

# FLEX CEUs



## Hormetic Stress: Successful Integration into Physical Therapy



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## Introduction

This course explores the concept of hormetic stress and its practical applications in physical therapy. Hormetic stress refers to the beneficial effects of the body's adaptive response to low doses of stressors. Controlled stressors can enhance physical therapy outcomes by promoting beneficial physiological adaptations, which can improve rehabilitation outcomes. The course covers types of hormetic stress and delves into the cellular and physiological responses to these stressors. Students will learn about the adaptation processes in the musculoskeletal and nervous systems, as well as cellular repair and regeneration mechanisms. The benefits of hormetic stress include enhanced physical resilience, improved immune function, and reduced inflammation, all of which can contribute to a more efficient and effective rehabilitation process. Additionally, hormetic stress has been shown to positively impact healthspan by promoting longevity and reducing the risk of age-related diseases. By integrating evidence-based hormetic strategies into physical therapy, healthcare professionals can provide personalized and innovative care that not only speeds up recovery but also enhances overall health and well-being.

## Background Information on Hormetic Stress

Hormetic stress refers to a biological phenomenon where exposure to a low dose of an otherwise harmful stressor can lead to adaptive beneficial effects on an organism. This concept is rooted in the broader framework of hormesis, which describes how low-level exposure to toxins, radiation, heat, or other stress-inducing agents can stimulate cellular and systemic responses that enhance resilience, repair mechanisms, and overall health. The hormetic stress response involves complex biochemical and physiological pathways, including the upregulation of antioxidant defenses, activation of stress response proteins, and

improved metabolic functions. Understanding hormetic stress has significant implications for fields such as medicine, aging research, and environmental health, as it highlights the potential of controlled stress exposure to boost vitality and prevent disease. This section will cover an overview of what hormetic stress is, forms of hormetic stress, and resources.

## What is Hormetic Stress?

**References:** 1, 2

Hormetic stress refers to the exposure to low levels of stressors or toxins that, instead of causing harm, trigger adaptive beneficial effects on an organism. This concept is rooted in hormesis, a biological phenomenon where a substance that is damaging at high doses can be beneficial at low doses. Hormetic stress can activate various cellular and molecular mechanisms that enhance resilience, repair damage, and improve overall health.

When an organism is exposed to a low level of a stressor, such as a toxin, heat, radiation, or oxidative stress, the initial effect is to mildly disrupt cellular homeostasis. This mild disruption is not enough to cause significant damage but is sufficient to alert the cell's protective mechanisms. The disruption caused by the stressor activates a series of cellular stress response pathways. One key response involves the production of heat shock proteins (HSPs), which assist in folding and refolding proteins, preventing aggregation, and aiding in the degradation of damaged proteins. This response is particularly beneficial as it ensures that proteins maintain their proper structure and function under stress conditions.

Exposure to oxidative stress can increase the production of antioxidant enzymes like superoxide dismutase (SOD), catalase, and glutathione peroxidase. These enzymes play crucial roles in neutralizing reactive oxygen species (ROS), thereby reducing oxidative damage to cells. This enhanced antioxidant defense system is

vital for maintaining cellular integrity and preventing damage from free radicals. Another important process activated by hormetic stress is autophagy. Autophagy involves the degradation and recycling of damaged organelles and proteins, thus maintaining cellular health by clearing out malfunctioning components. This process is essential for cellular renewal and longevity.

The activation of these cellular responses and pathways leads to systemic adaptations that enhance the organism's overall resilience. Improved mitochondrial function through increased efficiency and biogenesis enhances energy production and reduces oxidative stress. Enhanced DNA repair mechanisms reduce the accumulation of genetic damage, which is crucial for maintaining genomic integrity and preventing diseases like cancer. Properly regulated inflammation helps in healing and defending against infections while preventing chronic inflammatory conditions.

The long-term benefits of hormetic stress include improved health, increased resistance to various stressors, delayed aging, and reduced risk of age-related diseases. By regularly exposing the body to low levels of stressors, such as through exercise, intermittent fasting, or consumption of certain phytochemicals, the body's adaptive responses are kept active and efficient, promoting longevity and vitality. Hormetic stress works by exploiting the body's natural adaptive mechanisms to enhance resilience and health. Low-dose stressors activate protective pathways and processes, leading to improved cellular function and systemic benefits. Understanding and harnessing hormetic stress can provide powerful strategies for health maintenance, disease prevention, and longevity.

## Forms of Hormetic Stress

**References:** 3–8

Key types of hormetic stress include intermittent fasting, which can improve metabolic health; exposure to phytochemicals, which can bolster antioxidant defenses; low-dose radiation, which can stimulate DNA repair mechanisms; heat and cold exposure, which can enhance stress protein production and improve thermal tolerance; hypoxia, which can boost erythropoiesis and vascular function; and pulsed electromagnetic fields, which can promote tissue repair and reduce inflammation. Each of these stressors, when appropriately managed, can contribute to improved health and longevity by activating adaptive stress response pathways. Hormetic stress encompasses a broad spectrum of beneficial responses triggered by exposure to low levels of stressors, contrasting with the harmful effects seen at higher doses. These stressors span various domains, each exerting specific adaptive effects on the body.

### ***Exercise***

Exercise stands as a fundamental example, where physical activity induces controlled oxidative stress and mechanical strain on muscles. This stress prompts cellular repair mechanisms, leading to muscle growth, improved cardiovascular function, and enhanced overall resilience. Regular exercise also boosts mitochondrial biogenesis and antioxidant defenses, crucial for maintaining cellular health and combating aging-related oxidative damage.

### ***High Intensity Interval Training (HIIT)***

HIIT sessions typically involve short bursts (usually 20-90 seconds) of intense exercise followed by periods of rest or low-intensity exercise. This pattern of high-intensity effort interspersed with recovery challenges the body's metabolic and

cardiovascular systems in a unique way, inducing hormetic stress. HIIT training achieves muscular adaptations in a couple of ways. First, during high-intensity intervals, muscles experience increased oxidative stress due to heightened energy demands and oxygen utilization. This stress activates cellular pathways that enhance antioxidant defenses and improve mitochondrial function over time. Secondly, HIIT promotes muscle hypertrophy (growth) and endurance by stimulating the production of growth factors and improving muscle fiber recruitment and efficiency. HIIT enhances insulin sensitivity more effectively than steady-state aerobic exercise, crucial for regulating blood sugar levels and reducing the risk of type 2 diabetes. It also boosts fat oxidation during and after exercise, supporting improved body composition and weight management. Intense intervals followed by recovery periods challenge and strengthen the heart, enhancing cardiovascular efficiency and endurance. HIIT can lower blood pressure and improve heart function, reducing the risk of cardiovascular diseases. HIIT triggers increased production of growth hormone, vital for muscle growth, fat metabolism, and overall recovery. It also stimulates endorphin release, promoting a positive mood and reducing stress levels. The stress and recovery cycles of HIIT promote adaptive responses at the cellular level, enhancing resilience to oxidative stress and metabolic challenges. By stimulating cellular repair mechanisms and improving mitochondrial function, HIIT may also contribute to anti-aging effects and improved longevity.

### ***Intermittent Fasting***

Caloric restriction and intermittent fasting represent dietary approaches that impose metabolic stress. These practices stimulate autophagy, a cellular process that clears out damaged components and enhances cellular longevity. They also improve insulin sensitivity and metabolic flexibility, contributing to better metabolic health and potentially extending lifespan by reducing chronic disease



risks. Additionally, IF promotes fat metabolism by increasing fat oxidation during fasting periods, leading to improved body composition and weight management. During fasting periods, cells initiate autophagy, a process where damaged and dysfunctional cellular components are broken down and recycled. This cellular "clean-up" process helps to maintain cellular health and longevity by removing accumulated waste and promoting cellular renewal. Intermittent fasting has been shown to reduce markers of inflammation in the body. By lowering inflammation, IF may help protect against chronic diseases such as heart disease, Alzheimer's, and certain cancers. IF can influence hormone levels beneficially, including increasing the production of norepinephrine and enhancing the sensitivity of certain neurotransmitter receptors, which can improve mood and cognitive function. Through the hormetic effect, intermittent fasting strengthens cellular defenses against oxidative stress and metabolic challenges. This adaptive response improves the body's resilience to various stressors over time. Consistent practice of intermittent fasting has been associated with longevity benefits in animal studies, including increased lifespan and delayed onset of age-related diseases.

There are several schedules one might follow to intermittently fast. One method is the 16/8 where the fasting window is 16 hours, and the eating window is 8 hours. This is similar to the 20/4 or other ratios of hours of eating to fasting windows. Another method is the 5:2, where one would eat normally for 5 days per week and restrict to 500-600 calories on two non-consecutive days. There is also alternative day fasting, where normal eating days alternate with restricted to 500 calorie days or complete fasting.

### ***Phytochemicals***

Phytochemicals found in plants exert hormetic stress by inducing mild oxidative stress on cells, triggering adaptive responses that enhance cellular resilience and overall health. These bioactive compounds, such as polyphenols (e.g., resveratrol,

quercetin) and flavonoids (e.g., epigallocatechin gallate), activate antioxidant defense mechanisms that mitigate oxidative damage and reduce the risk of chronic diseases. Additionally, phytochemicals possess anti-inflammatory properties, modulating inflammatory pathways to bolster immune function and combat inflammatory conditions. They also influence cellular signaling pathways, improving insulin sensitivity, enhancing mitochondrial function, and promoting cellular detoxification through autophagy. Beyond cellular benefits, phytochemicals contribute to neuroprotection by supporting brain health and cardioprotection by maintaining cardiovascular function. Regular consumption of phytochemical-rich foods, such as fruits, vegetables, and teas, thus plays a crucial role in promoting longevity and overall well-being by harnessing hormetic responses in the body.

### ***Low-Dose Radiation***

Low-dose radiation, defined as exposure levels significantly below those causing immediate harm, exhibits a phenomenon known as radiation hormesis. This concept suggests that while high doses of radiation can be detrimental, low doses can actually stimulate beneficial responses in the body. At these low levels, radiation induces adaptive mechanisms such as enhanced DNA repair processes and the activation of antioxidant defenses like superoxide dismutase and catalase. These enzymes help mitigate oxidative stress and protect cells from damage. Additionally, low-dose radiation can modulate immune responses, improve cellular signaling pathways related to growth and survival, and potentially reduce chronic inflammation. This hormetic effect may prime cells to respond more effectively to subsequent stressors, enhancing overall resilience and potentially contributing to improved health outcomes. Ongoing research continues to explore the therapeutic applications of radiation hormesis in medical treatments and radiation safety protocols.

## ***Heat and Cold Exposure***

Heat and cold exposure are forms of hormetic stress that leverage controlled extremes in temperature to induce beneficial adaptations in the body. Heat exposure, such as sauna use or hot baths, stimulates the production of heat shock proteins (HSPs) that aid in protein repair and cellular resilience. It also enhances cardiovascular function by increasing heart rate and improving blood flow, promoting better vascular health over time. Heat therapy further contributes to improved heat tolerance and anti-inflammatory effects, which can alleviate muscle soreness and joint pain. Conversely, cold exposure through methods like cold showers or cryotherapy activates brown adipose tissue (BAT) to generate heat and maintain body temperature. This process, known as thermogenesis, supports calorie expenditure and metabolic rate. Cold exposure also enhances circulation by initially constricting blood vessels and then promoting vasodilation upon rewarming, which enhances oxygen and nutrient delivery to tissues. Additionally, cold therapy provides anti-inflammatory benefits and pain relief by reducing swelling and numbing nerve endings. It also stimulates the release of endorphins and norepinephrine, improving mood, mental clarity, and resilience to stressors.

## ***Hypoxia***

Breathwork and controlled hypoxia are effective hormetic stressors that induce beneficial physiological adaptations by temporarily reducing oxygen levels in the blood. This state of controlled hypoxia triggers adaptive responses such as the activation of hypoxia-inducible factors (HIFs), which upregulate genes involved in erythropoiesis (the production of red blood cells), angiogenesis (the formation of new blood vessels), and glycolysis (glucose metabolism). These adaptations enhance the body's ability to deliver and utilize oxygen more efficiently. Specifically, hypoxia stimulates the production of erythropoietin (EPO), increasing

red blood cell production and improving the oxygen-carrying capacity of the blood. Additionally, hypoxia-induced angiogenesis results in the formation of new blood vessels, boosting blood flow and tissue oxygenation.

Furthermore, controlled hypoxia enhances mitochondrial function by promoting mitochondrial biogenesis, which increases the number and efficiency of mitochondria in cells, thereby improving energy production and reducing oxidative stress. This process is complemented by the activation of antioxidant pathways, which increases the production of endogenous antioxidants like superoxide dismutase (SOD) and glutathione, protecting cells from oxidative damage. Breathwork techniques, such as deep diaphragmatic breathing, also stimulate the vagus nerve, enhancing parasympathetic tone and promoting relaxation. This increased vagal tone improves heart rate variability (HRV), reduces inflammation, and supports emotional regulation. Overall, the hormetic effects of breathwork and controlled hypoxia enhance resilience, metabolic health, and physiological function by inducing adaptive responses that optimize the body's ability to cope with stress and maintain homeostasis. These adaptations not only improve cardiovascular function and exercise performance but also confer neuroprotective effects by reducing neuronal damage and enhancing resilience in the face of ischemic events. Moreover, hypoxia can modulate inflammatory responses, potentially mitigating chronic inflammation and associated health risks. Overall, exposure to hypoxia demonstrates the body's remarkable ability to adapt and thrive under challenging conditions, highlighting its potential therapeutic applications in improving overall health and resilience.

### ***Pulsed Electromagnetic Field (PEMF)***

Pulsed electromagnetic field (PEMF) therapy harnesses the power of electromagnetic pulses to induce hormetic stress, triggering beneficial physiological responses in the body. By applying these electromagnetic fields in

controlled pulses, PEMF therapy penetrates tissues and cells, stimulating cellular repair mechanisms and enhancing energy production through ATP synthesis. This process supports accelerated healing and tissue regeneration, making PEMF particularly valuable in rehabilitation settings and for promoting recovery from injuries. Additionally, PEMF exhibits anti-inflammatory properties by modulating cytokine production and reducing oxidative stress, which can alleviate pain and facilitate healing in inflammatory conditions. Improved blood circulation is another notable benefit, as PEMF induces vasodilation and enhances microcirculation, aiding in the delivery of nutrients and oxygen to tissues. Moreover, PEMF therapy has demonstrated positive effects on bone and cartilage health by promoting osteogenesis and chondrogenesis, which is beneficial for conditions like osteoporosis and joint injuries. Beyond physical benefits, PEMF may also support neurological health by enhancing neuroplasticity and neuronal function. Overall, PEMF therapy represents a non-invasive approach to harnessing hormetic stress for therapeutic purposes, offering potential benefits across a range of medical applications and wellness interventions.

In summary, hormetic stress encompasses a diverse array of stressors that, when applied in controlled doses, stimulate beneficial adaptive responses in the body. These responses range from enhanced cellular repair and antioxidant defenses to improved metabolic health and physical performance. Understanding and harnessing hormetic mechanisms offer promising avenues for improving overall health, longevity, and resilience to disease.

## **Resources**

Patients, PTs, and PTAs should go to reliable sources for information on hormetic stress. Sources like social media and blog posts are subject to bias, whereas sources like academic journals, books, and professional societies have accurate

information. This section points patients and PTs to the best resources on hormetic stress.

## ***Books and Journals***

### **References: 9–11**

One of the foundational texts on hormetic stress is "Hormesis: A Revolution in Biology, Toxicology and Medicine" by Edward J. Calabrese. This comprehensive book delves deeply into the concept of hormesis, examining its implications across various fields such as biology, toxicology, and medicine. It offers a thorough analysis of how low doses of stressors can induce beneficial adaptive responses within biological systems.

Several scientific journals provide in-depth research on hormetic stress. "Frontiers in Physiology" features articles such as "Hormesis and the Evolution of Stress Response Pathways: Implications for Therapeutics," which explores the role of hormesis in stress response pathways and its therapeutic potential.

"Current Opinion in Toxicology" offers articles like "Hormesis and Its Impact on Human Health: A Review," which reviews current research and understanding of hormesis and its effects on health.

## ***Online Databases and Websites***

For further research, PubMed is an excellent resource where you can use search terms such as "hormesis," "hormetic stress," and "adaptive stress responses" to find relevant articles and reviews. <https://pubmed.ncbi.nlm.nih.gov/>

Google Scholar is another valuable tool for accessing academic papers and theses related to hormesis. Search using keywords like "hormetic stress," "cellular hormesis," and "adaptive response." <https://scholar.google.com/>

## ***Professional Associations and Societies***

**References:** 12, 13

The Society for Free Radical Research (SFRR) focuses on oxidative stress and free radicals, which are integral to understanding hormesis. <https://sfrbm.org/>

The American Physiological Society (APS) provides publications and resources related to physiological responses to stress, including hormesis. <https://www.physiology.org/?SSO=Y>

These resources offer a broad range of perspectives on hormetic stress, from scientific research and theoretical insights to practical applications and clinical considerations.

### **Section 1 Key Words**

Homeostasis – The process by which biological systems maintain a stable internal environment despite changes in external conditions

Autophagy – A cellular process in which cells degrade and recycle their own components

Phytochemicals – Naturally occurring compounds found in plants that possess antioxidant, anti-inflammatory, and antimicrobial properties, and they may play a role in reducing the risk of chronic diseases such as cancer, heart disease, and diabetes

Hypoxia – A condition in which there is an insufficient supply of oxygen to the tissues and organs of the body

## Section 1 Summary

In conclusion, hormetic stress is a biological phenomenon where exposure to low doses of otherwise harmful stressors leads to adaptive and beneficial effects on an organism. Rooted in the broader framework of hormesis, this concept demonstrates how low-level exposure to toxins, radiation, heat, or other stress-inducing agents can stimulate cellular and systemic responses that enhance resilience, repair mechanisms, and overall health. The hormetic stress response involves complex biochemical and physiological pathways, including the upregulation of antioxidant defenses, activation of stress response proteins, and improved metabolic functions. Understanding hormetic stress has significant implications for medicine, aging research, and environmental health, as it highlights the potential of controlled stress exposure to boost vitality and prevent disease. This section has provided an overview of hormetic stress, its various forms, and resources that physical therapists can use to learn more and refer their patients to.

## Physiological Impact of Hormetic Stress

This section explores the physiological impact of hormetic stress, focusing on how controlled exposure to mild stressors can significantly influence adaptive responses within the body. Hormesis, the concept wherein low-level stressors such as exercise, intermittent fasting, and environmental challenges elicit beneficial physiological adaptations, will be analyzed in detail. The discussion will cover how these stressors enhance cellular resilience, optimize metabolic functions, and contribute to overall health. Key physiological mechanisms, including the activation of antioxidant defenses, modulation of inflammation, and enhancement of neuroplasticity, will be examined. This section aims to provide a foundational understanding of how integrating hormesis principles into



therapeutic practice can support patient health, improve rehabilitation outcomes, and inform preventive care strategies in physical therapy.

## **Stress Effect on the Body and Rate of Rehabilitation**

**References:** 3, 4, 14, 15

As evident so far, hormetic stress affects the body in several beneficial ways that can accelerate healing, reduce inflammation, and more. This section will explore how hormesis affects oxidative stress levels, cortisol levels, inflammation, chromosome telomere shortening, and neuronal stress responses.

### ***Oxidative Stress***

Hormesis positively influences oxidative stress levels by stimulating adaptive responses that enhance the body's ability to manage and mitigate oxidative damage. Hormetic stressors, such as intermittent fasting, exercise, and mild toxin exposure, activate the body's antioxidant defense systems, leading to increased production of antioxidant enzymes like superoxide dismutase (SOD), catalase, and glutathione peroxidase. This enhancement in antioxidant defenses helps neutralize reactive oxygen species (ROS) and reduce oxidative stress, thereby protecting cells from damage. Additionally, hormesis induces the production of heat shock proteins (HSPs), which assist in maintaining cellular homeostasis by refolding damaged proteins and facilitating their removal, further reducing oxidative stress.

Hormetic stressors also stimulate cellular repair mechanisms such as autophagy, which degrades and recycles damaged cellular components, thus reducing oxidative damage. Improved mitochondrial function, a result of hormetic stress, leads to better energy production and reduced ROS production, supporting cellular health and longevity. Furthermore, hormesis activates the Nrf2 (nuclear

factor erythroid 2-related factor 2) pathway, which promotes the expression of antioxidant genes and detoxification proteins, helping to lower oxidative stress. The reduction in systemic inflammation, often associated with hormetic stress, also plays a crucial role in decreasing oxidative stress, as inflammation can exacerbate ROS production. Overall, by enhancing antioxidant defenses, promoting cellular repair, improving mitochondrial function, and reducing inflammation, hormesis helps to manage oxidative stress effectively and maintain cellular health.

### ***Cortisol Levels***

Hormesis can significantly affect cortisol levels by inducing adaptive stress responses that enhance the body's ability to manage and regulate stress. Hormetic stressors, such as intermittent fasting, exercise, and cold exposure, initially lead to increased cortisol levels as part of the acute stress response. However, over time, regular exposure to these mild stressors improves the efficiency of the hypothalamic-pituitary-adrenal (HPA) axis, resulting in a more balanced cortisol response and reduced chronic elevations. This increased resilience to stress helps normalize cortisol levels and prevent excessive or prolonged spikes.

Additionally, hormesis often reduces systemic inflammation through mechanisms such as improved metabolic health and optimized glucose metabolism, which lowers cortisol levels since chronic inflammation can drive excessive cortisol production. Hormetic stressors can also enhance sleep quality, which is crucial for maintaining normal cortisol rhythms by ensuring that cortisol peaks in the morning and declines in the evening. Furthermore, hormesis can balance the autonomic nervous system by promoting parasympathetic activity, which counters excessive sympathetic activation and helps lower cortisol levels. These combined effects of hormesis including better stress resilience, reduced inflammation,

improved sleep, and enhanced metabolic health contribute to more stable and regulated cortisol levels, supporting overall well-being and effective stress management.

## ***Inflammation***

Hormesis has a significant impact on inflammation by inducing adaptive responses that help regulate and reduce inflammatory processes. Hormetic stressors such as exercise, intermittent fasting, and exposure to mild toxins activate the body's antioxidant defense systems, increasing the production of antioxidant enzymes like superoxide dismutase (SOD), catalase, and glutathione peroxidase. These enhanced defenses help neutralize reactive oxygen species (ROS) and reduce oxidative stress, which is a key driver of inflammation. Additionally, hormesis activates various anti-inflammatory signaling pathways, leading to the production of anti-inflammatory cytokines like interleukin-10 (IL-10), which counteract pro-inflammatory cytokines and lower overall inflammation.

Regular exposure to hormetic stressors also helps prevent the chronic activation of inflammatory pathways by promoting cellular resilience and repair mechanisms. This reduces the incidence of chronic inflammation, which is associated with a lower risk of chronic diseases and improved overall health. Hormesis improves metabolic health by optimizing glucose metabolism and reducing insulin resistance, further reducing inflammation as metabolic dysregulation is linked to increased inflammatory responses. Furthermore, hormesis stimulates processes such as autophagy, enhancing cellular maintenance by degrading and recycling damaged components, which contributes to a decrease in inflammatory markers. Neuroendocrine adaptations from hormesis, including improved regulation of hormones like cortisol, also help control inflammatory responses. Additionally, increased production of heat shock proteins (HSPs) from heat or exercise-induced stress helps protect cells from damage and

inflammation. Overall, these combined effects of hormesis, enhanced antioxidant defenses, activation of anti-inflammatory pathways, improved metabolic health, and better cellular repair, contribute to a reduction in inflammation, supporting better health and resilience.

### ***Chromosome Telomere Shortening***

Hormesis can positively influence chromosome telomere shortening by triggering adaptive responses that help maintain telomere integrity and potentially slow down the aging process. Hormetic stressors such as exercise, intermittent fasting, and caloric restriction can activate telomerase, an enzyme that adds nucleotide sequences to the ends of chromosomes, counteracting telomere shortening and potentially enhancing cellular longevity. Additionally, hormesis stimulates cellular repair mechanisms, including autophagy and DNA repair, which help preserve chromosome stability and prevent damage that could accelerate telomere shortening.

By enhancing antioxidant defenses, hormesis also reduces oxidative stress, a significant factor in telomere degradation. For instance, exercise and intermittent fasting boost the production of antioxidant enzymes like superoxide dismutase (SOD) and catalase, which protect telomeres from oxidative damage.

Furthermore, hormesis helps regulate inflammation by activating anti-inflammatory pathways and improving metabolic health, both of which contribute to reduced systemic inflammation that can otherwise accelerate telomere shortening. Improved metabolic health from hormetic stressors like caloric restriction and regular exercise also supports longer telomere length by reducing the risk of conditions associated with accelerated telomere degradation. Overall, hormesis enhances cellular adaptation and resilience, helping to preserve telomere length and support cellular health, thereby potentially slowing the aging process and extending cellular lifespan.

## ***Neuronal Stress Responses***

Hormesis has a profound impact on neuronal stress responses by enhancing the brain's resilience and adaptability to stressors. Stressors such as intermittent fasting, exercise, and caloric restriction stimulate neuroplasticity, enabling the brain to reorganize itself and form new neural connections, which improves cognitive function and emotional resilience. Additionally, hormesis activates neuroprotective pathways, including the upregulation of brain-derived neurotrophic factor (BDNF) and heat shock proteins (HSPs), which support neuronal survival, repair, and overall brain health.

By boosting the body's antioxidant defenses, hormesis reduces oxidative stress, a major contributor to neuronal damage, and helps protect neurons from oxidative injury. Improved mitochondrial function from hormetic stressors supports better energy production and reduces neuronal stress, further contributing to brain health. Hormesis also helps regulate inflammatory responses, lowering neuroinflammation and reducing the risk of neurodegenerative diseases. Enhanced synaptic function from hormetic stressors improves communication between neurons, supporting better learning, memory, and cognitive performance. Furthermore, hormesis promotes hormonal balance by regulating stress-related hormones like cortisol and adrenaline, mitigating the negative impact of chronic stress on the brain.

Overall, hormesis enhances neuronal resilience and function, offering protection against stress-induced damage and supporting overall mental well-being.

## Vagal Nerve Reset and Toning

**References:** 4, 15, 16

The specific mechanisms by which hormesis impacts vagal nerve reset and enhances vagal tone involve a complex interplay of physiological and biochemical processes. This section will detail how the different types of hormesis affect vagal function.

Exercise positively influences vagal tone and vagal nerve reset through a range of physiological mechanisms that embody the principles of hormesis. One key effect is the increase in heart rate variability (HRV), which reflects a healthier balance between the sympathetic and parasympathetic nervous systems. Regular physical activity boosts HRV, indicating improved vagal tone and autonomic balance, leading to better stress management and cardiovascular health. Exercise also triggers a temporary increase in sympathetic nervous activity, followed by a period of parasympathetic dominance, enhancing vagal nerve activity and tone. Additionally, exercise stimulates mitochondrial biogenesis, improving cellular energy production and efficiency, which supports better vagal function. Regular physical activity helps reduce systemic inflammation by lowering pro-inflammatory cytokines and increasing anti-inflammatory cytokines. This reduction in inflammation positively affects vagal nerve function, contributing to improved vagal tone. Exercise enhances endothelial function by increasing nitric oxide production, which improves blood vessel dilation and overall cardiovascular health, further supporting vagal nerve activity. Moreover, exercise promotes neuroplasticity and resilience by stimulating brain regions involved in stress regulation, which is partly mediated through improved vagal tone. Overall, exercise acts as a hormetic stressor by imposing controlled physical stress that stimulates adaptive physiological responses, leading to better autonomic

regulation, enhanced vagal nerve function, and overall improved health and resilience.

Intermittent fasting activates AMP-activated protein kinase (AMPK), enhancing mitochondrial function and promoting cellular autophagy, which improves energy efficiency and reduces oxidative stress, positively influencing vagal tone. Fasting also increases brain-derived neurotrophic factor (BDNF) levels, supporting neuronal health and plasticity, including vagal neurons. Cold exposure triggers the release of noradrenaline, stimulating the vagus nerve and enhancing parasympathetic activity, while also promoting the expression of cold shock proteins that aid in cellular protection. Additionally, cold exposure activates brown adipose tissue, increasing thermogenesis and metabolic rate, which are feedback to improve vagal tone through enhanced metabolic health.

Heat exposure induces the production of heat shock proteins that protect cells from damage and modulate inflammatory pathways, enhancing vagal activity by reducing systemic inflammation. Heat also increases nitric oxide production, improving cardiovascular function and stimulating vagal afferents through enhanced blood flow and reduced blood pressure. Exercise increases heart rate variability, a marker of vagal tone, by upregulating parasympathetic activity and promoting mitochondrial biogenesis, which reduces oxidative stress and supports neuronal health, including the vagus nerve.

Breathwork and meditation directly activate the parasympathetic nervous system, increasing vagal tone through techniques like diaphragmatic breathing that stimulate vagal afferents. These practices also reduce cortisol levels, decreasing stress and systemic inflammation, thereby enhancing vagal function. Nutritional interventions, such as consuming omega-3 fatty acids and polyphenols, reduce systemic inflammation through their antioxidant properties, positively affecting the vagus nerve. Additionally, these nutrients influence the gut microbiota, which

interacts with the vagus nerve via the gut-brain axis, further enhancing vagal activity and overall health.

Pulsed electromagnetic fields (PEMF) therapy stimulates cellular repair and regeneration, promoting tissue health and reducing inflammation, which supports vagal nerve function. PEMF also enhances neuroplasticity, promoting the growth and connectivity of neurons, including those in the vagus nerve, thus improving vagal tone and autonomic regulation. These multifaceted mechanisms collectively improve cellular function, reduce inflammation, and promote autonomic balance, leading to enhanced vagal nerve activity and overall health benefits.

Understanding these processes provides a foundation for therapeutic interventions aimed at optimizing vagal function and resilience.

## **Effects of Hormesis on Biology and Toxicology**

**References:** 2, 17

Hormesis affects the body in many ways, especially with respect to aspects of biology and toxicology. This section will go into more detail on the biological impact of hormetic stress and aspects of toxicology to help physical therapists and assistants understand its place in rehabilitation.

### ***Biology***

Hormesis has a multifaceted impact on human biology by inducing a range of adaptive physiological responses that enhance overall health and resilience. This concept involves the beneficial effects resulting from exposure to low doses of stressors that might otherwise be harmful at higher levels. Here's a detailed exploration of how hormesis affects various aspects of human biology:



### ***Cellular Stress Response and Repair***

Hormesis activates cellular stress response pathways that enhance the body's ability to cope with damage. Low-level stressors such as exercise, caloric restriction, and exposure to mild toxins stimulate the production of heat shock proteins (HSPs) and other stress response proteins. These proteins help in stabilizing and refolding damaged proteins, preventing protein aggregation, and promoting cellular repair and recovery. Additionally, hormesis stimulates autophagy, a process that involves the degradation and recycling of damaged cellular components, thus maintaining cellular homeostasis and function.

### ***Antioxidant Defense and Oxidative Stress***

Exposure to mild stressors boosts the body's antioxidant defenses by upregulating the production of endogenous antioxidants such as superoxide dismutase (SOD), catalase, and glutathione. These antioxidants neutralize reactive oxygen species (ROS) and reduce oxidative stress, which is associated with aging and various diseases. By enhancing antioxidant defenses, hormesis helps protect cells from oxidative damage, thereby reducing the risk of chronic conditions like cardiovascular disease, neurodegeneration, and cancer.

### ***Metabolic Adaptation and Insulin Sensitivity***

Hormetic stressors such as intermittent fasting and physical exercise improve metabolic health by enhancing insulin sensitivity and optimizing glucose metabolism. These stressors stimulate processes like mitochondrial biogenesis and improve metabolic flexibility, which enhances the body's ability to manage energy production and utilization. Improved insulin sensitivity reduces the risk of metabolic disorders such as type 2 diabetes and supports overall metabolic health.

### ***Inflammatory Response Modulation***

Hormesis helps regulate inflammation by activating anti-inflammatory pathways and reducing systemic inflammation. For instance, hormetic stressors can lower the production of pro-inflammatory cytokines and enhance the production of anti-inflammatory cytokines. This modulation helps mitigate chronic low-grade inflammation, which is a contributing factor to numerous chronic diseases, including cardiovascular disease, diabetes, and autoimmune disorders.

### ***Neuroprotection and Cognitive Function***

Hormesis positively affects brain health by promoting neuroplasticity, enhancing cognitive function, and providing neuroprotection. Stressors such as physical exercise and caloric restriction stimulate the production of brain-derived neurotrophic factor (BDNF) and other neurotrophic factors, which support neuronal growth, survival, and repair. These adaptations help protect against neurodegenerative diseases and support cognitive function, memory, and overall mental well-being.

### ***Hormonal Regulation***

Hormesis can influence hormonal balance, including the regulation of stress hormones such as cortisol. Mild stressors help improve the efficiency of the hypothalamic-pituitary-adrenal (HPA) axis, leading to a more balanced cortisol response. This balanced hormonal regulation helps manage stress more effectively, reducing the negative impacts of chronic stress on health.

### ***Longevity and Aging***

By enhancing cellular repair mechanisms, reducing oxidative stress, and improving metabolic health, hormesis contributes to increased longevity and healthier aging. Low-level stressors stimulate adaptive responses that promote cellular

maintenance and function, potentially slowing the aging process and extending healthy lifespan.

Hormesis exerts a profound impact on human biology by enhancing cellular stress responses, boosting antioxidant defenses, improving metabolic health, modulating inflammation, and supporting cognitive function. By optimizing these physiological processes, hormesis contributes to better overall health, increased resilience, and potentially extended longevity. The beneficial effects of hormesis underscore the importance of understanding how controlled exposure to mild stressors can support and enhance human biological function.

### **Toxicology**

Hormesis significantly influences toxicology by challenging the traditional dose-response relationship and providing insights into how low doses of toxic substances can induce beneficial adaptive responses. Traditional toxicology typically follows a linear or threshold model, where higher doses of a substance result in greater toxic effects, and there is a threshold below which no adverse effects are observed. In contrast, hormesis introduces a biphasic dose-response curve, where low doses of a toxin or stressor elicit beneficial effects, such as enhanced cellular function and stress resistance, while higher doses cause harmful effects.

Low-level exposure to toxic substances can activate adaptive cellular responses, including the upregulation of stress response proteins, antioxidant enzymes, and DNA repair mechanisms. For instance, exposure to low levels of heavy metals like cadmium or arsenic can trigger the production of metallothioneins, proteins that sequester and detoxify these metals, thereby enhancing cellular resilience.

Similarly, low doses of radiation can activate the DNA damage response pathways, such as the ATM and ATR kinases, which coordinate DNA repair processes and maintain genomic stability.

Hormesis can also induce systemic adaptations that enhance the organism's ability to manage and recover from stress. For example, exposure to low doses of environmental toxins like polycyclic aromatic hydrocarbons (PAHs) can upregulate cytochrome P450 enzymes, enhancing the body's ability to metabolize and eliminate these and other toxins. Additionally, hormesis can promote better maintenance of homeostasis by modulating neuroendocrine and immune responses, leading to improved overall health and resilience.

Exposure to low doses of toxic agents can induce mild oxidative stress that triggers the activation of endogenous antioxidant defenses. For instance, low doses of hydrogen peroxide can stimulate the Nrf2 pathway, leading to the upregulation of antioxidant enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase. These enzymes neutralize reactive oxygen species (ROS) and protect cells from oxidative damage, thereby reducing the overall toxic impact of low-dose exposures.

Hormetic exposure can also lead to the induction of detoxifying enzymes. For example, exposure to low levels of xenobiotics can induce the expression of Phase I and Phase II detoxification enzymes. Phase I enzymes, such as cytochrome P450 monooxygenases, metabolize toxins into more water-soluble forms, while Phase II enzymes, such as glutathione S-transferase and UDP-glucuronosyltransferase, conjugate these metabolites to facilitate their excretion. This improved detoxification capacity reduces the accumulation of harmful agents in the body.

Low-dose toxic exposures can modulate inflammatory responses by reducing pro-inflammatory cytokine production and promoting anti-inflammatory pathways. For example, low doses of lipopolysaccharides (LPS) can precondition the immune system, leading to a more balanced cytokine response and preventing chronic inflammation. This balance helps to prevent chronic inflammation associated with various diseases and toxicological damage.

Furthermore, hormetic stressors can enhance DNA repair mechanisms, reducing the likelihood of mutations and genomic instability caused by toxic exposures. For instance, low-dose radiation can activate repair enzymes involved in base excision repair (BER) and homologous recombination (HR), ensuring the accurate repair of DNA damage and maintaining genomic integrity.

The concept of hormesis has important implications for toxicological risk assessment and regulatory policies, suggesting that low-dose exposures to certain toxicants may have beneficial effects. Understanding hormesis can help establish more accurate threshold levels for exposure, ensuring that regulatory limits are both protective and based on a more comprehensive understanding of dose-response relationships. By highlighting the potential benefits of low-dose exposures, hormesis challenges traditional toxicological paradigms and offers a nuanced perspective on the effects of toxic substances.

## **Stress Resilience**

**References:** 15, 16

Hormesis significantly enhances stress resilience by inducing adaptive physiological responses that improve the body's ability to cope with and recover from various stressors. This section provides information on how hormesis affects stress resilience.

### ***Activation of Stress Response Pathways***

Hormetic stressors, such as moderate exercise, intermittent fasting, and controlled exposure to environmental stressors, activate the body's intrinsic stress response pathways. These pathways involve the upregulation of key stress response proteins and signaling molecules, such as heat shock proteins and nuclear factor erythroid 2-related factor 2 (Nrf2). HSPs help stabilize and refold damaged

proteins, while Nrf2 promotes the expression of antioxidant and detoxification enzymes. By enhancing these stress response mechanisms, hormesis improves the body's ability to manage and recover from stress.

### ***Enhanced Cellular Resilience***

Exposure to hormetic stressors strengthens cellular resilience by promoting adaptive responses like autophagy, mitochondrial biogenesis, and the activation of repair mechanisms. Autophagy, the process of degrading and recycling damaged cellular components, helps maintain cellular homeostasis and function.

Mitochondrial biogenesis, stimulated by hormetic stressors, improves energy production and cellular function, enhancing the cell's ability to withstand stress.

These adaptations collectively contribute to improved cellular resilience and stress management.

### ***Improved Antioxidant Defenses***

Hormesis boosts the body's antioxidant defenses by increasing the production of endogenous antioxidants, such as superoxide dismutase (SOD), catalase, and glutathione. These antioxidants neutralize reactive oxygen species (ROS) and reduce oxidative stress, which can overwhelm cellular systems during periods of stress. By mitigating oxidative damage, hormesis supports cellular integrity and enhances the ability to endure and recover from stress.

### ***Regulation of Inflammatory Responses***

Hormesis modulates inflammatory responses by activating anti-inflammatory pathways and reducing systemic inflammation. Low-level stressors can decrease the production of pro-inflammatory cytokines and increase the production of anti-inflammatory cytokines. This balance helps to prevent chronic inflammation, which can exacerbate stress and negatively impact overall health. Improved

regulation of inflammation contributes to enhanced stress resilience by reducing the physiological burden of chronic stress.

### ***Neuroprotection and Cognitive Function***

Hormetic stressors positively impact brain health by promoting neuroplasticity and neuroprotection. Stressors such as physical exercise and caloric restriction stimulate the production of brain-derived neurotrophic factor (BDNF) and other neurotrophic factors that support neuronal growth, repair, and survival. Enhanced neuroplasticity and cognitive function improve the brain's ability to adapt to and manage stress, thereby increasing overall stress resilience.

### ***Hormonal Regulation and Stress Response***

Hormesis helps regulate stress-related hormones, such as cortisol and adrenaline, by improving the function of the hypothalamic-pituitary-adrenal (HPA) axis. Controlled exposure to stressors can enhance the body's ability to manage cortisol levels, leading to a more balanced and effective stress response. This hormonal regulation reduces the negative impacts of chronic stress and supports better stress resilience.

### ***Metabolic Adaptation and Energy Management***

Hormetic stressors improve metabolic health by enhancing insulin sensitivity, optimizing glucose metabolism, and promoting metabolic flexibility. These adaptations help the body efficiently manage energy resources and maintain metabolic balance, which is crucial for handling stress. Improved metabolic function supports overall stress resilience by ensuring that the body's energy needs are met during stressful periods.

Hormesis enhances stress resilience through multiple mechanisms, including the activation of stress response pathways, increased cellular resilience, improved

antioxidant defenses, and regulation of inflammatory responses. Additionally, hormesis supports neuroprotection, hormonal balance, and metabolic adaptation. By strengthening the body's ability to manage and recover from stress, hormesis contributes to improved overall stress resilience and better health outcomes.

## **Telomere Lengthening**

**References:** 15

Hormesis can positively affect telomere lengthening by inducing adaptive responses that help preserve or extend telomere length, which is crucial for maintaining cellular health and longevity. This section provides detail on how hormesis affects telomere lengthening.

### ***Activation of Telomerase***

Hormetic stressors such as intermittent fasting, exercise, and caloric restriction have been shown to activate telomerase, an enzyme responsible for adding nucleotide sequences to the ends of chromosomes. Telomerase activity helps counteract telomere shortening, which occurs with each cell division. By stimulating telomerase, hormesis contributes to the maintenance and potential elongation of telomeres, supporting cellular longevity and reducing the risk of age-related diseases.

### ***Enhanced Cellular Repair Mechanisms***

Exposure to mild stressors activates cellular repair mechanisms, including those that maintain telomere integrity. Hormesis promotes processes such as autophagy, which involves the degradation and recycling of damaged cellular components. This includes the repair of damaged DNA and telomeres, thereby



preventing further shortening. Enhanced repair mechanisms contribute to the preservation and potential extension of telomeres.

### ***Reduction of Oxidative Stress***

Hormetic stressors boost the body's antioxidant defenses, reducing oxidative stress, which is a significant factor in telomere shortening. Stressors like exercise and caloric restriction increase the production of antioxidant enzymes, such as superoxide dismutase (SOD) and catalase, which neutralize reactive oxygen species (ROS) and protect telomeres from oxidative damage. By mitigating oxidative stress, hormesis helps preserve telomere length and overall cellular health.

### ***Regulation of Inflammation***

Hormesis modulates inflammation by activating anti-inflammatory pathways and reducing systemic inflammation. Chronic inflammation accelerates telomere shortening by inducing oxidative stress and damaging cellular components. Hormetic stressors can lower levels of pro-inflammatory cytokines and enhance the production of anti-inflammatory cytokines, thereby protecting telomeres from inflammatory damage and supporting their maintenance.

### ***Improved Metabolic Health***

Hormetic stressors such as exercise and caloric restriction improve metabolic health by enhancing insulin sensitivity and optimizing glucose metabolism. These metabolic improvements help reduce the risk of conditions associated with accelerated telomere shortening, such as obesity and type 2 diabetes. By promoting better metabolic health, hormesis indirectly supports the preservation of telomere length.

## ***Enhanced Cellular Adaptation***

Hormesis promotes cellular adaptation and resilience by stimulating various stress response pathways. These pathways include the activation of transcription factors and repair enzymes that help maintain telomere integrity. Enhanced cellular adaptation supports the preservation of telomere length by improving the cell's ability to handle and recover from stress-related damage.

Hormesis positively impacts telomere lengthening by activating telomerase, enhancing cellular repair mechanisms, and reducing oxidative stress and inflammation. Improved metabolic health and cellular adaptation further support telomere maintenance. By promoting these beneficial processes, hormesis helps preserve telomere length, contributing to cellular longevity and reducing the risk of age-related diseases.

## **Geroscience and Effect on Healthspan**

**References:** 1, 14

Hormesis plays a significant role in geroscience by influencing healthspan, the period of life during which individuals remain healthy and free from serious diseases. In geroscience, the focus is on understanding the biological mechanisms of aging and how interventions can extend healthy lifespan. Hormesis, with its emphasis on how low doses of stressors can induce beneficial adaptive responses, contributes to improving healthspan in several key ways.

### ***Activation of Stress Response Pathways***

Hormetic stressors such as moderate exercise, intermittent fasting, and exposure to mild environmental challenges activate stress response pathways that promote cellular resilience and repair. These pathways, including the activation of heat

shock proteins (HSPs) and transcription factors like Nrf2, enhance the body's ability to manage and recover from stress, thereby supporting overall health and extending healthspan. By improving cellular repair and maintenance, these mechanisms help mitigate the effects of aging and reduce the incidence of age-related diseases.

### ***Enhanced Cellular Repair and Maintenance***

Hormesis stimulates processes such as autophagy, mitochondrial biogenesis, and the upregulation of repair enzymes, which are crucial for maintaining cellular function and integrity. Autophagy, for example, involves the degradation and recycling of damaged cellular components, including dysfunctional mitochondria and damaged proteins. This process helps prevent the accumulation of cellular damage that contributes to aging and age-related diseases. By enhancing these repair mechanisms, hormesis supports cellular health and contributes to a longer, healthier life.

### ***Reduction of Oxidative Stress***

Hormetic stressors boost the body's antioxidant defenses by increasing the production of endogenous antioxidants such as superoxide dismutase (SOD), catalase, and glutathione. These antioxidants neutralize reactive oxygen species (ROS) and reduce oxidative stress, a major contributor to aging and chronic diseases. By mitigating oxidative damage, hormesis helps preserve cellular function and integrity, thereby extending healthspan.

### ***Regulation of Inflammatory Responses***

Chronic inflammation is a key factor in aging and age-related diseases. Hormesis helps modulate inflammation by activating anti-inflammatory pathways and reducing systemic inflammation. Hormetic stressors can lower the production of

pro-inflammatory cytokines and enhance the production of anti-inflammatory cytokines. This balance helps prevent the chronic inflammation associated with aging, supporting better health and longevity.

### ***Improved Metabolic Health***

Hormesis influences metabolic health by enhancing insulin sensitivity, optimizing glucose metabolism, and promoting metabolic flexibility. Interventions like caloric restriction and regular physical exercise improve metabolic function and reduce the risk of metabolic disorders such as type 2 diabetes and obesity. By supporting metabolic health, hormesis contributes to a healthier aging process and extends healthspan.

### ***Neuroprotection and Cognitive Function***

Hormesis positively impacts brain health by promoting neuroplasticity, enhancing cognitive function, and providing neuroprotection. Stressors like physical exercise and caloric restriction stimulate the production of brain-derived neurotrophic factor (BDNF) and other neurotrophic factors that support neuronal growth and repair. Enhanced cognitive function and neuroprotection help maintain mental acuity and reduce the risk of neurodegenerative diseases, contributing to a longer healthspan.

### ***Hormonal Regulation***

Hormesis can improve hormonal balance by optimizing the function of the hypothalamic-pituitary-adrenal (HPA) axis and regulating stress hormones such as cortisol. Balanced hormonal responses help manage the effects of aging-related stress and maintain overall health. Effective hormonal regulation supports a healthier aging process and extends healthspan.

Hormesis contributes to extending healthspan by enhancing stress response pathways, improving cellular repair and maintenance, optimizing hormones, reducing oxidative stress and inflammation, and promoting metabolic health. By leveraging the beneficial effects of low-dose stressors, hormesis offers a promising approach to improving longevity and quality of life in aging populations.

## **Section 2 Key Words**

Vagal Tone - Reflects the influence of the vagus nerve on various physiological processes, including heart rate, digestion, and overall autonomic regulation

Telomere Lengthening - The process of increasing the length of telomeres, which are repetitive nucleotide sequences located at the ends of chromosomes

Geroscience - Field that studies the relationship between aging and age-related diseases with the goal of understanding and potentially intervening in the biological processes of aging to extend healthspan and lifespan

## **Section 2 Summary**

In conclusion, this section has examined the physiological impact of hormetic stress, highlighting how controlled exposure to mild stressors like exercise, intermittent fasting, and environmental challenges, can significantly affect adaptive responses within the body. By analyzing the concept of hormesis, it has been demonstrated how these low-level stressors enhance cellular resilience, optimize metabolic functions, and contribute to overall health. The discussion has covered critical physiological mechanisms, including the activation of antioxidant defenses, modulation of inflammation, and enhancement of neuroplasticity. This comprehensive understanding underscores the potential of integrating hormesis principles into therapeutic practice, offering valuable insights for supporting

patient health, improving rehabilitation outcomes, and informing preventive care strategies in physical therapy.

## Physical Therapy Integration

**References:** 18

Integrating hormetic stress into physical therapy care involves utilizing controlled, low-level stressors to induce adaptive beneficial responses in patients, thereby enhancing recovery, resilience, and overall health. This approach leverages the principles of hormesis to optimize therapeutic outcomes. This section provides a detailed, technical exploration of how hormetic stress can be integrated into physical therapy care.

### Intervention

Integrating hormetic stress into physical therapy involves using controlled, low-level stressors to stimulate adaptive responses in patients, enhancing recovery, resilience, and overall health. This section contains a detailed exploration of various interventions and their mechanisms so physical therapists and physical therapist assistants are informed on intervening with hormesis principles.

### *Aerobic Exercise*

**References:** 4

Moderate-intensity aerobic activities, such as walking, cycling, and swimming, serve as effective hormetic stressors. These activities induce mild oxidative stress and inflammation, prompting beneficial physiological adaptations. These adaptations include increased mitochondrial biogenesis, improved antioxidant defenses, and enhanced cardiovascular function, which collectively improve

endurance, reduce fatigue, and support metabolic health. To implement this, physical therapists should begin with a comprehensive patient assessment, evaluate health status, medical history, and baseline fitness levels, followed by setting individualized rehabilitation goals. Physical therapists should recommend a form of aerobic exercise to every patient who is physically capable and safe to participate. Exercise prescriptions should focus on appropriate aerobic activities tailored to patient preferences and abilities, starting at moderate intensity and gradually increasing in duration and complexity. Regular monitoring of patient responses, including heart rate and perceived exertion, ensures safety and allows for necessary adjustments. Integrating aerobic exercise with other therapies, such as resistance training and flexibility exercises, creates a holistic approach to rehabilitation. Educating patients about the benefits of hormesis and aerobic exercise, along with motivational strategies, encourages adherence to the exercise regimen. Safety considerations, including pre-exercise screenings and proper warm-up and cool-down routines, are essential to minimize risks. By leveraging the adaptive responses from controlled aerobic exercise, physical therapists can significantly enhance recovery, resilience, and overall health, optimizing therapeutic outcomes and supporting long-term well-being.

Parameters of aerobic exercise to induce hormesis include the following details:

### Type

Exercise type can be anything that is aerobic-based and should be tailored to the patient and their lifestyle and activity level. Walking, cycling, swimming, and elliptical machines are examples of exercise types.

RPE Scale (Rate of Perceived Exertion)	
1	<b>Very light activity</b> It doesn't even feel like you're exercising.
2-3	<b>Light activity</b> You could keep going for hours! It's easy to breathe and have a conversation.
4-6	<b>Moderate activity</b> You're breathing heavily, but you can have a conversation.
7-8	<b>Somewhat difficult activity</b> You're short of breath. You can speak, but only about one sentence at a time.
9	<b>Very difficult activity</b> You can barely breathe, and can only say a few words at a time.
10	<b>Maximum effort activity</b> You're completely out of breath, and can't talk.

<https://www.alphanet.org/managing-alpha-1/exercise/exertion-and-exercise-safety/>

## ***Intensity***

Aerobic exercise should be performed at a moderate intensity. Patients may ramp up to this level from easy to moderate if they do not regularly perform aerobic exercise. Heart rate should be 50 to 70 percent of maximum heart rate (220-age). The Borg rating of perceived exertion (RPE) should be somewhere within the 4-8 range.

## ***Duration and Frequency***

Sessions should last at least 30 minutes in the beginning, and progress to 60 minutes as tolerated. The minimum recommended frequency for overall health (cardiovascular, respiratory, muscular) and to apply hormesis benefits is three times per week. The ideal frequency for hormetic stress adaptations is five times per week.

## ***Progression***

It is recommended to gradually increase the duration and intensity of exercise every 1-2 weeks based on patient tolerance and progress. PTs and PTAs should regularly assess the patient's response to exercise, including heart rate, perceived exertion, and any signs of overtraining or adverse effects.

## ***Resistance Exercise***

### **References: 4**

Resistance training, an integral part of rehabilitation, leverages the principles of hormesis to induce beneficial physiological adaptations through controlled mechanical stress. This approach enhances muscle strength, endurance, and overall resilience by applying stress that prompts the body to adapt and grow stronger.



Integrating resistance training as a hormetic stressor in physical therapy involves using controlled mechanical stress to induce beneficial physiological adaptations. This method enhances muscle strength, endurance, and overall resilience by applying stress that prompts the body to adapt and grow stronger. The physiological basis of this approach includes muscle hypertrophy through microtears in muscle fibers, repaired via increased protein synthesis and cellular adaptation, leading to muscle growth and strength gains. Consistent resistance training also triggers neuromuscular adaptations, improving motor unit recruitment and firing rates. Additionally, the stress from resistance training induces mild oxidative stress and inflammation, activating cellular defense mechanisms and enhancing overall resilience and health. The health benefits of resistance training are numerous, including increased muscle mass and strength, enhanced metabolic rate, improved bone density, and better joint health. Implementing this in physical therapy starts with a thorough patient assessment to establish individualized goals.

Parameters of resistance training include the following:

### **Type**

The type of exercise can include free weights through the use of dumbbells, barbells, and kettlebells for versatile, functional strength training. Resistance bands may be utilized, typically for rehabilitation and progression to higher levels of resistance. Bodyweight exercises such as squats, push-ups, and lunges may be utilized, which require no equipment and can be modified for different abilities. In addition, weight machines can be used, which provide controlled resistance and support proper form and can assist those who need modifications for injuries or mobility.

## ***Intensity***

Physical therapists should have patients start with low to moderate intensity, typically 60-70% of the patient's one-repetition maximum (1RM). Then, they should progress to higher intensities as tolerated. Recommended volume is 2-4 sets of 8-12 repetitions per exercise, focusing on major muscle groups. Patients should have form fatigue at the last one to two repetitions; if not, they should increase the resistance until that is achieved.

## ***Frequency and Duration***

The minimum recommended frequency is two to three times per week, with at least one day of rest between sessions targeting the same muscle groups. The optimal frequency is 3-4 times per week, incorporating different muscle groups each session for balanced development.

## ***Progression***

Gradual progression involves increasing the resistance, volume, and complexity of exercises incrementally to continuously challenge the body and promote adaptation. Periodization, on the other hand, entails implementing training cycles that vary intensity and volume to prevent plateaus and overtraining, ensuring sustained progress. By combining these approaches, physical therapists can create effective and dynamic resistance training programs that optimize patient outcomes.

## ***High Intensity Interval Training (HIIT)***

### **References: 19**

High-Intensity Interval Training (HIIT) is an exercise regimen characterized by short bursts of intense physical activity followed by periods of lower-intensity recovery or rest. This training method has gained widespread acclaim for its efficiency and

effectiveness in improving various aspects of fitness. When integrated into physical therapy, HIIT leverages the concept of hormesis—whereby exposure to controlled, beneficial stressors leads to adaptive responses that enhance overall health and resilience.

Hormesis in the context of HIIT involves the deliberate introduction of physical stress, prompting the body to adapt and become stronger. These adaptations include improved cardiovascular function, increased muscle strength and endurance, and enhanced metabolic health. For physical therapy patients, these benefits translate into better heart health, improved circulation, and increased stamina, all of which are critical for effective rehabilitation. Moreover, the metabolic improvements associated with HIIT, such as better insulin sensitivity and glucose metabolism, can aid in weight management and reduce strain on the joints, further facilitating mobility and recovery.

To effectively integrate HIIT into physical therapy, it is essential to customize programs based on individual patient assessments, ensuring that the exercises are safe and aligned with their specific rehabilitation goals. The implementation should be gradual, starting with low-intensity intervals and progressively increasing as the patient adapts. Functional movements that mimic daily activities should be prioritized to enhance balance, coordination, and overall functional independence. Safety precautions, including medical clearance and close supervision, are paramount, especially for patients with chronic conditions or those new to high-intensity exercise.

By incorporating HIIT into physical therapy, practitioners can harness the powerful adaptive benefits of hormetic stress, optimizing patient outcomes and promoting long-term health and resilience. This approach not only accelerates recovery but also empowers patients to achieve and maintain a higher level of physical fitness and well-being.

The parameters of HIIT are below:

### ***Type***

HIIT can be performed with various types of exercises, such as running, cycling, rowing, bodyweight exercises (e.g., burpees, squats, push-ups), or resistance training. The choice of exercise can be tailored to the individual's preferences and specific training goals.

### ***Intensity and Duration***

High intensity intervals are typically performed at 80-95% of the individual's maximum heart rate (MHR). These intervals last typically between 30 seconds and 4 minutes. They should be challenging and push the participant close to their limit. The low intensity recovery periods should be performed at 40-50% of MHR, allowing for recovery while maintaining some level of activity. Some HIIT sessions may involve active recovery (walking or light jogging) and others involve passive recovery (complete rest) during the low intensity intervals. The duration of recovery is dependent on the exerciser's fitness level. It is typically a 1:1, 1:2, or 1:3 ratio of high to low intensity.

The number of intervals is dependent on goals. Typical sessions have 5 to 10 intervals, and the total workout time lasts between 20 to 30 minutes.

An example HIIT workout begins with a warm-up, consisting of 5 minutes of light cardio such as jogging or cycling. This is followed by a high-intensity interval where the individual performs 30 seconds of sprinting at approximately 90% of their maximum heart rate. The sprint is followed by a low-intensity recovery period of 1 minute, during which the participant walks or jogs slowly at around 50% of their MHR. This cycle of high-intensity and low-intensity intervals is repeated 8 times. The workout concludes with a cool-down phase of 5 minutes, incorporating light stretching or slow walking to aid in recovery and reduce muscle soreness.

## ***Heat Exposure***

### **References: 7**

Integrating heat exposure through hormesis into physical therapy leverages the concept of using controlled, beneficial stress to stimulate adaptive responses in the body, promoting healing and improving physical function. Hormesis involves exposing the body to mild, controlled stressors that trigger beneficial adaptive responses. In physical therapy, this can be achieved through controlled thermal stress, such as hot packs, warm baths, or saunas, which elicit physiological adaptations like increased blood flow, reduced muscle tension, pain relief, and accelerated healing.

Heat exposure causes vasodilation, enhancing circulation and bringing more oxygen and nutrients to injured tissues, which aids in tissue repair and reduces stiffness. Additionally, increased blood flow helps remove metabolic waste, reducing inflammation and promoting faster healing. Heat helps relax muscles by reducing the excitability of nerve endings and increasing tissue stretchability, reducing tension and spasms while improving flexibility and making stretching exercises more effective. It also triggers the release of endorphins, the body's natural pain relievers, providing relief from chronic pain and improving overall comfort. Moreover, elevated tissue temperatures boost cellular metabolism, accelerating tissue repair processes and reducing muscle spasms, thereby improving mobility and function.

Several methods can be used to apply heat in physical therapy. Hot packs, wrapped in a towel, can be placed on the affected area for 15-20 minutes, providing localized heat ideal for specific areas of discomfort or stiffness. Warm baths, immersing the affected body part or the whole body in warm water for 15-20 minutes, offer overall muscle relaxation and improved circulation. Heat pads and wraps can be used during inactivity or light activities for 15-20 minutes,

providing continuous heat application and sustained relief. Infrared therapy, using infrared lamps for 15-30 minutes, delivers deep, penetrating heat without direct contact. Sauna therapy involves spending 10-20 minutes in a sauna, offering controlled whole-body heat exposure, enhancing systemic circulation, and promoting relaxation.

Heat exposure can be integrated into physical therapy in several ways. As a pre-therapy warm-up, heat prepares muscles and joints for stretching or strengthening exercises, reducing injury risk and enhancing performance. Post-therapy, heat alleviates muscle soreness, reduces stiffness, and promotes relaxation, aiding recovery. For chronic conditions like arthritis or fibromyalgia, regular heat therapy helps manage symptoms, improve mobility, and enhance quality of life. Heat therapy can also be combined with other rehabilitation modalities, such as manual therapy, exercise, and electrotherapy, providing a comprehensive treatment plan.

Safety considerations are crucial when integrating heat exposure into physical therapy. PTs should conduct thorough evaluations to rule out contraindications, such as cardiovascular issues, skin conditions, or heat intolerance, and customize the duration, frequency, and method of heat application based on the patient's specific condition and response. Monitor the temperature of heat sources to avoid burns, using barriers like towels between the heat source and the skin, and start with shorter sessions, gradually increasing as tolerated. Physical therapists should encourage patients to stay hydrated before and after heat therapy to prevent dehydration, and continuously monitor for signs of discomfort, overheating, or adverse reactions, adjusting the therapy as needed. By applying heat strategically and safely, physical therapists can optimize rehabilitation outcomes, support tissue repair, and improve overall patient well-being.

Safe temperature range should be considered for heat application. For hot packs and heat pads, temperatures should typically be between 104°F and 113°F. Warm baths should be around 98°F to 104°F. Saunas usually range from 158°F to 212°F, with careful monitoring to prevent overheating. Warm baths and saunas should start in 10-minute sessions and gradually increase to up to 30-minute sessions. It is recommended to progress to three sessions per week for saunas and warm baths to get optimal benefit of hormesis.

### ***Cold Exposure***

#### **References: 20**

Integrating cold exposure into physical therapy as a form of hormetic stress involves using controlled cold applications to induce beneficial physiological responses that enhance healing, reduce inflammation, and improve functional outcomes. Cold exposure, a controlled environmental stressor, triggers adaptive responses such as improved circulation, reduced inflammation, and increased resilience. The primary mechanism involves vasoconstriction, where blood vessels constrict to reduce swelling and inflammation in injured tissues. Additionally, cold exposure slows metabolic processes, reducing the production of inflammatory mediators. The analgesic effect of cold provides pain relief by numbing the affected area and decreasing nerve conduction velocity, which lessens pain sensation. Methods of applying cold in physical therapy include ice packs, cold water immersion, and cryotherapy devices, with each method tailored to the patient's condition and response. Physical therapists should recommend beginning with shorter sessions, around 10-15 minutes, and gradually increasing duration and frequency based on tolerance and therapeutic goals. Combining cold exposure with other modalities such as manual therapy and exercise enhances its effectiveness. Ensure proper patient education on the benefits and safety of cold therapy, including avoiding direct contact with ice to prevent frostbite and

monitoring for adverse reactions. By carefully integrating cold exposure, physical therapists can promote faster recovery, alleviate pain, and improve overall patient outcomes.

Cold immersion also provides significant pain relief through its numbing effect and by decreasing nerve conduction velocity, which lessens pain sensation. The cooling effect can also reduce muscle spasms and improve muscle recovery by minimizing the microtrauma and soreness caused by intense physical activity. To integrate cold immersion into physical therapy, the immersion should typically be performed in water temperatures ranging from 50°F to 59°F for durations of 10 to 15 minutes, gradually increasing as the patient becomes accustomed to the cold. Sessions can be scheduled 2-3 times per week initially, increasing frequency based on the patient's response and therapeutic needs.

### ***Dietary Stress***

#### **References: 5**

Integrating dietary stress hormesis into physical therapy involves leveraging controlled dietary interventions to promote health, enhance recovery, and improve overall physical function. This approach uses dietary practices such as caloric restriction, intermittent fasting, and the consumption of specific phytochemicals to induce beneficial stress responses in the body, which can complement physical therapy efforts. Physical therapists can recommend that one try intermittent fasting, however patients should be referred to nutrition professionals for appropriate monitoring and plan development. Registered dietitians are qualified professionals who are trained in the safety and application of dietary plans like intermittent fasting.

Phytochemicals are bioactive compounds found in plants that can exert hormetic effects by enhancing antioxidant defenses, reducing inflammation, and supporting



detoxification. Physical therapists may recommend that patients incorporate a variety of phytochemical-rich foods into their diets, such as berries, cruciferous vegetables, and green tea. This may be an adjunct to therapy goals by improving outcomes, such as enhancing joint health, reducing inflammation, and supporting recovery.

## ***Hypoxic Stress***

**References:** 6, 18

Integrating hypoxic stress into physical therapy involves using controlled periods of reduced oxygen availability to induce beneficial adaptive responses in the body. This approach, known as intermittent hypoxic training (IHT), can enhance cardiovascular health, improve tissue oxygenation, and increase overall resilience. Hypoxic stress introduces controlled, low-dose exposure to reduced oxygen levels, prompting the body to adapt in beneficial ways, such as increased red blood cell production, improved oxygen utilization, enhanced endurance, and better cardiovascular health. Methods of applying hypoxic stress in physical therapy include intermittent hypoxic training (IHT), which involves alternating periods of breathing low-oxygen air with periods of normal oxygen levels, using hypoxic generators or masks to create controlled hypoxic environments during therapy sessions. Another method is altitude simulation, where high-altitude conditions are simulated using hypoxic tents or rooms, allowing patients to perform exercises or rest in these environments to induce hypoxic stress. Additionally, breath-holding exercises create short periods of hypoxia and can be incorporated into therapy sessions to promote adaptive responses.

To integrate hypoxic stress into physical therapy, therapists should conduct a thorough assessment of the patient's health status, including cardiovascular and respiratory function, to ensure they are suitable for hypoxic training. Developing individualized hypoxic training protocols based on the patient's condition,

therapeutic goals, and response to hypoxic stress is crucial. Starting with shorter and less intense hypoxic sessions and gradually increasing duration and intensity as tolerance improves is recommended. Combining hypoxic training with other physical therapy modalities such as aerobic exercise, resistance training, and manual therapy can enhance overall effectiveness. Continuous monitoring of the patient's response to hypoxic stress, including heart rate, oxygen saturation, and perceived exertion, is essential. Adjustments to the intensity and duration of hypoxic sessions should be made based on feedback and progress. Educating patients on the benefits and safety protocols of hypoxic training, including signs of overexertion and proper breathing techniques, is vital. Ensuring patients stay hydrated and well-nourished is also important, as hypoxic stress can increase metabolic demands.

Because intermittent hypoxic training requires reduced oxygen through equipment, it is not practical for integration in most clinic spaces. Physical therapists may instruct in breath holding as an alternative, integrated such into an exercise session. Patients may begin with 2-3 sessions per week. A session should include 15-30 seconds of breath-holding, followed by 1-2 minutes of normal breathing. This cycle should be repeated 3-5 times per session. They may progress to breath holds of one minute followed by one to two minutes of normal breathing, to be done 3-4 times per week.

## **Timing of Hormetic Stress**

**References:** 2, 20

The timing of hormetic stress is critical in achieving optimal therapeutic outcomes, as the key principle is to apply stressors in a way that allows sufficient recovery time for the body to adapt and strengthen, rather than become overwhelmed or damaged. Generally, stressors should be introduced gradually, starting with lower

intensity and shorter duration, and then increased as the body adapts. Recovery periods between sessions are essential to enable adaptive responses, with adequate rest preventing back-to-back high-intensity sessions without sufficient rest. The timing and frequency of stressors should be tailored to the individual's health status, fitness level, and specific therapeutic goals.

For specific hormetic stressors, heat exposure such as sauna sessions should initially be 2-3 times per week for 5-10 minutes per session, gradually increasing to 4-5 times per week for 15-20 minutes, with at least one day of rest between intense sessions. Cold exposure should be 2-3 times per week, starting with 2-3 minutes of cold immersion and increasing to 5-10 minutes, allowing at least one day of rest between sessions. Intermittent hypoxia, such as breath-holding exercises, should begin with 2-3 times per week, holding for 15-30 seconds followed by normal breathing for 1-2 minutes, and gradually increase to 60-90 seconds, ensuring adequate rest between sessions. High-Intensity Interval Training (HIIT) should be conducted 2-3 times per week for 20-30 minutes per session, with at least 48 hours of rest between sessions to prevent overtraining. For dietary stress, intermittent fasting can be implemented daily with methods such as the 16/8 method, starting with shorter fasting windows and gradually increasing, while ensuring balanced and nutrient-dense meals during eating windows.

Practical implementation involves scheduling the integration of hormetic stressors into the therapy regimen with clear schedules for each type of stress, avoiding clustering multiple high-intensity stressors close together, and spacing them out to allow recovery. Regular monitoring of patient responses to the stressors, including physiological markers and subjective feedback, is crucial to adjust the timing and intensity based on the patient's adaptation and progress. Educating patients on the importance of timing and recovery in hormetic stress and encouraging them to listen to their bodies and communicate any discomfort or

adverse effects promptly is vital. Gradual progression in the intensity and duration of stressors is necessary as patients build tolerance and resilience, with periodic review and adjustment of the schedule to continue challenging the body without causing undue stress or harm. By carefully timing the application of hormetic stressors and allowing adequate recovery, physical therapists can maximize the benefits of these interventions, supporting improved health, resilience, and overall well-being for their patients.

## **Measuring the Effect of Hormetic Stress Integration**

**References:** 20

Measuring the effect of hormetic stress integration in physical therapy involves a combination of objective and subjective assessments to monitor the adaptive responses and overall benefits experienced by patients. Objective measures include physiological markers such as heart rate, heart rate variability, blood pressure, blood biomarkers (erythropoietin, red blood cell count, hemoglobin), and oxygen saturation using pulse oximetry. Improvements in HRV, reductions in resting HR, better BP readings, and positive changes in blood biomarkers and oxygen levels indicate enhanced cardiovascular health and adaptations to hypoxic stress. Performance metrics, such as exercise capacity assessed through standardized tests (VO<sub>2</sub> max, timed walk tests) and recovery rates after exertion, also provide valuable data. Additionally, body composition measurements like body mass index (BMI), muscle mass, and fat percentage using tools like bioelectrical impedance analysis (BIA) or dual-energy X-ray absorptiometry (DEXA) scans help track overall health changes.

Subjective measures include patient self-reports, where symptom diaries track symptoms, energy levels, sleep quality, and overall well-being. Perceived exertion scales, such as the Borg Rating of Perceived Exertion (RPE), measure how hard

patients feel they are working during sessions, and quality of life surveys (SF-36, WHOQOL) assess changes in physical and mental health. Pain and discomfort levels can be quantified using visual analog scales or numerical rating scales (NRS) before, during, and after therapy sessions. Functional measures involve mobility and flexibility assessments using range of motion (ROM) measurements with goniometers and functional tests like the Sit-to-Stand Test or the Timed Up and Go (TUG) test to evaluate improvements in mobility and functional capacity.

Regular assessments, conducted bi-weekly or monthly, track progress and enable data-driven adjustments to therapy regimens. Establishing feedback loops with patients ensures their experiences and observations are incorporated into therapy adjustments. Comprehensive reporting, combining data from objective, subjective, and functional measures, helps create a detailed overview of the patient's progress, which is used to adjust therapy plans to fit the patient's evolving needs and responses. By systematically measuring the effects of hormetic stress integration through these methods, physical therapists can ensure that the interventions effectively enhance patient health, resilience, and overall therapeutic outcomes.

## **Future Directions of Research**

**References:** 1, 14

The future directions of research on hormetic stress and its integration into physical therapy are promising and multifaceted. As the understanding of hormesis deepens, several key areas warrant further exploration to optimize therapeutic outcomes and enhance patient care.

### ***Precision Medicine and Personalized Therapy***

One of the most significant future directions involves the development of personalized therapy protocols. Research should focus on identifying biomarkers that can predict individual responses to various hormetic stressors. By understanding genetic, epigenetic, and metabolic profiles, physical therapists and other medical professionals can tailor interventions to maximize benefits and minimize risks. This precision medicine approach will enable more effective and individualized treatment plans.

### ***Long-Term Effects and Safety***

While the short-term benefits of hormetic stress are well-documented, research on the long-term effects and safety is still limited. Longitudinal studies are required to assess the sustained impact of hormetic stress interventions on health and disease outcomes. Additionally, safety profiles for different populations, including the elderly, individuals with chronic diseases, and athletes, need thorough evaluation to ensure that hormetic stressors are applied safely and effectively.

### ***Combination Therapies***

Exploring the synergistic effects of combining different types of hormetic stressors, such as heat, cold, hypoxia, and dietary interventions, could lead to more comprehensive therapy protocols. Research should investigate how these combinations can be optimized to enhance therapeutic outcomes without overwhelming the body's adaptive capacity. The potential interactions between various stressors and their cumulative effects on health need systematic study.

## ***Technological Advancements***

The development and application of advanced technologies, such as wearable devices and mobile health apps, can facilitate the monitoring and assessment of hormetic stress in real-time. These technologies can provide continuous data on physiological responses, enabling more precise adjustments to therapy protocols. Future research should explore how technology can enhance the implementation and effectiveness of hormetic stress interventions in physical therapy.

## ***Clinical Trials and Evidence-Based Practice***

There is a need for well-designed clinical trials to establish the efficacy of hormetic stress interventions in various clinical populations. Randomized controlled trials (RCTs) with large sample sizes and diverse participant demographics will provide robust evidence for the integration of hormetic stress into standard physical therapy practice. This evidence will help develop clinical guidelines and best practices for using hormetic stressors therapeutically.

## **Section 3 Key Words**

Intermittent Hypoxic Training (IHT) - A conditioning method that involves exposing the body to periods of reduced oxygen levels, alternated with periods of normal oxygen levels

Precision Medicine - An approach to medical treatment and healthcare that tailors interventions to individual characteristics, including genetic, environmental, and lifestyle factors

## Section 3 Summary

Integrating hormetic stress into physical therapy care involves utilizing controlled, low-level stressors to induce adaptive beneficial responses in patients, thereby enhancing recovery, resilience, and overall health. By leveraging the principles of hormesis, this approach optimizes therapeutic outcomes. This section provides a detailed and technical exploration of the ways in which hormetic stress can be effectively incorporated into physical therapy practice, through intervention, timing, and evidence-based practice.

## Case Study

John, a 52-year-old male with chronic lower back pain and mild osteoarthritis in both knees. He is seen by Karen, an orthopedic outpatient physical therapist. John works a sedentary desk job and has a history of conventional physical therapy, medication, and lifestyle modifications. The objectives for John's treatment are to alleviate chronic lower back pain and improve function, enhance range of motion and strength, and address his sedentary lifestyle to support overall well-being. John is open to trying any type of treatment to improve his health, pain and function.

## Reflection Questions

1. How might Karen educate John on implementing hormetic stress practices to help improve his outcomes?
2. What hormetic stress interventions and parameters may be helpful in this case?
3. What are key indicators of success in this integrated approach and how are they measured?



## Responses

1. Karen should educate him on the many benefits of hormesis, including but not limited to, reducing inflammation and creating mental and physical resilience. She should educate John on the process of implementing hormetic stress and its various forms, such as dietary stress, exercise, intermittent hypoxia, and cold/heat exposure. She should also ensure that John is healthy and free of medical conditions that would put him at risk of complications, such as heart disease and diabetes.
2. John could utilize heat exposure through a sauna for 15-minute sessions, 2-3 times per week, aiming to improve blood circulation, reduce muscle stiffness, and promote relaxation. He could use cold exposure through 5-minute cold immersion baths, also 2-3 times per week, designed to reduce inflammation, alleviate pain, and enhance recovery. Karen could recommend HIIT training twice a week, starting with shorter intervals at a lower intensity and gradually increasing, to improve cardiovascular fitness, muscle strength, and endurance. Additionally, John could try intermittent fasting with a 16/8 fasting/eating window to support metabolic health and weight management.
3. Success indicators could be reductions in pain levels, improvements in mobility, and increased fitness. Pain levels should be assessed by numeric or visual analog scale, mobility measured through range of motion measurements and functional tests, such as the Sit-to-Stand Test. Fitness can be evaluated based on performance metrics from HIIT sessions and overall physical activity levels.

## Conclusion

This course delved into the concept of hormetic stress and its practical applications in physical therapy, emphasizing its beneficial effects derived from the body's adaptive response to low doses of stressors. By exploring various types of hormetic stress and their cellular and physiological impacts, physical therapists and assistants gain insights into the adaptation processes of the musculoskeletal and nervous systems, as well as cellular repair and regeneration mechanisms. The course highlights the numerous benefits of hormetic stress, including enhanced physical resilience, improved immune function, and reduced inflammation, which collectively contribute to more efficient and effective rehabilitation. Furthermore, hormetic stress has been shown to positively affect healthspan by promoting longevity and reducing the risk of age-related diseases. Through the integration of evidence-based hormetic strategies, healthcare professionals will be equipped to provide personalized and innovative care that accelerates recovery and enhances overall health and well-being.

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