Experimental Gerontology 196 (2024) 112550

Contents lists available at ScienceDirect

Experimental Gerontology

journal homepage: www.elsevier.com/locate/expgero

Review article

# Neurobiological and anti-aging benefits of yoga: A comprehensive review of recent advances in non-pharmacological therapy

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A R T I C L E I N F O

*Keywords:*
Aging
Yoga
Cellular mechanism
Molecular mechanism
Oxidative stress

A B S T R A C T

Aging is an unavoidable process marked by numerous physiological and psychological changes that profoundly impact overall health and quality of life. As the global population ages, there is a growing interest in non-pharmacological therapies that can mitigate the adverse effects of aging and promote longevity. This narrative review explores the broad spectrum of non-pharmacological mechanisms offering anti-aging benefits, with a special emphasis on holistic practices such as yoga, meditation, and lifestyle interventions. These therapies influence critical biological processes, including reducing oxidative stress, modulating chronic inflammation, enhancing immune function, and preserving telomere length—key markers of cellular aging. Additionally, these practices contribute to improved cardiovascular health, musculoskeletal strength, and mental well-being, fostering a comprehensive approach to healthy aging. Yoga, for instance, combines physical postures, breath control, and meditation to enhance physical flexibility, mental clarity, and emotional balance. Meditation practices are shown to reduce stress and improve cognitive function, further supporting healthy aging. Lifestyle modifications, such as diet and regular physical activity, complement these therapies by promoting overall vitality and reducing the risk of age-related diseases. This review underscores the potential of integrating these non-pharmacological strategies into daily routines to enhance resilience against aging, improve quality of life, and extend healthspan. Furthermore, it highlights the need for continued research to fully elucidate the mechanisms by which these therapies exert their anti-aging effects and to develop evidence-based guidelines for their implementation.

## 1. Introduction

Aging is defined as a persistent decline in an organism's age-specific fitness components due to internal physiological deterioration (Rose, 1991). This 1991 definition expanded Comfort's earlier definition by incorporating reproductive fitness components and introducing qualifiers indicating that the decline in fitness components should be persistent and attributed to 'internal physiological deterioration,' a term broadly interpreted (Rose et al., 2012). Aging can also be understood as a sequence of breakdowns in signaling pathways within the DNA-environment system that unfold over time. Since signaling within this system must adhere to a highly structured order for an organism to maintain proper function, its failure suggests broader dysfunctions across molecular mechanisms and their interactions (Martin, 2009, 2012). Consequently, the aging phenotype arises from the progressive deterioration of molecular mechanisms over time within the DNA-environment system, leading to disorder within the system. This breakdown often manifests as stochastic 'epigenetic drift' (Lakatta, 2015). As individuals age, they experience a decline in lean mass, a process influenced by changes in body weight (Suryadinata et al., 2020). Research indicates that with weight fluctuations, older individuals undergoing weight loss tend to lose relatively more lean mass compared to those gaining weight, particularly among older men (Newman et al., 2005). These findings suggest that older adults who undergo cycles of weight loss followed by regain may end up with a more sarcopenic body composition compared to those who maintain a stable weight. There are conflicting theories about the negative metabolic, physiological, behavioral, and health effects of weight cycling, including the potential for a shift in body composition towards a higher proportion of body fat (Lee et al., 2010). The concept of age-related differentiation between subjective and objective assessments of the mind has been proposed, supporting the idea that the mind is a multifaceted cognitive ability influenced, to some extent, by executive processes (Duval et al., 2011). Aging impacts both the body and mind, leading researchers to examine a variety of interventions aimed at preventing lifestyle diseases and promoting health and longevity. These interventions include drugs

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https://doi.org/10.1016/j.exger.2024.112550
Received 22 July 2024; Received in revised form 12 August 2024; Accepted 19 August 2024
Available online 2 September 2024

targeting specific hallmarks of aging, as well as lifestyle factors such as physical exercise, nutrition, caloric restriction, and antioxidants (Madhivanan et al., 2021; Tolahunase et al., 2017; Choudhary et al., 2019). This study examines the potential of yoga as an anti-aging intervention.

The Sanskrit term ‘yoga’ originates from the root ‘yug,’ meaning ‘to join’ or ‘to yoke,’ signifying the act of binding together or concentrating. Primarily, however, ‘yoga’ has evolved to denote a method of discipline or a pathway to unity: the union of body and mind, culminating in the connection between the individual self (soul) and the transcendental self. Yoga emerges from an oral tradition where teachings were passed from teacher to student, fostering a lineage of knowledge transmission (Scholz and Vander Stichele, 2024). The practice of yoga is believed to have originated with the dawn of civilization, predating the earliest religions or belief systems. According to yogic tradition, Shiva is revered as the first yogi, or Adiyogi, and the primal Guru, or Adi Guru. Several thousand years ago, on the shores of Lake Kantisarovar in the Himalayas, Adiyogi imparted his profound knowledge to the legendary Saptarishis, or ‘seven sages.’ These sages then disseminated this potent yogic science to various parts of the world, including Asia, the Middle East, Northern Africa, and South America. Modern scholars have observed striking parallels among ancient cultures worldwide. However, it was in India that the yogic system flourished most profoundly. Agastya, one of the Saptarishis who traveled across the Indian subcontinent, shaped this culture around a fundamental yogic way of life (Basavaraddi, 2015; White, 2012). Yoga, regarded as a scientific and widely embraced lifestyle practice, embodies the integration of mind, body, and soul (Sathyanarayanan et al., 2019). Since ancient times, yoga has demonstrated profound benefits for physical, mental, and social well-being, and its popularity is rapidly growing worldwide (Sathyanarayanan et al., 2019; Cramer et al., 2014). Despite this, there is currently a lack of comprehensive reviews examining the effects of yoga on aging as an anti-aging intervention. This study aims to address this gap by exploring the role of yoga in anti-aging. We investigate various aspects, including aging processes, the holistic benefits of yoga, its physical benefits for anti-aging, mental and cognitive advantages, as well as the cellular and molecular impacts of yoga. Additionally, we delve into specific yoga practices tailored for anti-aging purposes.

## 2. Understanding aging

### 2.1. Biological processes of aging

Biological processes of aging include cellular senescence, telomere shortening, and oxidative stress. Senescence, derived from the Latin word ‘senex,’ meaning ‘growing old,’ refers to an irreversible form of long-term cell-cycle arrest triggered by excessive intracellular or extracellular stress or damage (Hooten and Evans, 2017). This cellular response, aimed at preventing malignant transformation following exposure to stressors, involves the arrest of cells in the G1 phase of the cell cycle (Vicencio et al., 2008). Despite their arrested state, senescent cells remain functionally and metabolically active, exhibiting changes such as alterations in protein degradation pathways and enhanced mitochondrial metabolism and energy generation (Salama et al., 2014). The primary goal of senescent cell arrest is to restrict the proliferation of damaged cells, thereby preventing the spread of damage to subsequent cell generations, eliminating accumulated harmful factors, and thwarting potential malignant transformation (Vicencio et al., 2008; Coppé et al., 2010). In young tissues, transient senescence can have beneficial effects, as seen in pregnancy, where it contributes to proper fetal development and the timing of parturition. However, senescence can also have detrimental effects on reproductive capacity, leading to a decrease in the number of ovarian follicles, and in later stages of life, contributing to declines in ovarian and uterine function (Velarde and Menon, 2016). The onset of senescence may be accelerated by elevated levels of oxygen or exposure to various toxic substances (Ogrodnik et al., 2019), while factors that slow down the accumulation of damage can delay its onset. Cellular senescence is characterized by stable and typically irreversible proliferative arrest, accompanied by diverse morphological, structural, and functional alterations, including heightened expression and secretion of pro-inflammatory and tissue-remodeling mediators. This senescent state plays a pivotal role in tissue physiology and pathology, emerging as a response to potentially harmful stress signals (Varela-Eirín and Demaria, 2022).

Telomeres, the repetitive DNA sequences located at the ends of linear eukaryotic chromosomes, play a critical role in protecting chromosome ends from degradation and illegitimate recombination. These telomeres are essential for determining cell fate and influencing the aging process (Cai et al., 2013). Due to the mechanism of replication, telomeres naturally shorten with each cell division, a phenomenon that contributes to cellular senescence and mitochondrial dysfunction. Cells, as the fundamental units of organismal structure and function, rely on mitochondria as the powerhouse and metabolic hub. Therefore, when cellular senescence and mitochondrial dysfunction occur, they can lead to tissue or organ degeneration and dysfunction, ultimately contributing to somatic aging through various pathways (Zhu et al., 2019). Numerous studies have demonstrated a strong correlation between telomere length and the aging process. For example, experiments involving the manipulation of telomere function or length in mice have shown improvements in lifespan. Additionally, telomerase gene therapy has been found to reverse premature aging and delay physical aging in mice (Derevyanko et al., 2017; Steenstrup et al., 2017). According to the telomere theory, the shortening of telomeres acts as a trigger for the aging process (Zhu et al., 2019).

Oxidative stress and inflammation are key mechanisms underlying endothelial dysfunction and arterial damage, linking these risk factors to vascular disease, arterial stiffness, and aging. These processes contribute to the development of macro- and microangiopathy, renal dysfunction, cardiac ischemia, and cognitive decline (Guzik and Touyz, 2017). Oxidative stress has been shown to impact both innate and adaptive immune responses. However, a more comprehensive analysis of the overall molecular and biochemical signature of oxidative stress is needed. This is particularly significant for immune system cells, such as macrophages, granulocytes, and dendritic cells, which have very short lifespans and are continuously replaced by newly produced cells. Consequently, these cells might benefit from short-term therapies aimed at reducing oxidative stress (Liguori et al., 2018; Hussain and Kayani, 2020). In conclusion, aging is characterized by the progressive loss of tissue and organ function. The oxidative stress theory of aging suggests that age-associated functional declines result from the accumulation of damage induced by reactive oxygen and nitrogen species (RONS) (Liguori et al., 2018; Hussain and Kayani, 2020).

### 2.2. Physical signs of aging

As individuals age, a gradual loss of muscle mass, known as sarcopenia, becomes a common physical sign. This decline typically begins around age 30 and accelerates after age 60. Reduced physical activity in older adults often leads to muscle atrophy, while declines in hormones such as testosterone and growth hormone—crucial for muscle growth and maintenance—further contribute to muscle loss. Additionally, older adults often consume less protein, which is essential for muscle repair and growth (Velarde and Menon, 2016). Joint stiffness is another prevalent sign of aging, often resulting from the gradual wear and tear of cartilage, the connective tissue that cushions joints. This condition, known as osteoarthritis, can lead to pain and decreased mobility. Over time, the protective cartilage deteriorates, causing stiffness and pain. Moreover, the production of synovial fluid, which lubricates joints, decreases with age, exacerbating stiffness (Loeser, 2010). Aging also leads to a reduction in bone density, which increases the risk of fractures and conditions such as osteoporosis, particularly in postmenopausal women due to decreased estrogen levels (Kanis et al., 2013).

### 2.3. Psychological and cognitive aspects of aging

As individuals age, they may experience changes in memory function, such as difficulty recalling recent events, names, or details, and a slower processing speed for information. Age-related memory decline is a natural aspect of aging and varies among individuals (Nyberg et al., 2012). While stress is a common experience throughout life, older adults may face unique stressors related to aging, including health concerns, financial worries, and social isolation. Chronic stress can negatively impact both physical and mental health, contributing to conditions such as hypertension, depression, and anxiety. It is crucial for older adults to develop effective coping strategies and seek support when needed to manage stress (Mayordomo et al., 2021).

Emotional health encompasses factors such as feelings of happiness, contentment, and satisfaction with life. Despite the challenges associated with aging, many older adults report high levels of emotional well-being and resilience. However, they may also face an increased risk of mental health disorders, including depression and anxiety (Reynolds 3rd et al., 2022).

Cognitive health refers to the ability to think, learn, and remember. While some cognitive decline is a natural part of aging, significant impairments can impact daily functioning and quality of life. Older adults may experience difficulties with multitasking, problem-solving, or processing speed. Engaging in mentally stimulating activities—such as solving puzzles, reading, or learning new skills—can help maintain cognitive function and delay age-related decline (Wilson et al., 2013).

Overall, maintaining psychological and cognitive health is crucial for promoting well-being and quality of life in older adults. This involves staying socially connected, participating in meaningful activities, managing stress effectively, and seeking support when needed (Wilson et al., 2013).

## 3. The holistic benefits of yoga

The components of yoga are as follows.

Asanas are the physical postures or poses practiced in yoga. These postures are designed to develop strength, flexibility, balance, and coordination in the body. Each asana targets specific muscles, joints, or organs, and they are often performed in sequences to create a flow. Examples include downward-facing dog, warrior poses, tree pose, and child's pose. Consistent practice of asanas can improve physical health, posture, and overall well-being (Brems, 2020).

Pranayama refers to the practice of breath control in yoga. This includes various techniques aimed at regulating and manipulating the breath to enhance vitality, mental clarity, and energy flow throughout the body. Pranayama techniques range from simple breath awareness to more advanced practices, such as alternate nostril breathing (Nadi Shodhana) and breath retention (Kumbhaka). By focusing on the breath, practitioners can cultivate calmness, reduce stress, and improve concentration and mental clarity (Givens, 2020).

Meditation is a core component of yoga that involves training the mind to achieve focused awareness, mindfulness, and inner peace. Techniques can vary widely but often include sitting quietly, observing thoughts and sensations without judgment, and cultivating a sense of presence and stillness. Regular meditation practice promotes emotional balance, reduces anxiety and depression, enhances self-awareness, and deepens spiritual connection (Al-Refae et al., 2021).

Yoga also encompasses a holistic approach to life that extends beyond physical practice. Lifestyle principles, known as the Yamas and Niyamas in yoga philosophy, offer ethical guidelines and moral values for living a harmonious and meaningful life. The Yamas include principles such as non-violence (Ahimsa), truthfulness (Satya), and non-attachment (Aparigraha). The Niyamas include self-discipline (Tapas), self-study (Svadhyaya), and contentment (Santosha). By integrating these principles into daily life, practitioners can cultivate greater self-awareness, compassion, and connection with themselves and others (Field, 2011).

### 3.1. General health benefits of yoga

Yoga is renowned for its ability to enhance flexibility. Through a diverse range of poses (asanas) that stretch and lengthen various muscle groups, regular practice can significantly increase joint range of motion and overall mobility. Many yoga poses also involve supporting one's body weight in different positions, which helps build muscle strength. For instance, poses such as plank, chair pose, and various arm balances are particularly effective at strengthening muscles throughout the body (Li et al., 2021; Isath et al., 2023).

Yoga also includes poses that challenge and enhance balance, such as tree pose and warrior III. These practices engage core muscles and improve proprioception—the body's sense of its position in space—leading to better balance and overall stability (Ko et al., 2023). Additionally, yoga integrates mindfulness and meditation practices that can significantly improve mental clarity and focus. By promoting relaxation and reducing stress, yoga enhances cognitive function and sharpens mental acuity (Liu et al., 2020; Liang et al., 2023).

In addition to its physical benefits, yoga incorporates mindfulness and meditation practices that profoundly impact mental clarity and cognitive function. Mindfulness, a core component of yoga, involves focusing attention on the present moment, which helps reduce stress and promote relaxation. This reduction in stress is linked to improved cognitive functions such as better memory, concentration, and mental acuity. Furthermore, meditation practices within yoga enhance neuroplasticity—the brain's ability to reorganize itself by forming new neural connections. This enhancement in neuroplasticity is associated with improvements in learning, memory, and overall mental performance. Extensive research supports the cognitive benefits of yoga, highlighting its potential to sharpen mental focus and clarity, making it a powerful tool for mental well-being.

In summary, yoga offers a holistic approach to enhancing both physical and mental well-being. Through its diverse range of poses, yoga improves flexibility, builds strength, and enhances balance, contributing to overall physical health. Additionally, the integration of mindfulness and meditation practices in yoga yields significant mental health benefits, including enhanced cognitive function, reduced stress, and improved mental clarity. These benefits are well-documented in scientific literature and reflected in the experiences of countless yoga practitioners worldwide. By incorporating yoga into a regular routine, individuals can achieve notable improvements in their overall quality of life, making it a valuable practice for maintaining health and well-being throughout the lifespan.

## 4. Physical benefits of yoga for anti-aging

### 4.1. Muscle preservation and strength enhancement

As you age, muscle fibers shrink and muscle mass decreases, leading to a decline in muscle strength that typically begins around age 40 and accelerates after age 60. Many yoga poses engage multiple muscle groups and require individuals to support their body weight while transitioning between positions (Bagchi et al., 2018). This weight-bearing exercise provides a crucial stimulus for maintaining and even promoting muscle growth, which is essential for preserving muscle mass as we age. Poses such as Boat Pose and Plank are particularly effective for strengthening core muscles, which are vital for maintaining balance and stability in older age.

Regular yoga practice also enhances flexibility by elongating muscles and improving joint mobility, which is vital for sustaining mobility and alleviating the stiffness commonly associated with aging (Gothe and McAuley, 2016). Yoga's gentle and repetitive movements help lubricate the joints with synovial fluid, thereby improving joint function and reducing the risk of degenerative conditions like osteoarthritis.

Additionally, yoga enhances proprioception, which heightens the body's ability to perceive its position in space (Ni et al., 2014).

This heightened awareness is fundamental for maintaining balance and coordination, which reduces the likelihood of falls and related injuries. Furthermore, yoga's comprehensive approach—integrating physical postures, breath control (pranayama), and mindfulness—promotes overall well-being. This holistic approach not only strengthens the body but also enhances mental clarity and emotional resilience, ultimately contributing to a higher quality of life as we age (Kishan, 2020).

A study investigating the effects of yoga on muscle strength found that a 16-session yoga program increased muscle strength in the elderly by 12.5 %. This suggests that yoga can be an effective option for muscle strength training in older adults, helping them maintain the ability to perform daily activities (Kumara et al., 2022). A meta-analysis of 656 studies reported that yoga practice has moderately positive effects on muscle strength, balance, mobility, and lower body flexibility, though it does not significantly affect cardiorespiratory endurance or upper body flexibility. Notably, subjects in their 60s and 70s who practiced yoga for 9–12 weeks experienced substantial improvements in physical fitness. As a multimodal activity, yoga effectively enhances muscle strength, balance, and flexibility in the elderly. Therefore, physical activity policies should continue to promote yoga as a means to improve both physical and mental well-being in this population (Shin, 2021). Integrating yoga into a consistent exercise regimen can yield substantial benefits for older adults, including the preservation of muscle mass, increased strength, and improved flexibility and balance. These combined advantages are crucial for fostering a healthier, more dynamic lifestyle, which is essential for maintaining independence and promoting overall well-being in later stages of life.

### 4.2. Joint health and increased flexibility

Enhancing joint health and flexibility is crucial for overall physical well-being, especially as individuals age (Hagen, 2007). Yoga excels in addressing these essential aspects through a series of gentle yet effective stretching and strengthening exercises. Many yoga poses are designed to elongate muscles, release tension, and nourish the joints, thereby improving range of motion and alleviating stiffness (Carson and Krucoff, 2016). For example, poses like Downward-Facing Dog, Forward Fold, and Warrior Poses specifically target areas such as the hips, spine, and shoulders, promoting flexibility and enhancing mobility. Additionally, the mindful approach inherent in yoga encourages practitioners to move with a heightened sense of awareness, respecting their body's limitations and avoiding strain or injury (Giampapa et al., 2008). This mindful engagement not only helps prevent potential harm but also fosters a deeper connection between mind and body. Consistent yoga practice yields substantial benefits, including improved joint function, increased flexibility, and enhanced overall mobility. These positive outcomes support healthy aging and elevate overall quality of life, enabling individuals to lead active and fulfilling lives as they age.

Moreover, yoga's mindful approach encourages practitioners to move with heightened awareness and sensitivity to their body's capabilities and limitations. This mindfulness not only helps prevent strain or injury but also fosters a deeper connection between the mind and body. Practitioners learn to listen to their bodies, making adjustments as needed to avoid pushing beyond their limits—an aspect particularly important for older adults or those with pre-existing joint conditions. The integration of breath work with movement further supports this process by promoting relaxation and reducing muscle tension, which can alleviate joint discomfort. Consistent participation in yoga has been shown to yield substantial benefits, including improved joint function, increased flexibility, and enhanced overall mobility. These benefits are especially significant for aging populations, as they counteract the natural decline in physical abilities that often accompanies aging. By maintaining or even improving joint health and flexibility, individuals are better equipped to lead active, independent lives. In summary, yoga's emphasis on gentle stretching, muscle strengthening, and mindful movement makes it an excellent practice for enhancing joint health and flexibility. Regular practice can significantly improve physical capabilities, supporting a more active and fulfilling lifestyle as individuals age.

### 4.3. Bone density maintenance and fall prevention

Engaging in activities like walking, jogging, and weight lifting is well-known for building and maintaining bone density. Yoga, a mind-body practice that integrates physical postures, breathing exercises, and meditation, offers additional benefits by enhancing muscle tone and flexibility, supporting joint health, and improving balance. Notably, yoga also contributes to maintaining bone density and reducing stress and anxiety, which positively impacts overall health. Furthermore, yoga increases body awareness, which aids in fall prevention by improving balance and stability (Carson and Krucoff, 2016). A systematic review found that combining Pilates and yoga helps maintain bone mineral density in postmenopausal women, a period often associated with bone density loss (Fernández-Rodríguez et al., 2021). Yoga has also been shown to decrease fracture risk in the elderly by improving balance, reducing fall risk and fear of falls, enhancing functionality, reducing hyperkyphosis, and promoting better bone turnover (Balk and Bernardo, 2011). These benefits address multiple fracture risk factors, including strength and balance. Additionally, regular yoga practice positively impacts the quality of life and physical-functional capacity of older adults, contributing significantly to fall prevention (Silva et al., 2022). By incorporating yoga into daily routines, individuals can support bone density, prevent falls, and enjoy a range of anti-aging benefits.

Furthermore, yoga's ability to reduce stress and anxiety positively impacts overall health, including bone health. Chronic stress elevates cortisol levels, a hormone that, when elevated for extended periods, can contribute to bone loss. Yoga's mindfulness and relaxation techniques help lower cortisol levels, thereby protecting bone health over time. Additionally, yoga fosters greater body awareness, which is crucial for fall prevention. Enhanced awareness of the body's movements and limitations enables individuals to move more mindfully, reducing the risk of falls. Regular yoga practice not only helps maintain bone density and reduce fracture risk but also significantly improves the quality of life and physical-functional capacity of older adults. This holistic approach to health promotes longevity and supports anti-aging practices by addressing multiple risk factors associated with aging. By integrating yoga into daily routines, individuals can enhance bone health, prevent falls, and reap the comprehensive benefits of this ancient practice, which extends beyond physical fitness to include mental and emotional well-being.

### 4.4. Cardiovascular health: improved circulation and heart function

Yoga is a holistic practice that integrates physical postures, breathing exercises, and meditation to enhance overall well-being. Its impact on cardiovascular health, circulation, and aging is both profound and multifaceted (Santaella et al., 2011). Various yoga poses—such as forward bends, backbends, and inversions—promote blood flow by enhancing circulation to different body areas, which improves the delivery of oxygen and nutrients to tissues. Breathing techniques, including deep breathing and alternate nostril breathing, increase oxygen intake, thereby boosting circulation efficiency. Regular yoga practice is associated with a reduction in blood pressure through relaxation and stress reduction, which eases the strain on the heart (Patil et al., 2017). Additionally, yoga improves heart rate variability (HRV), an important marker of heart health that indicates better autonomic control and a lower risk of cardiovascular diseases. By lowering cortisol levels and inducing a relaxation response, yoga helps counteract the detrimental effects of chronic stress on the cardiovascular system (Barrows and Fleury, 2016).

In terms of physical health, yoga helps maintain muscle mass and flexibility, which reduces the risk of falls and injuries in older adults. Weight-bearing poses in yoga contribute to maintaining bone density, thereby reducing the risk of osteoporosis and fractures (Krishna et al., 2014). Yoga and meditation also improve mental clarity, concentration, and memory, helping to counteract age-related cognitive decline. Additionally, yoga practices elevate mood by increasing levels of serotonin and endorphins, combating depression and anxiety often associated with aging. By reducing stress, yoga supports overall health and helps prevent age-related diseases (Krishna et al., 2014). Practicing yoga enhances mindfulness and body awareness, helping individuals better manage their health and well-being. As a comprehensive practice, yoga significantly benefits cardiovascular health by improving circulation and heart function while also promoting healthy aging (Guddeti et al., 2019). The Hatha yoga program did not alter any anthropometric measurements; however, it led to an increase in VO2max and maximal expired air volume, as well as an increase in high-density lipoprotein cholesterol levels. Meanwhile, triacylglycerols and low-density lipoprotein cholesterol levels remained stable in both middle-aged and older groups (Ramos-Jimenez et al., 2009).

On the other hand, cardiac patients are encouraged to exercise and stay active due to the multiple benefits, including the improvement of inflammatory markers and vascular reactivity. Heart failure (HF) patients often have comorbidities that prevent them from participating in traditional exercise programs, necessitating individualized exercise prescriptions. The metabolic demand of yoga is highly adaptable, ranging from chair-based exercises to continuous flow sequences. For HF patients, yoga can be delivered through various methods, including participation in a cardiac rehabilitation facility or a supervised home-based program using smart and connected technology, which fosters a sense of mastery and connection (Pullen et al., 2018). Another study reported that yoga improved exercise tolerance and positively affected levels of inflammatory markers in patients with heart failure, with a notable trend towards improvements in quality of life (Pullen et al., 2008). Other studies have also reported a significant reduction in diastolic blood pressure among those practicing yoga, indicating that yoga provides substantial benefits for aging individuals by reducing morbidity and mortality from cardiovascular diseases (Devasena and Narhare, 2011).

Yoga significantly benefits cardiovascular health by enhancing circulation and optimizing heart function. Poses such as forward bends, backbends, and inversions are particularly effective at improving blood flow throughout the body. These asanas help increase oxygen and nutrient delivery to tissues by promoting the efficient movement of blood, which is crucial for maintaining cellular health and function as the body ages. Improved circulation also aids in the removal of metabolic waste, further supporting overall health. For individuals with HF, yoga offers a tailored approach to physical activity that can be adapted to varying levels of fitness and mobility. Studies have shown that yoga can improve exercise tolerance, reduce levels of inflammatory markers, and enhance the quality of life in patients with heart failure. This adaptability makes yoga an accessible form of exercise for those who may be unable to participate in traditional exercise programs due to comorbidities. Programs can range from chair-based yoga to more dynamic sequences, all of which can be delivered in various settings, including cardiac rehabilitation facilities or home-based programs using smart technology.

In summary, yoga provides substantial benefits for cardiovascular health by lowering blood triglycerides, cholesterol, and blood pressure while improving circulation and heart function. These benefits, combined with its positive impact on muscle and bone health, cognitive function, and emotional well-being, make yoga a powerful anti-aging strategy. Regular practice can help reduce morbidity and mortality from cardiovascular diseases, support overall health, and contribute to a longer, healthier life.

## 5. Mental and cognitive benefits of yoga

### *5.1. Stress reduction and its impact on aging*

Yoga is celebrated for its profound capacity to alleviate stress and foster relaxation, making it particularly impactful in the context of aging. Through regular practice, yoga effectively regulates cortisol levels, the body's primary stress hormone, thereby inducing a state of deep relaxation and mitigating the adverse physiological effects of chronic stress (Bhargav et al., 2021). By integrating mindfulness techniques and meditation, yoga cultivates present-moment awareness and inner tranquility, empowering individuals to navigate life's challenges with resilience and equanimity. Additionally, yogic breathing exercises, such as deep breathing and alternate nostril breathing, activate the parasympathetic nervous system, triggering a relaxation response that counteracts the body's stress reaction (Innes et al., 2012). Chronic stress accelerates cellular aging by fueling inflammation and oxidative stress. By alleviating stress, yoga serves as a powerful tool in slowing down cellular aging processes and promoting cellular repair and rejuvenation. Moreover, stress takes a toll on brain health, contributing to cognitive decline and neurodegenerative diseases. Yoga's stress-reducing effects play a crucial role in preserving cognitive function and shielding against age-related cognitive decline (Selfe et al., 2012). Furthermore, prolonged stress compromises immune function, leaving individuals more vulnerable to infections and diseases. The stress-relieving benefits of yoga bolster immune resilience, fortifying the body's defenses against pathogens and supporting overall health. Additionally, chronic stress diminishes quality of life by disrupting mood, sleep, and overall well-being.

Through stress alleviation, yoga enhances the quality of life for older adults, fostering greater vitality, resilience, and emotional balance (Loucks et al., 2015). Participating in yoga can enhance mental and emotional well-being, reduce exhaustion levels, and alleviate stress among elderly individuals, irrespective of any measurable improvements in physical function (Lindahl et al., 2016). In conclusion, yoga's capacity to mitigate stress has profound implications for aging, offering a holistic approach to counteracting both the physiological and psychological effects of chronic stress. By promoting relaxation, mindfulness, and emotional well-being, yoga supports healthy aging and elevates the overall quality of life for older adults. Integrating yoga into daily life serves as a potent strategy for mitigating the impact of stress and nurturing greater resilience and vitality as we age. The incorporation of yoga into routine health practices could potentially revolutionize approaches to aging, emphasizing the importance of mental and emotional health as integral components of overall well-being.

### *5.2. Enhanced cognitive function: memory, focus, and mental agility*

Yoga's positive impact on cognitive function, encompassing the mental processes involved in knowledge acquisition through thought, experience, and sensory perception, is noteworthy. Through various mechanisms, yoga enhances cognitive function. Research indicates that consistent yoga practice improves memory function (Eyre et al., 2016). Specific yoga poses, along with focused breathing techniques and meditation practices, can bolster concentration and focus, which are vital for memory formation and retention. Moreover, yoga's stress-reducing and relaxation-promoting effects can also positively influence memory recall. By incorporating mindfulness techniques, yoga encourages individuals to be fully present, heightening awareness of thoughts, sensations, and surroundings. This mindfulness fosters improved focus and attention span, enhancing performance in daily tasks and activities. Additionally, mental agility, characterized by quick thinking, adaptability, and effective problem-solving, is promoted through yoga. Physical postures, breathing exercises, and meditation practices stimulate the brain, fostering neural growth and enhancing cognitive flexibility. This enables individuals to respond adeptly to changing circumstances (Gothe et al., 2014). It has been reported that a brief yoga program incorporating mindfulness meditation may offer improvements in working memory (WM) functioning and enhance attentive mindfulness (Brunner et al., 2017). Furthermore, yoga-related mind-body interventions have emerged as safe, feasible, and effective alternatives for preserving cognitive functions in older adults, including those experiencing age- and disease-related cognitive decline. Incorporating yoga into daily routines can serve as a valuable strategy for maintaining cognitive function throughout older adulthood (Bhattacharyya et al., 2021). Hoy et al. reported positive effects of yoga-based interventions on cognition, including improvements in gross memory functioning and executive functions. However, it's worth noting that intervention characteristics and assessment methods varied between studies, leading to a high overall risk of bias. Despite these limitations, yoga-based interventions are associated with notable enhancements in cognition among healthy older adults (Hoy et al., 2021). Incorporating yoga into daily routines offers a valuable strategy for maintaining cognitive function throughout older adulthood. Regular engagement with yoga can lead to notable improvements in memory, focus, and mental agility, thereby supporting overall cognitive health and potentially slowing the aging process. Yoga's holistic approach addresses physical, mental, and emotional aspects of well-being, contributing to a comprehensive enhancement of cognitive function. In summary, yoga provides a multifaceted approach to augmenting cognitive function by addressing both the physiological and psychological aspects of mental health. Through improvements in memory, concentration, and mental agility, yoga nurtures overall cognitive health and well-being, offering a promising strategy for mitigating cognitive decline associated with aging.

### *5.3. Emotional well-being and resilience: managing anxiety and depression*

Yoga plays a pivotal role in the management of anxiety and depression by integrating various relaxation techniques, such as deep breathing, meditation, and mindful movement. These practices elicit the body's relaxation response, effectively reducing levels of stress hormones like cortisol while fostering a profound sense of calm and tranquility. By mitigating stress, yoga serves as a powerful tool in alleviating symptoms of anxiety and depression (Cramer et al., 2018). Moreover, yoga encourages practitioners to embrace mindfulness, emphasizing the importance of being fully present in the moment and cultivating awareness of thoughts, emotions, bodily sensations, and the surrounding environment without judgment. Through consistent practice, individuals develop enhanced self-awareness and emotional regulation skills, which are crucial for effectively coping with anxiety and depression (Brinsley et al., 2021). Certain yoga poses and movements are specifically designed to release tension stored in the body, facilitating the cathartic release of suppressed emotions. This therapeutic process provides a healthy outlet for expressing and processing emotions, ultimately diminishing the intensity of anxiety and depression symptoms (Brinsley et al., 2021).

Furthermore, regular yoga practice has been scientifically proven to elevate mood and enhance overall well-being. The combination of physical activity, breathwork, and relaxation techniques triggers the release of endorphins, neurotransmitters responsible for feelings of happiness and pleasure. Additionally, yoga promotes the production of serotonin, a neurotransmitter associated with mood stabilization and emotional equilibrium (Cramer et al., 2013). Yoga fosters resilience by nurturing mental strength, adaptability, and inner fortitude. Through challenging physical postures and mindful practices, individuals develop the capacity to confront life's adversities with equanimity and resilience, cultivating a profound sense of inner strength and confidence (Pascoe et al., 2017).

Lastly, practicing yoga within a supportive community or group setting can foster a sense of belonging and social support, which are paramount for emotional well-being. Connecting with others who share similar experiences and aspirations can mitigate feelings of isolation and loneliness, common contributors to anxiety and depression. In summary, yoga offers a holistic approach to managing anxiety and depression by addressing the physical, mental, and emotional facets of health. Through its emphasis on relaxation, mindfulness, emotional release, mood enhancement, resilience-building, and community support, yoga equips individuals with valuable tools for promoting emotional well-being and cultivating resilience in the face of life's challenges. Regular practice of yoga can significantly alleviate symptoms of anxiety and depression, support overall mental health, and enhance quality of life.

### *5.4. Neuroplasticity and brain health*

Yoga integrates a variety of physical postures, movement sequences, and balance poses, engaging diverse muscle groups and enhancing blood flow to the brain. Regular engagement in physical activities like yoga has been associated with heightened neuroplasticity, the brain's remarkable capacity to establish new connections and adapt to change. Additionally, mindfulness meditation, a fundamental aspect of yoga, has been linked to structural modifications in the brain, such as increased gray matter density in regions crucial for memory, emotion regulation, and self-awareness. These alterations signify augmented neuroplasticity and improved brain health (Gothe et al., 2019).

Moreover, yoga's emphasis on relaxation, deep breathing, and stress reduction techniques plays a pivotal role in diminishing levels of stress hormones like cortisol. This, in turn, shields the brain from the deleterious impacts of chronic stress. Furthermore, by alleviating symptoms of anxiety, depression, and mood disturbances, yoga fosters emotional well-being and augments brain health. Through the enhancement of emotional regulation and resilience, yoga bolsters overall brain health and fortifies neuroplasticity (Tolahunase et al., 2018). In essence, yoga fosters neuroplasticity and sustains brain health through a multifaceted approach that integrates physical exercise, mindfulness practices, stress reduction techniques, cognitive stimulation, emotional well-being, and social engagement. By incorporating yoga into their daily routines, individuals can potentially bolster brain function, sustain cognitive vitality, and navigate the aging process with grace. The comprehensive benefits of yoga make it a valuable practice for enhancing cognitive health and supporting overall brain function.

## 6. Cellular and molecular impact of yoga

### *6.1. Yoga's role in reducing oxidative stress*

Yoga plays a significant role in mitigating oxidative stress, a condition marked by an imbalance between free radical production and the body's ability to neutralize these radicals through antioxidants. This imbalance can lead to cellular damage and contribute to various diseases and aging processes. Yoga addresses oxidative stress through multiple mechanisms:

Regular yoga practice has been shown to increase levels of endogenous antioxidants such as superoxide dismutase (SOD), glutathione peroxidase, and catalase (Patil, 2019). These enzymes play a crucial role in neutralizing free radicals and reducing oxidative damage. Enhanced antioxidant enzyme activity helps protect cells from oxidative stress and its harmful effects. Yoga-induced increases in antioxidant enzyme activity are thought to be mediated through improved oxidative balance and reduced production of reactive oxygen species (ROS). This enhancement helps maintain cellular homeostasis and prevents oxidative damage. Additionally, yoga and meditation effectively lower cortisol levels, a hormone that, when elevated, is associated with increased oxidative stress (Lim and Cheong, 2015). High cortisol levels exacerbate oxidative stress by promoting the production of ROS and reducing the effectiveness of antioxidant defenses. By reducing cortisol levels, yoga helps lower oxidative stress, thereby protecting cells and tissues from oxidative damage and contributing to overall health. Yoga activates the parasympathetic nervous system (rest and digest) and calms the sympathetic nervous system (fight or flight) (Tyagi, 2014). This balance reduces stress hormone production and subsequently decreases oxidative stress. The activation of the parasympathetic nervous system promotes relaxation and reduces the physiological impact of stress, further mitigating oxidative damage. Yoga also reduces levels of pro-inflammatory cytokines such as TNF-α, IL-6, and CRP (Viswanathan et al., 2021). Chronic inflammation is a major source of oxidative stress, and by decreasing inflammation, yoga helps minimize oxidative damage. Yoga's anti-inflammatory effects are achieved through its impact on various signaling pathways involved in inflammation and oxidative stress. This reduction in inflammation contributes to a more balanced oxidative state.

Regular yoga practice improves mitochondrial function and efficiency (Gautam et al., 2021). Healthier mitochondria produce fewer free radicals during energy production, thereby reducing oxidative stress. Improved mitochondrial function enhances cellular energy production and reduces oxidative damage, supporting overall cellular health and resilience. Yoga fosters a strong mind-body connection, enhancing mental well-being and reducing psychological stress, a significant contributor to oxidative stress (Venkatesh et al., 2020). Improved mental health is associated with lower levels of oxidative damage. By promoting emotional regulation and reducing stress, yoga helps lower oxidative stress associated with psychological factors, further protecting the body from oxidative damage. Yoga also improves cardiovascular and respiratory functions, leading to better oxygen delivery and utilization, which reduces oxidative stress on tissues (Manna, 2018). Efficient oxygen delivery helps minimize oxidative damage and supports overall health. Enhanced muscle strength and flexibility from yoga reduce the risk of injury and associated oxidative stress from tissue damage. Improved physical fitness contributes to a better oxidative balance. Improved muscle strength and flexibility from yoga practice reduce the risk of injury and the subsequent oxidative stress associated with tissue damage. Research suggests that a lifestyle incorporating meditation and yoga may decrease free radical levels in the blood and reduce seminal oxidative stress. This, in turn, can lower oxidative damage to both mitochondrial and nuclear genomes, resulting in a reduced mutagenic load in DNA. Lower oxidative damage in sperm might help couples pursuing assisted conception conceive naturally and decrease the incidence of pre- and post-implantation losses, recurrent spontaneous abortions, or children with congenital malformations or cancer. Additionally, regular practice of yoga and meditation could promote healthy aging by mitigating age-related DNA damage and enhancing repair capacity (Dada et al., 2015).

Furthermore, yoga can be an effective lifestyle practice for alleviating oxidative stress and boosting antioxidant defenses in elderly individuals with hypertension (Patil et al., 2014). The cellular and molecular mechanisms through which yoga reduces oxidative stress include enhancing antioxidant enzyme activity, reducing the production of ROS, and improving mitochondrial function. Yoga enhances the activity of vital antioxidant enzymes, such as superoxide dismutase and glutathione peroxidase, while concurrently diminishing ROS generation. Additionally, yoga fosters improvements in mitochondrial function, contributing further to oxidative balance. Moreover, yoga influences the modulation of gene expression related to oxidative stress response and repair, thereby fortifying cellular resilience and minimizing oxidative damage. Yoga, through its multifaceted approach combining physical postures (asanas), breathing exercises (pranayama), and meditation, effectively reduces oxidative stress. This holistic practice enhances the body's antioxidant defenses, reduces stress hormones, mitigates inflammation, improves mitochondrial function, and promotes overall physical and psychological well-being. Regular yoga practice is thus a valuable tool in managing oxidative stress and enhancing health and decreasing aging. Yoga reduces oxidative stress through a multifaceted approach that includes enhancing antioxidant defenses, reducing stress hormones, decreasing inflammation, improving mitochondrial function, and promoting psychological well-being. By integrating physical postures, breathing exercises, and meditation, yoga supports oxidative balance and overall health. Regular practice of yoga is thus a valuable tool for managing oxidative stress, supporting cellular health, and promoting healthy aging.

### *6.2. Effects on inflammation and immune function*

The relationship between inflammation and aging is complex and significant, involving numerous biological and physiological changes. Chronic low-grade inflammation, commonly known as "inflammaging," is a key characteristic of the aging process and is linked to a wide array of age-related diseases such as cardiovascular diseases, neurodegenerative disorders, and cancer (Bousounis et al., 2021). This condition reflects a persistent, systemic inflammatory response that exacerbates aging and contributes to various health issues. Inflammaging involves a dysregulation of the immune system, with increased production of pro-inflammatory cytokines and a decline in anti-inflammatory mechanisms. This chronic inflammation contributes to tissue damage, impaired repair processes, and ultimately accelerates the aging process. Understanding and managing the interplay between inflammation and aging is crucial for developing strategies to promote healthy aging and prevent age-related diseases (Howcroft et al., 2013). Yoga's effects on inflammation and immune function in aging are mediated by intricate molecular mechanisms. It entails modulating the activity of pro-inflammatory cytokines, such as interleukin-6 and tumor necrosis factor-alpha, while promoting the release of anti-inflammatory molecules like interleukin-10 (Estevao, 2022).

Additionally, yoga enhances the function of immune cells, such as natural killer cells and T lymphocytes, contributing to a more robust immune response in older individuals. These molecular mechanisms collectively underscore yoga's potential as a holistic approach to mitigating age-related inflammation and bolstering immune function (Falkenberg et al., 2018). Yoga's impact on inflammation and immune function in aging is orchestrated through intricate cellular mechanisms. It involves downregulating the activity of pro-inflammatory transcription factors like Nuclear Factor kappa B (NF-κB), thereby reducing the expression of pro-inflammatory cytokines such as interleukin-6 and tumor necrosis factor-alpha. Moreover, yoga promotes the activation of anti-inflammatory pathways, including the nuclear factor erythroid 2-related factor 2 (Nrf2) pathway, which enhances the expression of antioxidant and anti-inflammatory genes (Eda, 2014). At the cellular level, yoga also influences immune cell function by modulating the proliferation, differentiation, and activity of immune cells such as lymphocytes and macrophages. These cellular mechanisms collectively highlight yoga's potential as a holistic approach to counteracting age-related inflammation and bolstering immune function (Gautam et al., 2021).

In recent times, there has been a notable increase in yoga practice among the elderly population, driven by growing awareness of its benefits. Yoga offers significant support to individuals dealing with acute or chronic illnesses, leveraging the practice of asanas, pranayama, and meditation. Consequently, yoga presents numerous advantages and is accessible to people of all ages and health conditions (Mahalingam and Premavathy, 2020).

Yoga provides significant support for managing both acute and chronic illnesses by improving physical function, reducing stress, and enhancing overall well-being. Its holistic approach addresses various aspects of health, making it a valuable tool for older adults seeking to manage inflammation and improve their quality of life. Yoga's impact on inflammation extends beyond individual health to influence broader aspects of aging. By reducing inflammation, improving immune function, and enhancing psychological well-being, yoga supports healthy aging and reduces the risk of age-related diseases. Incorporating yoga into daily routines can serve as both a preventive and therapeutic strategy for managing chronic inflammation and promoting longevity. Its comprehensive approach addresses physical, mental, and emotional aspects of health, contributing to a more balanced and resilient aging process. The interplay between inflammation and aging underscores the importance of managing chronic inflammation to promote healthy aging and prevent age-related diseases. Yoga's multifaceted approach, involving modulation of cytokine activity, enhancement of immune function, and activation of anti-inflammatory pathways, offers a holistic strategy for addressing inflammaging. By integrating physical postures, breathing exercises, and meditation, yoga provides valuable support for older adults, contributing to improved health outcomes and a higher quality of life.

### 6.3. Influence of yoga on telomere length and cellular aging

Exploring the impact of yoga on telomere length and cellular aging is becoming increasingly important in scientific inquiry. Evidence suggests that consistent engagement in yoga may play a role in preserving telomere length, a marker of cellular longevity and vitality. Through its stress-reducing and relaxation-promoting effects, yoga has the potential to counteract the processes of cellular aging, potentially leading to better health outcomes and an enhanced sense of well-being. Further research into the interplay between yoga and cellular aging holds promise for informing preventive healthcare strategies and promoting longevity. Studies have reported that regular practitioners of yoga maintain well-preserved leukocyte telomere length (LTL), even in the absence of medical conditions, and exhibit lower systemic oxidative stress compared to individuals with a relatively sedentary lifestyle. Furthermore, habitual yoga practice appears to impede replicative cellular senescence, suggesting its potential in promoting cellular longevity and overall health (Krishna et al., 2015). Another study reported that embracing a lifestyle centered around yoga and meditation is linked to the reversal of aging markers, particularly oxidative stress, telomerase activity, and oxidative DNA damage. This has the potential not only to delay aging and extend a period of youthful vitality but also to postpone or mitigate the onset of numerous lifestyle-related diseases, notably those stemming from oxidative stress and inflammation (Kumar et al., 2015).

A review paper highlighted a promising correlation between mindfulness practices and telomere length (TL), indicating potential benefits for both cellular aging and cognitive well-being. The findings underscore the importance of further research to elucidate the most effective strategies for positively influencing TL and its broader implications for holistic health (Aghajanyan et al., 2023).

The evidence linking yoga to preserved telomere length underscores the potential of this practice as a holistic strategy for promoting healthy aging. By integrating yoga into daily routines, individuals may not only improve their physical health but also enhance emotional resilience, cognitive function, and overall quality of life. Understanding the relationship between yoga, telomere length, and cellular aging can inform preventive healthcare strategies aimed at reducing the risk of age-related diseases. As research in this area grows, yoga could become a key component of public health initiatives designed to promote longevity and healthy aging. While current evidence is promising, further research is needed to elucidate the specific mechanisms by which yoga influences telomere length and cellular aging. Longitudinal studies and randomized controlled trials would provide more definitive insights into the long-term effects of yoga on telomere dynamics and overall health outcomes. Exploring the impact of yoga on telomere length and cellular aging is an exciting and evolving area of scientific inquiry. By preserving telomere length and reducing cellular aging, yoga holds the potential to enhance health outcomes, delay the onset of age-related diseases, and promote longevity. As the understanding of this relationship deepens, yoga may play an increasingly important role in preventive healthcare, offering a holistic approach to aging that integrates physical, mental, and emotional well-being.

## 7. Yoga practices specifically for anti-aging

Yoga's foundation lies in asanas, specific physical postures designed to cultivate various benefits, such as vitality and a youthful spirit. Practiced mindfully and in sync with the breath, these postures have a profound impact on the body, mind, and soul. The essence of yoga asanas is to foster balance and unity within the body by engaging muscles, aligning joints, and nurturing internal organs (McGonigle and Huy, 2022). Consistent practice enhances flexibility, boosts circulation, and contributes to overall physical wellness. Moreover, asanas are believed to activate the flow of vital life force, or prana, revitalizing the practitioner from within. Certain poses are renowned for their rejuvenating effects on both the body and mind. Backbends, inversions, and twists, for instance, stimulate circulation, refine posture, and elevate energy levels, often inducing a tranquil state of mind by soothing the nervous system and alleviating stress. In essence, the practice of asanas in yoga is a potent vehicle for nurturing vitality and youthfulness, fostering not only physical resilience but also mental clarity and emotional well-being (Bhatia, 2023).

Pranayama, a core aspect of yoga, encompasses breath control techniques aimed at regulating respiration, bolstering lung capacity, and harmonizing the flow of prana (life force energy) within the body. Embedded within its practice is the longstanding notion of fostering longevity and vitality. Central to pranayama are deliberate breath manipulations, encompassing diverse patterns, rhythms, and breath retentions (Bhatia, 2023).

Meditation techniques encompass a diverse array of practices geared towards enhancing mental and emotional well-being by honing focused attention, mindfulness, and relaxation. Stemming from ancient contemplative traditions, these methods have surged in popularity due to their recognized therapeutic effects in contemporary society. Extensive research underscores the manifold benefits of regular meditation, ranging from stress alleviation and mood enhancement to heightened cognitive function and improved emotional regulation. Moreover, meditation demonstrates promise in mitigating symptoms associated with anxiety, depression, and sleep disorders, underscoring its significance as a holistic wellness tool (Bhatt et al., 2024). In essence, meditation serves as a potent avenue for nurturing mental and emotional health, fostering profound self-awareness, and cultivating an enduring sense of tranquility and balance within oneself.

## 8. Challenges and considerations

Yoga faces various challenges, including physical limitations. Many individuals encounter barriers due to chronic pain, injuries, medical conditions, or mobility issues, making yoga practice uncomfortable or unsafe. Some poses may worsen existing injuries or conditions if not approached mindfully or adapted appropriately. Those with limited flexibility, strength, or balance might feel discouraged or intimidated. Overcoming these limitations often involves modifications, adjustments, and tuning into one's body. Seeking guidance from a qualified yoga instructor who can tailor modifications and alternatives to individual needs can effectively address physical barriers. Time constraints also hinder consistent yoga practice. Busy schedules and competing priorities make it challenging to carve out time for yoga amid work, family, and social commitments. The perception that yoga demands lengthy sessions at specific times discourages many. Overcoming time limitations entails prioritizing self-care and recognizing that even short, daily practices yield benefits. Integrating yoga into daily activities, practicing mindfulness during chores, or incorporating brief yoga sequences during breaks can help. Additionally, exploring flexible options like online classes or attending shorter sessions accommodates hectic schedules. Acknowledging and addressing these barriers through modifications, time management strategies, and flexible practice options enable individuals to cultivate a sustainable and rewarding yoga practice tailored to their unique circumstances and needs.

## 9. Conclusions and implications for future research

This narrative review illuminates yoga's profound potential as a holistic strategy for anti-aging, offering comprehensive benefits that extend to both physical and mental well-being. By consolidating current knowledge, it underscores the diverse spectrum of advantages yoga presents, spanning from the preservation of muscle and joint health to the alleviation of stress and the bolstering of emotional resilience, along with insights into its molecular and cellular mechanisms. To advance the field, future research should prioritize the exploration of specific molecular and cellular pathways through which yoga exerts its anti-aging effects. Particular focus should be given to mechanisms such as the modulation of oxidative stress, inflammation, and telomere dynamics, all of which are crucial in the aging process. Utilizing advanced methodologies, such as high-throughput omics technologies and longitudinal studies, will be essential to unravel the complex biological interactions underlying yoga's impact on aging.

Additionally, a detailed table summarizing the cellular and molecular mechanisms involved in yoga's anti-aging effects could provide a comprehensive overview for readers, enhancing understanding and facilitating future research. Further research should also explore the effects of yoga across diverse populations, encompassing various age groups, ethnicities, and socioeconomic backgrounds. Such studies could inform tailored interventions that promote healthy aging across different demographics, ensuring inclusivity and accessibility. By delving deeper into these areas, the scientific community can better understand yoga's efficacy in counteracting age-related changes, ultimately leading to the development of precise interventions that can be integrated into preventive healthcare strategies, promoting longevity and enhancing the quality of life for all.

## Ethical approval

Not applicable.

## CRediT authorship contribution statement

**Qiaoyan Chen:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation.

## Declaration of competing interest

The author declares no conflicts of interests.

## Data availability

Data will be made available on request.

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