The Science of Yoga

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SUPERHUMAN YOGI POWERS (SIDDHIS)

A large number of Siddhis – supernatural or magical powers – have been attributed to yogis. Siddhis include the ability to:

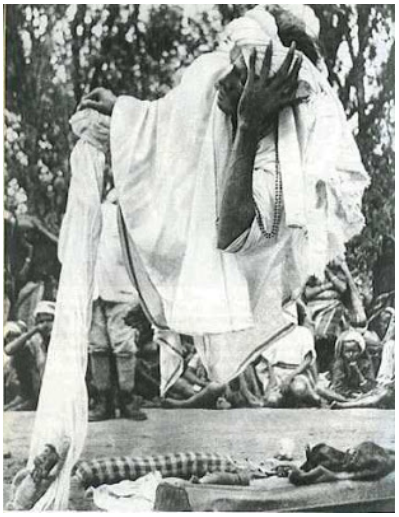
- fly and levitate
- become very large or very small, very heavy or very light
- suspend breathing and stop the heart
- become invisible
- walk through walls
- project into other bodies, manifest and control things (psychokinesis)
- telepathy, clairvoyance, and precognition
- be in more than one place at once
- touch the moon
- walk on water
- survive live burial
- die at will and bring the dead back to life
- neutralize poisons and destroy all diseases
- overcome old age and achieve immortality.

The Indian Skeptic Society demonstrated the use of magician's tricks for the "miracles" performed by some prominent modern yogis. They offered a substantial financial reward for any yogi who could prove they had such supernatural powers. No one was able to claim the reward.

Although no yogi has been able to prove "supernatural powers" in a properly monitored environment, the scientific scrutiny that has occurred has demonstrated that advanced yogis can have an amazing control over their mind and body – to a degree that has allowed them to perform feats that normal people would deem impossible.

Levitation

The ability to float above ground is a siddhi that is well documented. Below is an account that includes photos of a levitating yogi.



"Yogi Pullavar's attendants erected a small tent in an open area. Yogi Pullavar began by ritualistically pouring water in a circle around the tent. Shoes were prohibited within the area marked by the circle. Yogi Pullavar then entered the tent where he remained hidden from view for a few minutes. The attendants then removed the tent. Yogi Pullavar was seen suspended horizontally several feet above the ground. He was in a trance, lightly resting his hand on top of a cloth covered stick. He did not exert pressure on the stick. He apparently used the stick as a point of reference rather than for support. Many photographs were taken from various angles of this exhibition. Witnesses were permitted to thoroughly examine the levitation. They thoroughly searched for strings, props and any means of possible support above, below and around the levitating Pullavar. Nothing was found."
(first picture and text from: http://www.amazingabilities.com/amaze8a.html, second picture from: http://wisdomquarterly.blogspot.co.nz/2009/03/levitation-literally-in-india-tibet.html)

This is a magic trick regularly done by street performers. (1) A platform is hidden under the yogi's clothing. (2) A post connects the platform to (3) a support, hidden underneath something laid on the ground. The post supporting Yogi Pullavar in the above account is clearly visible, despite the description in the above account where witnesses were not able to find any possible support.
(image from 10 Secrets Behind The Most Popular Magic Tricks Revealed http://www.worldfactsftw.com/10-secrets-behind-the-most-popular-magic-tricks-revealed/)

In another documented situation, a group of American yogis believed they levitated during meditation. They began their meditation sitting in one position and when they finished, they found they had moved. They set up cameras to film this feat. The video showed they started bouncing during their meditation and this is what caused their movement.

Control of body temperature

There are tales of Tibetan yogis going semi-naked in the freezing cold of the Himalayas. This is one amazing feat that has been shown possible without the use of trickery.

Tibetan monks were examined by Harvard researchers in 1982 and 2013 where they demonstrated their ability to raise their body temperatures to as high as 100 degrees Fahrenheit. In another study, Swami Rama changed the temperature of his hand, creating a gap of up to 11 degrees Fahrenheit across his palm. He did this by widening and contracting the arteries in his wrist.

More recently, Wim Hof, a Dutch extreme athlete known as "The Iceman" for his ability to withstand extreme cold, has demonstrated breathing techniques based on Tibetan Tummo meditation. In 2007 Hof climbed to 6.7 kilometres (22,000 ft) altitude at Mount Everest wearing nothing but shorts and shoes. In 2009 he reached the top of Mount Kilimanjaro wearing shorts. He also completed a full marathon (42.195 kilometres), in 5 hours and 25 minutes above the Arctic Circle in Finland, in temperatures close to −20 °C dressed only in shorts. The investigative journalist Scott Carney took an assignment to debunk the Wim Hof Method, but ended up learning his techniques and writing about this in the New York Times bestselling book *What Doesn't Kill Us*.

Ability to stop heart beating

A well-known siddhi is to stop the heart beating. Shri T. Krishnamacharya was known to be able to stop the heart beat for several minutes. When tested, no pulse could be found, even with a stethoscope. However, when tested with an electrocardiogram, a very faint heartbeat was found.

Although we now know that stopping the heart beat is a myth, the same testing also provided the scientific evidence to prove that advanced yogis do have an amazing ability to control these functions. Medical text books were rewritten following this research. Advanced yogis appear to have a superhuman power to control their autonomic nervous systems, to slow down their metabolic rate to an incredible degree – effectively going into hibernation.

Live burial / Returning from the dead / Going without food for 40 days

This “miracle” involves food being surreptitiously provided or having the yogi leave their cage through a secret hole. In one infamous case, a yogi who was supposed to have been buried was found by local townsfolk strolling beside a river.

In 1896 at the Millennial Exposition in Budapest, Hungary, two yogis took turns going into a deep trance in a glass coffin where they appeared to die, and then would later return from the dead. They switched places every week or two. Their ruse was revealed when some skeptics hid themselves nearby one night and watched as the coffin lid opened and the yogi got out to eat some cake and drink a bottle of milk.

A more rigorous test involved a yogi who had done live burials for up to a month at county fairs. He was put in an airtight chamber where he had no opportunity to sneak out or have food delivered to him. In several attempts, the longest he could last was 18 hours.

An explanation for the live burial feat without cheating has been provided by the “hibernation” ability described above. It has been suggested that where cloth is placed over the yogi’s face and the soil is sufficiently porous, when combined with an extremely low metabolic rate, sufficient transfer of oxygen and carbon dioxide might occur to keep the yogi alive. This would explain why the yogi in the test discussed above would be willing to undergo a test where there was no possibility of cheating, but failed where the chamber was airtight.

Long life

While there is no evidence to support claims of living for 1,000 years, there is evidence to support claims of longer than normal life. In particular, there is evidence to suggest yoga can "turn back the body clock" to some extent as well as addressing problems that shorten our lives. This is discussed in the benefits section.

Many yoga gurus have famously lived long lives (Krishnamacharya and Indra Devi both lived to 100, Iyengar came close). But this may depend on the type of yoga practiced. Yogananda, whose style did not incorporate the asanas of hatha yoga, was pudgy and died of a heart attack at 59.

BENEFITS

Yoga excels in bringing a range of health benefits unmatched by any other form of exercise. Evidence for this is provided by a large body of research. Yoga helps in managing stress, performance anxiety, chronic pain, coronary artery disease, asthma, diabetes, lymphoma, breast cancer, depression, anxiety, obsessive-compulsive disorder, post-traumatic stress disorder, and schizophrenia. Yoga also helps improve quality of life measures such as psychological well-being, satisfaction with life, and self-esteem.

A 2010 review of more than 80 studies found that yoga equalled or surpassed all other forms of exercise examined in all areas except physical fitness.

Fitness

Traditional Hatha Yoga, with its stationary poses, was found to have an aerobic benefit equivalent to a slow walk. More modern yoga, which included sun salutations, can help improve fitness in unfit or sedentary individuals. Hard styles such as Ashtanga Vinyasa, are more affective at improving fitness, but still not as good as an aerobic workout.

Weight loss

Yoga generally slows down metabolism, although this can vary, depending on the type of yoga practiced. Slowing down metabolism could potentially result in increased weight if calorie intake is not reduced. However, a study looking at metabolism found no change in weight. Anecdotal evidence suggests that yoga can help reduce weight. This has been attributed to yoga's ability to reduce stress. In addition, yoga promotes a healthy diet that can also play a major role in controlling weight.

Improved sleep

Several studies have linked regular yoga practice with improved sleep:

- Researchers at Harvard Medical School found daily yoga practice improved sleep efficiency, total sleep time, total wake time, sleep onset latency (the amount of time it takes to fall asleep) and wake time after sleep onset.
- A study of 410 cancer survivors who practiced yoga twice a week for 75-minute sessions found that yoga was linked to improved sleep quality, reduced feelings of fatigue, reduced frequency of use of sleep medication, and an improved sense of quality of life.
- A study of post-menopausal women with insomnia found a reduction in symptoms and the severity of the sleep disorder occurred with yoga practice.
- A study of women with osteo-arthritis and sleep problems, found an evening yoga practice was linked to significant improvements in sleep efficiency and a decrease in the frequency of individual nights of insomnia.
- Another study found relaxing muscles led to improved sleep.

Balance and proprioception

Our balance is affected by three systems. These are the:

- vestibular system – a group of canals in the inner ear that tell us when the head is tilted, rotated, flexed or extended
- visual system – sight provides feedback as to our body's position
- proprioceptive system – sensory receptors in the muscles and tendons that tell us as how and where our body and limbs are oriented in space.

As we age, our vision and our vestibular system deteriorate, making balance more difficult and increasing the risk of injury. Falls are a major contributor to injury, particularly amongst the elderly where they are the leading cause of death by injury. Further exacerbating this is the decreasing bone density that occurs as we age, which increases the risk of fractures from falls. We can reduce these risks through proprioceptive training and this is an area where yoga excels.

The benefits of proprioceptive training are not limited to the elderly. In one study, a proprioceptive intervention program tested was associated with a 35% reduction in risk of recurrence of ankle sprain in athletes.

Arthritis

Yoga excels at fighting arthritis. A 2015 study by the Johns Hopkins Arthritis Center looking at both rheumatoid arthritis and osteoarthritis found participants who completed an 8-week yoga program were still feeling the benefits 9 months later. Another study published in 2011 found doing intensive yoga practice for a week eased trauma from rheumatoid arthritis. Measurements made at the beginning and end of the week showed drops in rheumatoid factor - an indicator in the bloodstream of the disease - as well as improvements in the ability of the practitioners to get out of bed, dress, walk, eat and grip objects. Several other studies have also found similar benefits in the use of yoga to reduce the effects of rheumatoid arthritis.

Counteracting signs of aging

Our bodies dehydrate and stiffen with age. By the time we become adults, our tissues have lost around 15 percent of their moisture content, making them less supple and more prone to injury. With aging, our muscle fibres start to adhere to each other, developing cellular cross-links that prevent parallel fibres from moving independently. The elastic fibres gradually get bound up with collagenous connective tissue and become progressively more unyielding. Stretching slows this process of dehydration by stimulating the production of tissue lubricants. It pulls the interwoven cellular cross-links apart and helps muscles rebuild with healthy parallel cellular structure.

Further to this, we shrink in size as we age due to the disks between our vertebrae gradually drying out and becoming thinner. Thinning of the disks can result in pinching of the nerves passing through the vertebrae, leading to severe pain with a number of nerve conditions. This thinning occurs because the disks of adults have no blood supply of their own, instead, relying on nearby vessels to nourish them. With normal aging, this already limited supply of blood diminishes even further and the disks gradually dry out and become thinner. Scientific research found yogis had less degeneration of their spinal discs. This was explained by the spinal flexing in yoga causing more nutrients to diffuse into the disks.

Reverse aging – turning back the body clock

DNA tips, known as telomeres, get shorter each time a cell divides. They are like an internal clock that determines the life span of the cell. The telomeres are eroded by a range of conditions, including stress. Yoga can help reverse this, helping telomeres grow longer. Pilot studies have found levels of telomerase (an indicator of telomere health) increased significantly for people who made lifestyle changes that included yoga or meditation for relaxation and stress reduction.

Dealing with anxiety and depression

Yoga has been demonstrated to be effective in reducing depression and anxiety. Depression has been linked to low levels of Gamma-aminobutyric acid (GABA), which is a chemical in the brain that affects the firing of neurons. Medical researchers found increased levels of GABA in people who did yoga. GABA has a calming effect, promoting relaxation and reducing anxiety.

Reducing blood pressure and risk of heart attack, helping boost immunity

Yoga has been shown to lower cardiovascular risk factors such as high blood pressure, blood sugar, cholesterol, and levels of fibrinogen. It has been associated with reduced signs of atherosclerosis – an underlying factor in heart disease that arises when cholesterol and other fatty deposits begin to clog arteries. Yoga has also been found to raise levels of antioxidants in the bloodstream.

Staying calm and reducing stress

Science has shed light on the interaction between the different parts of our brain. We have an "emotional brain" (amygdala and its connections and medial forebrain structures including the medial prefrontal cortex) and a "logical brain" (the dorsolateral prefrontal cortex, other parts of the prefrontal cortex, parts of the cingulate cortex and parts of the hippocampus). The emotional brain initiates a "stress response" through the sympathetic nervous system which leads to adrenaline and cortisol racing through our circulatory system. The logical brain restrains the emotional brain, turning off the stress response and activating the parasympathetic nervous system, which relaxes the body.

The brain activates the parasympathetic nervous system through the vagus nerve, which flows through the spinal column, connecting the brain to the body. When the parasympathetic nervous system is activated, energy is directed to organs that maintain bodily functions such as digestion or health-related body maintenance (the "rest and digest" function). The bending, flexing and breath work in yoga tones the vagus nerve and exercises the logical brain.

Research suggests that the proper functioning of the vagus nerve promotes emotion regulation, social competence, and prosocial behaviour, and dampens aggression, hostility, depression and anxiety. The findings of one research project suggested '…that even a short practice of yoga poses may positively affect the vagal tone, making us feel more satisfied and happy'.

Thus, yoga helps improve our ability to stay calm and manage stress through its physical (asana) and breathing (pranayama) exercises. In a process known as neuroplasticity, the nerve connections in our brain that relate to the relaxation response are strengthened. This improves the ability of the logical brain to keep control over the emotional brain and its stress response.

Inspiration

There are numerous examples of yoga helping improve creativity. This has been attributed to inspiration arising from the release of psychological tension and the quietening of the mind. In

addition, brain scans have demonstrated that yoga can activate the brain's right hemisphere – the part of our brain that affects our creativity.

Flexibility

Being flexible helps with muscular balance and posture by realigning tissue and thereby reducing the effort it takes to maintain good posture throughout the day. Flexible joints require less energy to move through a greater range of motion. This decreases risk of injury and increases physical performance as well. Stretching also increases the temperature of tissues and this increases the transportation of nutrients to tissues. This in turn increases the range of motion and reduces degeneration of joints. Importantly, flexibility in pelvic muscles, hamstrings, hip flexors, and quadriceps reduces stress on the lower back, helping to reduce back pain.

Reducing costs for our health system

Clinical studies have shown that patients who do yoga have fewer hospital visits, less need for drug therapy, and a smaller number of serious coronary events ranging from heart attacks to death. A University of Virginia team reviewed 70 studies and concluded yoga shows promise as a "safe and cost-effective intervention" for improving cardiovascular health.

A study by Harvard-affiliated Massachusetts General Hospital Institute for Technology Assessment and the Benson-Henry Institute of people who did an eight-week program of meditation, yoga and stress-reduction exercises found they used 43% fewer medical services than they had in the previous year. A second analysis comparing the relaxation group to a control group of people with identical medical-services usage rates found a 25% drop in medical services for the relaxation group. As the costs of attending the relaxation classes were less than the medical costs, savings were calculated to be (US) $2,360 per patient each year.

DANGERS

Joint injuries

Surveys have found that most yoga injuries are joint injuries. Many of the poses can place a lot of pressure on joints if not done properly. For example, Lotus can place substantial pressure on knee and ankle joints. Ego can drive practitioners to force their bodies into positions such as Lotus before they are ready for the pose. Thus, practicing physical yoga without overcoming ego can result in problems and this is why the Yamas and Niyamas come before Asana and Pranyama in classical yoga.

Alignment needs to be carefully monitored in many poses to protect against joint injuries. A survey of yoga teachers identified the following key areas that created higher risks:

- Large classes – teachers are unable to keep an eye on all students.
- Inadequate teacher training – organisations such as Yoga Australia and Yoga Alliance set standards to address this problem.
- Idyllic vacation spots where highlighted as being "particularly treacherous".

Nerve damage

There are many reports of people who have pushed too hard in their bending and twisting, leading to nerve damage. This can result from holding a pose that cuts off blood supply to part of the body for too long (e.g., a student who sat in Thunderbolt cutting the flow of blood to the lower leg, depriving the nerve of oxygen, resulting in nerve deadening).

Stroke

Extreme bending of the neck has the potential to damage arteries. This can compromise the blood supply to the brain, destroying parts of the brain. Shoulder stand is a high risk asana when done in the traditional manner. Bridge, Wheel and Cobra have also been identified as problem Asanas.

Pranayama

Intense forms of pranayama, such as Kapalabhati, Bhramari and Khumbaka (breath retention) should be done under the supervision of qualified teachers. Where there is insufficient guidance to prevent students from overexertion, there is a risk of students doing damage to themselves. For example, a woman suffered a partly collapsed left lung from trying too hard with Kapalabhati.

Modern yoga – response to dangers

Yoga has evolved to become safer in response to risks of injury. Extreme positions of the neck in poses such as shoulder stand, as demonstrated by B.K.S. Iyengar in classic texts such as *Light on Yoga*, are no longer taught in a typical western yoga class.

Modern yoga teacher training programs examine common Asanas and Pranayama in detail, paying attention to appropriate cues for good alignment and what to take care of to keep students safe. Specialist lecturers are brought in to teach anatomy. Organisations such as Yoga Alliance and Yoga Australia oversee accreditation of teacher training programs to ensure standards are met and they encourage ongoing professional development of yoga teachers. This is one of the reasons why we recommend anyone interested in practicing yoga should ensure they are taught by qualified yoga teachers who have Yoga Alliance or Yoga Australia accreditation.

GOOD YOGA

Safe yoga

Perhaps the most important contribution of western science to yoga is in terms of safety. In the classical yoga practiced in ancient times in India, students were guided through their stages of development by their gurus. They learnt to overcome their egos before progressing to more challenging asanas. In modern western yoga classes, students start with the practice of asana and our western society is one that encourages competition. Students are apt to push themselves, with the risk of injury. Hence, it is all the more important that we practice with safety in mind, modifying our practice to do what is best for our own individual bodies.

Asanas

Cobra and Wheel – avoid bending neck back too far.
Shoulder stand – avoid pressure on neck – place blankets under shoulders to create space for neck.
Headstand – avoid pressure on head – use arms to take weight off head.
Bridge – avoid pressure on neck – take weight on shoulders and upper arms. Lengthen your neck.

A better stretch – the Inverse Stretch Reflex

Muscles have an automatic response that makes them tighten when stretched too hard. This is called the “stretch reflex”. However, if a stretch is moved into slowly, and particularly if it is held for long enough, the golgi tendon organ sends signals for the muscle to relax so as to protect the tendon from tearing. This is called the “inverse stretch reflex”. It takes from 15 seconds to 30 seconds to phase in. Therefore, to fully stretch a muscle, we hold the stretch for at least 15 seconds and preferably over 30 seconds.

Activating the parasympathetic nervous system

Activating the parasympathetic nervous system improves our health and lifts our mood, reducing anxiety and depression and increasing happiness.

The key to activating the parasympathetic nervous system is slowing down the breath. We do this naturally when sleeping and when relaxing. Yoga teaches us to slow the breath when exercising. This is most easily done in restorative yoga (which may help explain its popularity) and is key for good meditation. It is something we practice and get better at with Hatha yoga (i.e. typical yoga classes). When we hold a stretch, we soften into it. We practice relaxing into the stretch – and the more we relax, the more the breath slows down. When we do our sun salutes, we practice flowing with the breath and we learn to slow down the breath for each movement. The stretching, twisting and balancing of yoga asana places stress on our body, but all the while we are training our minds to relax and activate the parasympathetic nervous system. This carries on into everyday life, where the better our yoga is, the better we are able to relax and deal with everyday stressors.

Exercising the metabolic brake and accelerator

William Broad describes activating the parasympathetic nervous system as applying a metabolic brake and activating the sympathetic nervous system as applying a metabolic accelerator. He suggests a good yoga workout should cycle through the metabolic brake and accelerator a number of times. This can be achieved through sequences of Asanas that work through forward bends and back bends, and work through low-intensity (meditation, cat-cow, child's pose, etc) and high-intensity (sun salutations, arm balances, peak poses) sequences. This gives the nervous system a workout that improves our ability to apply the metabolic brake.

Inversions

Inversions place a larger portion of the body higher than the heart, increasing blood flow into the right atrium, causing the heart to slow down. This activates the metabolic brake (parasympathetic nervous system). Headstands and shoulder stands place more of the body above the heart than "legs against the wall", but also have higher risks requiring more care and expertise.

A final note: Body, Breath and Mind = Asana, Pranayama and Meditation

Calming the mind helps activate the parasympathetic nervous system, with its "rest and digest" benefits. As we get better at our yoga, we learn to move the mind into a meditative state throughout our practice, not just as we hold an Asana, but also as we flow from one Asana to another. We learn to move with our body and breath and the focus of our mind all in synchronisation. This trains our body and mind to develop a calm, relaxed state with mental clarity.

In classical yoga, there are eight "limbs". We begin with the Yamas and Niyamas, which teach us good attitude (including kindness to ourselves and overcoming ego), and prepare us for the following "limbs". Next come Asana – the physical postures we practice, then Pranayama – the breathing exercises. These four "lower limbs" prepare us for the higher limbs which deal with the mind. Pratyahara (sense withdrawal) and Dharana (focus) prepare us for Dhyana (continual focus – meditation). Here, the mind becomes one with the body and we discover Samadhi (bliss).

The paths provided by classical yoga's eight limbs are in effect a roadmap for a journey to better health and happiness. Through science we have a better understanding of the physical and psychological processes through which this is achieved. While science has debunked some of the myths attached to yoga, and led us to change some practices to reduce incidences of injury, it has also confirmed the incredible benefits that yoga gives.

Acknowledgment

This paper has drawn material from a large number of sources. One source in particular stands out and has been quoted directly or paraphrased often in the paper:

William J. Broad (2012) *The Science of Yoga: The Risks and the Rewards*