# YOGA AND BIOMECHANICS: A New View of Stretching Part 1

How often do you encounter a patient with 'tightness' in parts of their musculoskeletal system and encourage stretching to 'loosen' it and improve flexibility and range of motion? How often do we ourselves practise yoga to stretch and improve our own flexibility? We use these terms glibly, because, well, everyone knows what 'stretching' means, right? And the answer to that question, is actually, probably not! This article is Part 1 of two, which will really get you thinking about what exactly you mean when you use the word 'stretch' and will allow you to do the right kind of stretches for the best result depending on the desired outcome. This article has been extracted from chapter 2 of the author's book *Yoga and Biomechanics: Stretching Redefined*.
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Select any yoga posture to analyse in the context of load and you will easily identify, in addition to the compressive loading on bones and cartilage, the tensile loading on the soft musculoskeletal tissues. In other words, most of the positions we place our bodies in to accommodate the shapes of yoga asana require some stretch and flexibility. Perhaps it is this reason that leads the public to associate yoga with stretching, much to the dismay of many teachers. There appears to be a divide within the yoga community – some ardently refute that yoga is stretching, while others seem to enthusiastically connect the two. My intention is not to defend either position, but to offer an alternative view of stretching so that we may move beyond the disparity and come together to have a fresh conversation on what it means to put tissues under tension.

In order to achieve this, we will need to define some terms – a lot of terms. I find that many conversations I have out in the world about stretching are inconclusive because we are all speaking the same words but with different definitions. Just recently a colleague, who is also a yoga educator, asked me a seemingly simple question about the best way to stretch tendons. My first answer did not satisfy her because she was invested in what she had already learned about the topic through her previous yoga studies. Not until we started breaking down all the components of the question for clarity and defined all the terms until we were certain we understood each other, did we make progress. At this point, we rephrased the question altogether to ask about the best way to load tendons and the discussion became quite enriching.

In this article we will learn about stretching and how it may or may not be a part of yoga (Thought Provoker 1). Through a careful exploration into stretching, not just whether it improves flexibility, but some of the possible mechanisms at work, we can deconstruct many stretching sound bites commonly recited in class.

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●● SOME YOGA TEACHERS ARDENTLY REFUTE THAT YOGA IS STRETCHING, WHILE OTHERS SEEM TO ENTHUSIASTICALLY CONNECT THE TWO ●●

## Thought Provoker 1: What is Stretching?

Have you ever stopped to ponder what stretching means exactly? Could you explain what stretching does, how it works, and why we do it? Could you go further and define precisely what words like mobile, flexible, tight, loose, lengthen, release, resistance, etc., mean? Take a few moments to ponder what structures are involved, what mechanism is contributing to your explanation (ie. how it works), and how confident you would be explaining it to a room full of exercise scientists.

I encourage you to do this because it was this self-imposed exercise that led me to many of the conclusions I will present to you. I first had to become uncomfortably aware of the fact that I was using words without a clear understanding of what they meant.

### Conventional Stretching

Stretching is widely accepted as an essential practice for maintaining physical activity. The general population overwhelmingly believes that stretching is good. Some commonly associated benefits may include improved athletic performance, injury prevention and, of course, flexibility. If you can reach your toes, although you probably have not acquired any sort of special skill resulting from it, you may have been the subject of 'flexibility envy' on more than one occasion.

Culturally, stretching is promoted ubiquitously. My grade school physical education teacher led us through stretches before sending us off to run laps, a practice which continued through my high school soccer years. Commercial gyms provide stretching areas, some community racing events provide organised stretching often alongside the massage services, and stretching related products are sold everywhere.

For a more formal assessment of the benefits of stretching we turn to a governing body for health and fitness, the American College of Sports Medicine (ACSM). Founded in 1954, the ACSM is 'the largest sports medicine and exercise science organisation in the world. With more than 50,000 members and certified professionals worldwide, ACSM is dedicated to advancing and integrating scientific research to provide educational and practical applications of exercise science and sports medicine' (1*). Every several years the ACSM publishes a series of position statements. These in-depth reviews of current research in exercise and sport science serve as the gold standard for exercise recommendations in different populations. For the general population, they have selected five components of fitness (Table 1) (2*).

Flexibility is one of the components of fitness, as is neuromuscular training. Interestingly, yoga falls under the mind–body category, not the flexibility category (although they do reference yoga in the flexibility guidelines). Yet, the number one reason the consumer chooses yoga is to become flexible (followed by stress relief, general fitness, improvements in general health, and physical fitness), as reported in the 2016 Yoga in America study conducted by Yoga Journal magazine (Thought Provoker 2)(3*). Note the difference between the sport science and consumer impressions of yoga.

**Table 1: Components of fitness**

| Component | Example activity |
|---|---|
| Cardiovascular | Running |
| Strength | Weightlifting |
| Body mass index (BMI) | Measure of body fat percentage |
| Flexibility | Stretching |
| Neuromuscular fitness | Qi gong, yoga |

## Thought Provoker 2: Yoga and Flexibility

For the 35 million people in the US practising yoga in 2016, it is the desire to attain flexibility that is bringing them to their mats. Additionally, flexibility is what keeps them coming back, as it has been reported as the number one motivation to continue practising. If yoga and conventional stretching are not related, as many argue, then perhaps yoga has a serious publicity problem.

What are your thoughts on yoga, stretching, and flexibility? What role do the mainstream media, social media, and the leaders in your own yoga community play in perceptions about yoga?

If a yoga student wants to improve her flexibility, what responsibility does the yoga teacher have to either meet the demand or change her perception?

The ACSM classifies the activity of stretching as flexibility training. They clearly define five different approaches to achieving greater range of motion (ROM). Surprisingly, the ACSM guidelines for how to stretch and the reported benefits are somewhat underwhelming. In the 25-page position stand offering exercise guidelines, less than one page is dedicated to stretching. A full-body stretching routine can be completed in under 10 minutes and 2–3 days per week should suffice (2*). In the absence of a detailed and compelling argument for more than 20–30 minutes a week, tradition appears to be the driving force for the promotion of stretching.

### Types of Stretching

Here, we will review in detail

## MANY CONVERSATIONS ABOUT STRETCHING ARE INCONCLUSIVE BECAUSE WE ARE ALL SPEAKING THE SAME WORDS BUT WITH DIFFERENT DEFINITIONS

each type of stretching to highlight that not all stretching is the same. Just as compressive loads can vary in magnitude, rate, and time parameters, so can tensile loads. The purpose, at this time, is not to value one type of stretching over others, but to clearly outline the similarities and differences. Later, when we examine how different loading modes and parameters affect muscle and connective tissue, you will be able to determine which type of stretching satisfies a specific outcome. A mantra to which I adhere is that there is no right way to teach a yoga pose or sequence a class, as long as you can provide sound reasoning for your methods.

*Figure. 1: Legs-Up-the-Wall Pose or a passive stretch supported by the wall*

*Figure 2: Upward Extended Feet Pose (supine double leg raise) or an active stretch held with agonist contraction*

### Ballistic Stretching

The first type of stretching, ballistic stretching, is characterised by bouncing repeatedly into a stretch. I am always reminded of the type of stretching we did in physical education class in elementary school before running a few laps; we would sit on the grass, stretch one leg out, bend the opposite leg in, and bounce repeatedly while reaching for our toes. The process looks very Jane Fonda and very 1980s. This technique fell out of fashion for some time; rumours told us bouncing was unsafe and would lead to injury. Lack of evidence has weakened this position and while it is now more acceptable to bounce and stretch, it is still not something we see very often. I expect someone will soon discover this untapped market, develop a system of ballistic stretching reinforced by several optimistic claims of superiority, trademark the brand, train others to teach it, charge them an annual licensing fee to be associated with the brand, and further monetise it by manufacturing widgets necessary to achieve the greatest benefits. Sound about right?

### Dynamic Stretching

Dynamic stretching, also called slow movement stretching, is characterised by repetitive slow movements that progressively increase in range. You may relate this to joint rotations such as full shoulder circles or ankle rolls, for example. Qualities of dynamic stretching appear in the Vinyasa style of yoga where classes are often sequenced to progressively increase one's range through repetition. For example, Plank Pose becomes Downward-Facing Dog Pose becomes Handstand, eventually. Or Side Angle Pose becomes Bound Side Angle Pose, which then becomes Bird of Paradise. While these configurations are far more complex than the basic and isolated joint rotations characteristic of dynamic stretching, the underlying concept is still there. Incidentally, the currently preferred (because ideas change as research progresses) method of pre-sport or pre-activity stretching among coaches and athletes is dynamic stretching (for reasons we will discuss ahead).

### Static Stretching

Static stretching encompasses a larger range of stretching styles than the previous two and is considered either *active* or *passive*. Both types of static stretching consist of holding a stretched position for a specified amount of time. The most common durations you will find in the literature are 15-second increments up to 60 seconds, but you will certainly see others, and sometimes, although rarely, upwards of 5 minutes. If you consider the average slow-breathing yoga practitioner takes approximately 12 breaths per minute, each breath would last about 5 seconds; therefore holding a yoga posture for five breaths approximates a 25-second static stretch. The category of static stretch depends on the nature of the pose.

Static stretching is most often done passively. Passive stretching requires an external force to hold the stretch. Legs-Up-the-Wall Pose, although not a pose with a central purpose of stretching the hamstrings, is technically a static passive stretch because the wall provides the support for the position (Fig. 1). Reclining Hand-to-Big-Toe Pose with the index and middle finger hooking the big toes or supported with a belt is a passive stretch because the arm is holding the leg in hip flexion to stretch the hamstring. Because of the ubiquity of passive stretching in the flexibility research, many papers use the terms static stretching synonymously with static passive stretching. It is prudent, therefore, to read the methods section of any paper on static stretching to reveal exactly what type of stretching the intervention entailed.

### Active Stretching

In contrast, active stretching, according to ACSM, recruits the opposing muscle group to hold the position. By this description, the active muscle is the prime mover (agonist) and the target muscle being stretched is the opposing one (antagonist). The active version of Supported Legs-Up-the-Wall Pose is Supine Double Leg Raise Pose (Fig. 2) and of Reclining Hand-to-Big-Toe Pose is a hands-free, prop-free, unsupported expression of the same pose. In both, the absence of any external support

recruits the agonist hip flexor group to hold the position, stretching the targeted antagonist hamstring group. The active stretching category is the only section in the ACSM flexibility guidelines which refers to yoga. Arguably, any standing pose in yoga held statically is an active stretch across one or more joints, as is any arm balance, inversion, or seated posture as long it recruits agonist muscle contractions.

In some seated postures, however, the distinction between active and passive stretches may be somewhat ambiguous. For example, in Seated Forward Bend Pose, one individual may effortlessly rest her trunk on her thighs and the pose would be passive (Fig. 3). In another person, the trunk may deviate backwards, perhaps due to the lack of a hip hinge, and the pose would be active as she works against gravity to maintain a forward leaning position (Fig. 4). Brace the back against a wall, however, and it would become passive again (Fig. 5). Therefore, the same pose may be active for one student and passive for another, determined by the source of force (ie. internal, external). An active stretch requires internal force production on the part of the student to hold the position whereas a passive stretch is supported by any external force, including gravity.

## Proprioceptive Neuromuscular Facilitation

The fifth and final approach to stretching recognised by ACSM is proprioceptive neuromuscular facilitation (PNF), or as manual therapists often call it, muscle energy technique (MET). The stretching applications of this technique vary, mostly combining some aspect of isometric contractions with passive stretches through a given ROM. The most recognised method is probably the *contract–relax method*, where a partner takes a subject to the end-range stretch of a target muscle, the subject then isometrically contracts the target muscle against the partner's resistance for a period of time (usually around 6–10 seconds), after which the subject relaxes, and the partner passively stretches the target muscle further. What is unique about contract–relax is the emphasis on the contraction of the target, or stretched, muscle instead of the opposing muscle.

Although used more by athletic trainers and manual therapists than yoga teachers, PNF techniques are widely accepted as an effective method of ROM training. Moreover, the immediate, albeit temporary gains in ROM make PNF an easily demonstrable technique susceptible to exaggerated claims about its benefits. Rife with assertions about the role of muscle reflex activation in flexibility, plenty of misinformation circulates around PNF. For this reason, moving forward, we will focus on the isometric component and refer to PNF and MET stretching as isometric stretches, where the target muscle is isometrically contracted for some period of time at end range. Isometric stretching is, therefore, distinct from active stretching and also from **resistance stretching**.

## Resistance Stretching

Resistance stretching, although not identified by the ACSM, is a method of stretching using eccentric contractions. Most often performed with a partner, an inanimate external weight can also be used to apply resistance. The subject will warm-up the muscle with a few resisted concentric contractions, isometrically pause briefly at the shortened range, and then in a slow and controlled manner, lengthen the muscle with the resistance still applied. Unlike isometric stretching, this method is less about a contraction

*Figure 3: Seated Forward Bend Pose, passive, supported by gravity*

*Figure 4: Seated Forward Bend Pose, active, working against gravity*

*Figure 5: Seated Forward Bend Pose, passive, supported by a wall with some gravitational assistance*

## NOT ALL STRETCHING IS THE SAME

**Table 2: Types of stretching**

| Flexibility exercise | Descriptions | Example |
|---|---|---|
| Ballistic | Bouncing stretches using momentum to increase range | Jane Fonda workouts |
| Dynamic | Slow movements gradually increasing in range | Joint circles |
| Static passive | Holding position using support | Legs-Up-the-Wall Pose |
| Static active | Holding position using opposing muscle | Supine Double Leg Raise |
| Proprioceptive neuromuscular facilitation | Stretch involving some combination of isometric contractions and passive stretching | Contract–relax (isometrically contracting target muscle at end range followed by a deeper passive stretch) |
| Resistance stretching | Slow, controlled eccentric lengthening against resistance | A partner-assisted stretch where the person being stretched tries to concentrically contract against the partner's efforts to lengthen the muscle |

## RESISTANCE STRETCHING IS A METHOD OF STRETCHING USING ECCENTRIC CONTRACTIONS

at end range, and more about a loaded controlled eccentric contraction through the entire range. Extreme ranges are usually avoided because the stretch ends when the subject loses the ability to effectively control the joint position, regardless of the subject's available passive range. Resistance stretching is not well represented in the literature, presumably because it is not commonly identified as a stretching method. Eccentric training has been extremely well studied, especially in recent years and, therefore, the eccentric training research will inform us about the effects of this particular method of tensile loading.

With so many options available, it becomes apparent why definitions are needed in a conversation about stretching. Clarification of variables is required when speaking of specific outcomes. For example, resistance stretching might essentially be eccentric loading, but it's a relatively low load eccentric contraction when compared with the types of eccentric loading used as an intervention in a study. Static stretching can be active or passive, and not all stretching types suggest the stretched muscle must be relaxed as is often assumed. Now that we have identified the different ways in which we can stretch (Table 2), we turn to a discussion on all the reasons why we are supposed to stretch and whether or not those reasons are satisfied by the method.

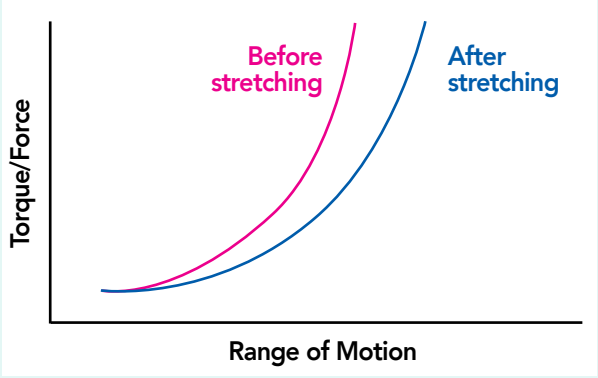



*Figure 6: A decrease in passive resistance torque after stretching*

### Why We Stretch

Surprisingly, the bulk of the research on the effects of stretching is relatively new. In the last 10–20 years, when papers on the subject were first published, the data on static stretching began to reveal that influences on performance, injury prevention, and ROM may not be as positive as we originally assumed. This discovery caused a reversal of opinion in many fitness circles and, in some cases, stretching was even vilified. Fortunately, continued research has shown that those conclusions may have also been premature. There is still much we do not understand and, for now, the conclusions lie somewhere in the middle – stretching is sometimes good, but not that good, and when good, only under certain conditions.

What the body of literature lacks in tenure, reliability, validity and reproducibility it makes up for in volume. Literally hundreds of papers set out to determine once and for all why we should or should not stretch. It can be quite dizzying as they examine multiple types of stretching of varying dosages against different controls on diverse populations. Fortunately, a recent collaboration between the top stretching researchers produced a systematic review summarising the results of the high-quality RCTs published to date (4*). My book *Yoga Biomechanics: Stretching Redefined* sets out to explore how tissues behave under tension beyond the constraints of conventional stretching. We will rely on this current and high-quality review to provide us with a condensed, yet focused, summary of stretching outcomes so that we may move on to explore other biomechanical principles and how they fit into yoga asana.

Regarding sports performance, the researchers assembled the data into multiple configurations to establish various relationships. To begin, all types of stretching were evaluated for acute influences on overall performance (whichever specific performance outcome was being measured in any given paper). Acute effects of stretching refers to the results immediately (usually within 1 hour) after a stretching bout. Stretches under 60 seconds resulted in an average decrease in performance by 1.1% and stretches over 60 seconds *decreased* performance by 4.6%. Whereas both results had a negative impact, the evidence may only have clinical significance in highly competitive situations like training for the Olympics. The results may not be compelling enough to advise a recreational athlete who enjoys his stretching routine before his sport, and who feels better because of it, to forgo it.

When the same data were rearranged to divide performance into the categories strength and power, the numbers told a different story. The acute effects of stretching resulted in a 4.8% deficit in strength, but only a 1.3% deficit in power-speed. The caveat here is that the duration of the stretches in the strength data was longer and we have no way of determining if time in the stretch was a factor in the greater deficit. The variable, strength, is measured by how much weight someone can move, power is measured by the speed at which one can move said weight. Power has a time component to it, strength does not. This is discussed further in chapter 3 of the book *Yoga Biomechanics: Stretching Redefined*.

Arranged by type of stretch, static stretching diminished overall performance by 3.7% and PNF by 4.4%, but dynamic stretching improved performance by 1.3%. Anyone familiar with the literature expects dynamic stretching to improve performance as it has been the recommended pre-activity stretching method for roughly the last decade. ACSM suggests engaging in static stretching or PNF either post-activity or entirely separate from the activity or sport.

Static stretching affected tasks requiring short-range performance negatively by 10.2% but positively by 2.2% in tasks requiring long-range performance. It seems that specificity, as should be expected, applies again – end-range training improves end-range performance.

Concerning injury, the acute effects of static stretching or PNF seem to slightly reduce injury frequency in

muscle injuries relating to sprinting-type activities but not endurance sports. For overuse injuries and other 'all-cause' injuries, stretching did not appear to have any effect. In any case, there appeared to be no adverse effects from pre-activity static stretching, rendering the intervention harmless but only somewhat beneficial, and sometimes even slightly detrimental, depending on the performance goals.

The authors examined dozens of other configurations in addition to the few I selected above. Among the many outcome variables they examined, those I have highlighted tell us enough of the story for our purposes here. I mention this for full transparency, so it does not seem I am cherry-picking data to support my own opinions. I encourage you to read the paper in its entirety if the subject matter intrigues you (4*).

As per our discussion on why we stretch, it appears the evidence does not hold up to the popular consumer belief about performance and injury prevention. One issue with measuring performance and injury prevention as primary outcomes, however, is that there are any number of internal factors and external environmental conditions that could influence outcomes. This complicates study design for the long-term effects of stretching on performance. If the subjects continue to train, any long-term benefits could be a result of the actual training. If subjects discontinue training, we would expect to see deficits and injuries, but I'm not aware of any studies looking at the effects of stretching on injury occurrences in sedentary populations as that would seem irrelevant. I'm also unaware of any studies designed to test whether stretching causes injuries because that is not the theory sports scientists are striving to validate. The emerging yoga narrative about the stretching injuries that yoga may cause is discussed in subsequent chapters in the book *Yoga Biomechanics*. We must first exhaust our investigation of conventional stretching and how the body responds and adapts to it.

## Passive Resistance Torque

Torque, as you may recall, is the word for a rotational force. In ROM research, when a subject's limb is passively moved into a stretch, a torque occurs within the joint space, measurable by a torque meter. Passive resistance torque (PRT) is the measurement of resistance against a joint rotation (Fig. 6). The deformation behaviour of the soft tissue crossing the joint as it is stretched contributes to this resistance.

Imagine practising yoga in stretchy yoga pants versus jeans. The jeans contribute greater resistance than the stretchy pants, thereby limiting ROM. Now imagine those jeans developed less resistance after several stretches. We could call that a decrease in PRT.

The word passive implies that the movement is not initiated through an internal force, but is achieved through the application of an external force. In a biomechanics lab, this is usually a rig with a pulley. A goniometer measures joint angle and a dynamometer measures the torque. A subject with less PRT responds with less resistance than a subject with greater PRT.

Research shows acute stretching reduces PRT, thereby increasing ROM. In the early years of flexibility research, Magnusson published what is today considered a classic paper. His work established some of the testing protocols of the time, before technological advancements in ultrasound became the measurement tools of choice. One of his discoveries was that the acute changes in PRT were fleeting, lasting only about an hour. The subjects had decreased PRT with 5×90-second stretches, spaced 30 seconds apart. PRT returned to baseline in a follow-up test, 1 hour later (5). His work has been replicated, and also refuted, by many over the years, including himself.

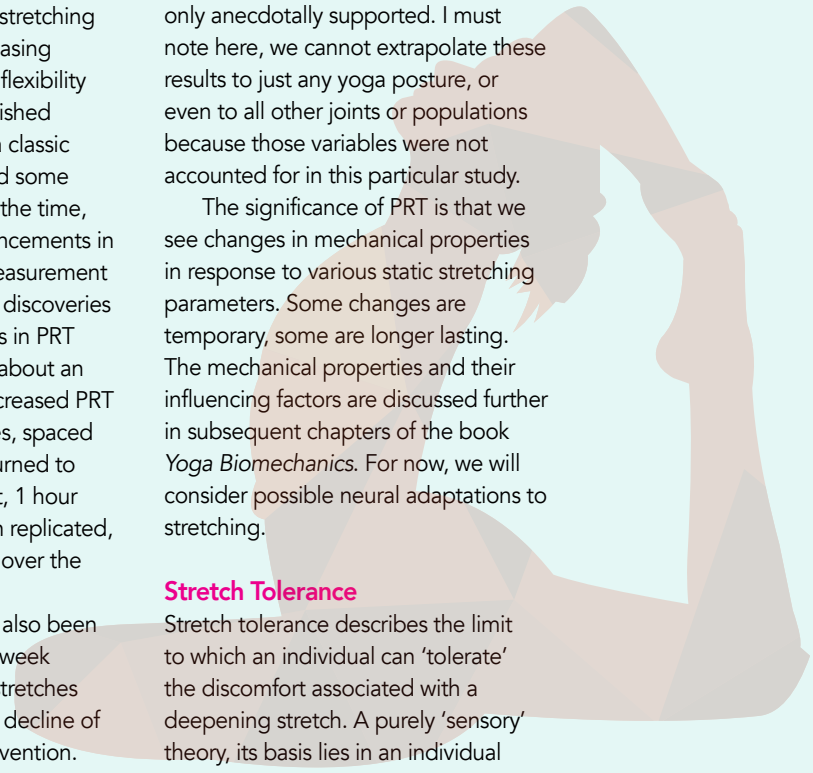
Chronic stretching has also been shown to reduce PRT. A 4-week protocol of 2×60-second stretches twice per day resulted in a decline of PRT at the end of the intervention. Final PRT measurements were taken 24 hours after the last stretching dose, indicating that reductions in PRT last more than an hour when stretching is consistently performed. No follow-up test was conducted in the weeks or months after the daily stretching protocol, providing no indication of the lasting duration of change (6).

Finally, long-held stretches also have an acute effect on PRT. Subjects held a passive stretch for 1, 2, 3, 4, and 5 minutes. After 1 minute, PRT was not yet significantly lower than baseline, but every additional minute thereafter, it was. The 4- and 5-minute stretches resulted in significantly lower PRT than the 1-minute. Moreover, the 5-minute stretch was significantly lower in PRT than the 2-minute one (7). We can conclude that in men averaging 20 years of age, a 5-minute static stretch should reduce passive resistance in ankle dorsiflexion more than a 2-minute stretch will. In sports science, it is a long-held belief that diminishing returns do not warrant holding a stretch longer than about 30–60 seconds (which is still the ACSM recommendation). This paper suggests that changes might continue to occur 3–5 minutes into the stretch, which is interesting because certain types of yoga are characterised by long-held stretches, although their practice is only anecdotally supported. I must note here, we cannot extrapolate these results to just any yoga posture, or even to all other joints or populations because those variables were not accounted for in this particular study.

The significance of PRT is that we see changes in mechanical properties in response to various static stretching parameters. Some changes are temporary, some are longer lasting. The mechanical properties and their influencing factors are discussed further in subsequent chapters of the book *Yoga Biomechanics*. For now, we will consider possible neural adaptations to stretching.

## Stretch Tolerance

Stretch tolerance describes the limit to which an individual can 'tolerate' the discomfort associated with a deepening stretch. A purely 'sensory' theory, its basis lies in an individual



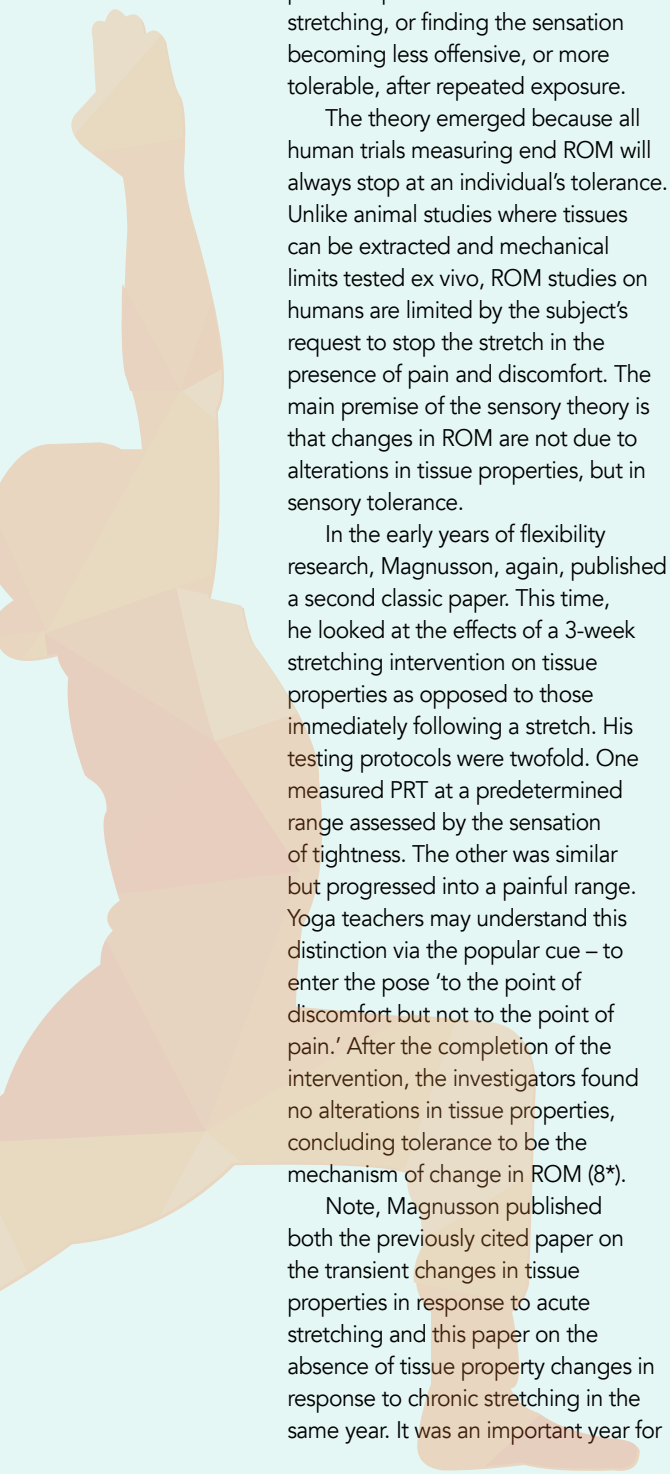
●● NOT ALL STRETCHING TYPES SUGGEST THE STRETCHED MUSCLE MUST BE RELAXED ●●

## Thought Provoker 3: Tightness

How do you explain the feeling of tightness that compels people to stretch?

Do you think tightness is a function of mechanical tissue properties or a sensory experience?

How can you determine if a muscle is tight; would it require a laboratory setting? Does this method of measurement support your explanation of tight?



adapting to and becoming less sensitised to what most consider the painful experience associated with stretching, or finding the sensation becoming less offensive, or more tolerable, after repeated exposure.

The theory emerged because all human trials measuring end ROM will always stop at an individual's tolerance. Unlike animal studies where tissues can be extracted and mechanical limits tested ex vivo, ROM studies on humans are limited by the subject's request to stop the stretch in the presence of pain and discomfort. The main premise of the sensory theory is that changes in ROM are not due to alterations in tissue properties, but in sensory tolerance.

In the early years of flexibility research, Magnusson, again, published a second classic paper. This time, he looked at the effects of a 3-week stretching intervention on tissue properties as opposed to those immediately following a stretch. His testing protocols were twofold. One measured PRT at a predetermined range assessed by the sensation of tightness. The other was similar but progressed into a painful range. Yoga teachers may understand this distinction via the popular cue – to enter the pose 'to the point of discomfort but not to the point of pain.' After the completion of the intervention, the investigators found no alterations in tissue properties, concluding tolerance to be the mechanism of change in ROM (8*).

Note, Magnusson published both the previously cited paper on the transient changes in tissue properties in response to acute stretching and this paper on the absence of tissue property changes in response to chronic stretching in the same year. It was an important year for stretching science.

These papers launched a debate among the mechanical and sensory theorists, and the subsequent publication of multiple papers defending either position or both.

Magnusson continued to publish, and 14 years later coauthored a perspective paper proposing that the sensory theory explains the inconsistencies across the literature resulting from the challenges posed in attempts to control for all variables (9*). In spite of these methodological challenges, today, the evidence is compelling enough for us to validate both theories concurrently, but there is still much we do not know (Thought Provoker 3).

For example, we do not understand the neurophysiology behind tolerance and how it is regulated in the nervous system. We do have some limited research on the topic of anaesthesia and ROM. Subjects undergoing knee surgery were tested on the 'healthy leg' (ie. the leg not operated on). ROM during a passive hamstring stretch was tested pre , intra , and post-operatively. The aim was to compare four variables: spinal anaesthesia, general anaesthesia, a nerve blocker, and an epidural. In all cases, the intra-operative ROM was significantly greater than the pre- and post-operative measurements, which did not change significantly. The spinal anaesthesia resulted in the greatest increase in ROM, suggesting neural regulation of stretching may occur at the level of the spinal cord (10). In another study focusing on the role of pain in ROM, subjects undergoing total knee arthroscopic surgery as a treatment for osteoarthritis were tested. The operative knee was measured for maximal knee flexion and extension prior to surgery and during surgery after a spinal anaesthesia followed by a femoral and sciatic nerve blocker (which blocks nerve impulses, not feeling). Average passive ROM across 141 subjects was greater by 13.4° in flexion and 3° in extension under anaesthesia (11). Whether stretch tolerance or other painful symptoms are the limiting factor in ROM, we have support for a sensory theory that warrants further research.

At this point, we are treading dangerously close to the field of neuromechanics, which is not the remit of this article. It is my position that influences in ROM are likely a function of both sensory and mechanical mechanisms, but exactly how, when, or why each is a factor, we don't yet understand. Thus, where my interest lies is in the question of how, when and why tissues adapt their mechanical properties when loaded in tension. In Part 2 of this article we will delve into the topic of muscle length to elucidate this point, followed by a discussion of eccentric stretching and stretching redefined.

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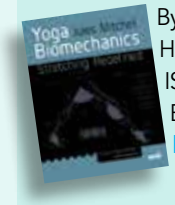
## Key Points

- Some teachers do not think that yoga is stretching while some do.
- In the American College of Sports Medicine (ACSM)'s five components of fitness, yoga is given as an example activity for neuromuscular training rather than flexibility.
- The ACSM classifies stretching as an activity for flexibility training.
- There are several ways to stretch: ballistic, dynamic, static passive and active, proprioceptive neuromuscular facilitation and resistance stretching.
- Static stretching is mostly done passively but can be active.
- Different types of stretching affected different performance parameters differently.
- Stretching may improve joint range of motion (ROM) by reducing the passive resistance torque within the joint space (mechanical theory).
- Stretching may also improve ROM through improving stretch tolerance (sensory theory).

## Yoga Biomechanics: Stretching Redefined



By Jules Mitchell
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*Yoga Biomechanics: Stretching Redefined* provides a unique evidence-based exploration into the complexities of human movement and what a safe, effective yoga practice entails. The emphasis is taken off flexibility and centred around a narrative of body tissue adaptation. Conventional approaches to modern yoga are examined through a biomechanist's lens, highlighting emerging perspectives in both the rehabilitation and sport science literature. Artfully woven throughout the book is a sub-text that improves the reader's research literacy while making an impassioned plea for the role of research in the evolution of how teachers teach, and how practitioners practise. Yoga teachers and yoga practitioners alike will discern yoga asana for its role in one's musculoskeletal health. Yoga therapists and other allied healthcare providers can apply principles discussed to their respective professions. All readers will understand pose modifications in the context of load management, reducing fears of injury and discovering the robustness and resilience of the human body.

### Contents



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**Jules Mitchell MS, CMT, ERYT500 is a Las Vegas based yoga educator, yoga teacher, and massage therapist. Her unique approach blends the tradition of yoga with her extensive study of biomechanics to help yoga teachers develop their craft, and empower them through education. It is her passion to share the most useful and applicable findings from exercise science with the yoga community, and to build confidence in students and teachers by giving them a well-grounded understanding of related research. She leads her own advanced teacher training, teaches workshops and immersion courses worldwide, and offers an ongoing selection of online education and mentoring programmes. As an adjunct faculty member at Arizona State University, she serves as a yoga consultant on various research studies measuring the effects of yoga therapy on special populations including pregnant women, women with depressive symptoms associated with perinatal loss, and patients with cancer. Her future research goals include studying the effects of asana on tissue adaptation, and bridging the gap between research in exercise science and the practice of yoga.**

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