. Jacques Forestier, an internationally acclaimed rheumatologist and spine specialist, described a similar observation in AS patients on lateral bending that he called the "bowstring sign." Forestier indicated that the bowstring sign was a useful physical finding in diagnosing early AS (11).

Table 1: Integrated Biomechanical Influences on Ankylosing Spondylitis (AS) Features*

1. **The body's muscular and fascial (myofascial) networks are pre-tensed to resist gravity.**
2. **Body pre-tensing (stiffness) varies with age and sex and by the individual's inheritance.**
3. **The inherent polymorphic degree of myofascial stiffness may be excessive in AS.**
4. **Excessive pre-tension decreases mobility and enhances enthesopathy.**
5. **Excessive pre-tension and enthesopathy concentrate forces and reduce transmission.**
6. **The body's tensional integrity ("biotensegrity") is an efficient design for energy and strength.**
7. **Chronically excessive biotensegrity can stress attachments and lead to syndesmophytes.**
8. **Splinting of myofascial anatomical chains creates compressional forces across the sacroiliac joints.**
9. **Hip joints can be compressed by the coupling of several musculoligamentous systems.**
10. **Spinal myofascial hypertonicity biomechanics can explain many typical features of AS.**

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Drs. Masi and John C. Hannon subsequently reviewed the vital role of human resting muscle tone (HRMT) (12). That effort signaled that individuals vary in such a morphological (structural) trait (9,12). HRMT occurs as part of the body's tensional integration (biotensegrity) system, which consists of tensional and compressional elements and provides our body with stability and flexibility (5,7,13,14).

Axial myofascial hypertonicity or excessive spinal stiffness in AS is now only documented objectively by the bowstring sign (11) and observations of increased palpable hardness of patients' lower back muscles in a full resting prone position (5,7). Axial myofascial hypertonicity needs to be tested as a significant primary susceptibility mechanism in the onset and expression of AS. If confirmed, the biomechanical and biotensegrity principles can help explain the unique enthesopathy, SIJ, hip, and tarsitis lesions in this disease (5,8). Quantitative research is needed and planned to measure myofascial properties in AS patients compared to control subjects without back pain or other disorders.

Vignettes and Biomechanical Interpretations

Periodically, readers of the SAA news magazine inquire about possible precipitating factors related to AS. The vignettes and responses below answer some of those questions. These views are not intended to be definitive; rather, they offer interpretation of important questions that need to be scientifically studied.

Vignette 1. Over the years, people with AS have reported a higher proportion of serious self-identified juvenile or young adult athletes with AS compared to what would be normally expected in the general population. Is this true?

A Biomechanical View: Some juveniles and young adults have earlier constitutional or developmental maturation, strengthening and myofascial toning that can enhance athletic performance. If those young athletes are also genetically predisposed to AS, such otherwise advantageous constitution could further amplify axial myofascial tone to excessive amounts. To the contrary, low or generally insufficient musculoligamentous tone could modulate axial myofascial tone, which is suspected to predispose one to AS. Scientists need to vigorously define these physical associations in athletes.

Vignette 2. Many people with AS have correlated the onset of their symptoms with trauma, including motor vehicle accidents or some other sort of physical injury. Several SAA members have raised this cause-and-effect relationship. Does it exist?

A Biomechanical View: Susceptibility to injury following trauma is complicated and depends on multiple factors, including actual physical impacts, biomechanical morphology, and central nervous system coordination and reflexes. Individuals vary in degree of injury following similar types of trauma. A flexible body often has less physical reaction to stressful impact (e.g., children vs. adults). It is often stated in a car accident that a sober person incurs greater injury than an intoxicated person. The sober person is generally more aware of what is happening and tenses up. Another example is an elderly person who may fracture a hip on falling, even before actual impact.

This raises a question: Are AS patients more susceptible to injury, even before recognizing the first medical symptoms of the disease? One may suspect that AS patients have stiffer spines than people without the disease, preceding the onset of chronic pain, which would likely increase the risk of impact injuries. A scientific answer to this question, however, requires accurate measurement of axial myofascial properties in both AS and non-AS patients and their respective susceptibilities to similar injuries.

Does trauma simply reflect an alerting (i.e., first incident) event or is it a meaningful initiating factor in the development of AS? Currently, a conservative, tentative reply would be that the injury more likely first brought the condition to the individual's notice, rather than caused the onset of disease. Again, scientific research is needed on this issue.

Further suggested research for future studies is outlined in Table 2. Preferably, these studies should be performed at the earliest detectable stages of AS. The objective would be to test the validity of the proposed hypothesis and to interpret its sequential influences in multifactor pathways (5,7).

In later or progressive stages, one may expect to find an expanded number of factors that contribute to the disease (4,5,7). Thus, a greater complexity of mechanisms is expected, as opposed to the initial predisposing and preclinical pathways. Better understanding of the initiating mechanisms of AS, however, is essential for more effective control and eventual prevention of this mysterious disease.

Dear readers: Questions or comments? We encourage you to give us feedback on this article. Please send your response to:

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Table 2: Areas of Controlled Research to Test Axial (Spinal) Myofascial Hypertonicity in AS

1. **Noninvasively quantitate tension of spinal muscles at rest and with activity.**
2. **Noinvasively quantitate stiffness of spinal muscles at rest and with activity.**
3. **Quantitate paraspinal muscle hardness, as is done with tension-type headache.**
4. **Nonivasively quantitate sacroiliac joint stiffness under varied conditions.**
5. **Explore imaging (MRE and ultrasonography) to quantitate muscle tone.**
6. **Investigate bioenergetics of AS patients vs. control subjects under varied conditions.**
7. **Confirm or refute axial myofascial hypertonicity and study sequential risk pathways.**

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