



Review Article

Ayurveda and the science of aging

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ABSTRACT

Since time immemorial, humanity has been concerned with developing and preserving youthful vigor, and extending longevity by stopping or delaying the aging process. By 2030, one in five of the world population will be over 65 years old. Longevity and old age are accompanied with a variety of health challenges and population studies indicate that the elderly will use between three to five times more healthcare services compared to the younger population. Modern medicine has made a great deal of progress in understanding the aging process and in controlling age-associated health issues including heart attacks, strokes, diabetes, cancer, senility, and arthritis. Thus, every individual is now looking forward to a youthful, productive lifespan of 100 or more years filled with unlimited health and opportunity. Research by aging experts is focused on ways to go against the natural order of the aging process in order to delay it. Interventions include among other things anti-aging pills, restricted food consumption and cloning body parts to stay young and delay biological aging. Ayurveda, one of the world's most authoritative mind-body-spirit medicinal systems, offers various concepts of the aging process. This system of medicine includes therapies for healthy aging so as to create an optimal health and lengthen an individual's healthspan by living in harmony with nature. This review will explore various aspects of aging and longevity by comparing the science of aging as defined by modern medicine with the Ayurvedic treatise of *Jara* and *Vriddhavastha*.

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1. Introduction

Aging has been defined as the total sum of physiological changes that progressively leads to the death of the individual. It is also defined as the intrinsic, inevitable, and irreversible age-associated loss of viability that render us more susceptible to a number of diseases and death or a progressive functional decline of physiological function and a decrease in fecundity with age [1–4]. Undoubtedly, human aging is associated with a wide range of physiological and cellular changes that limit our normal functions and make us more susceptible to death. Aging has two main components, Chronological Aging which refers to the actual age of the person in terms of years, months, and days. This component of aging is unstoppable, unchangeable and irreversible. Physiological/Biological aging is the second component and refers to an individual's development and changes based on certain cellular or

molecular parameters. This involves looking at the individuals as they are and as they function, and not when they are born [5,6]. Thus, biological aging is a set of processes that triggers deterioration of health and ultimately to death as a function of chronological age. Unlike chronological aging, biological aging can be reversed or delayed [5,6]. Other terms that constitute aging include:

Lifespan: It is the period of time during which we are alive. Lifespan also includes the years spent in poor health as there are several age-associated health conditions that lack proper treatment or cure [7,8].

Morbidity: The period of ill health during an individual's lifespan is referred to as morbidity. Although our lifespans have increased significantly due to better nutrition and modern medicine, middle-aged and elderly people suffer many years of ill health before they die. Age-associated diseases include heart disease, stroke, diabetes, osteoporosis, and other chronic problems resulting in the individual being in a state of morbid condition [7,8].

Healthspan: Health span is equal to the lifespan devoid of the amount of time an individual spends in ill health (Lifespan–morbidity). This is the period in an individual's life during

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which the person is generally healthy and free from serious or chronic illness. Thus, healthspan refers to how long an individual lives a disease-free healthy life [4,9,10].

Therefore, biological aging in terms of healthspan is a result of complex structural and functional changes across molecules, cells, tissues and whole body systems. Its manifestation is influenced by several factors including genomic instability, telomere attrition, epigenetic alterations, loss of proteostasis, deregulated nutrient sensing, mitochondrial dysfunction, cellular senescence, stem cell exhaustion, and altered intra- and intercellular communication. Since aging is accompanied by impairment of normal physiological functioning of cells, tissue, organs and bodily systems that increases the risk of death, some in the aging field consider aging itself to be a deadly disease [11,12].

There is no one single cause or trigger of the aging phenomenon as there are many different and often conflicting theories of aging. At the cellular level, changes that contribute to aging include reduction in stem cell proliferation in a number of tissues, accumulation of toxic protein aggregates and free radicals, accumulation of senescent cells that trigger inflammation and impairment in mitochondrial function. At the genomic level, accumulation of mutations in DNA together with faulty DNA repair processes and telomere shortening are all associated with early signs of aging. Several researchers believe that a combination of several of these factors may contribute to overall aging [13–16]. Theories of aging include but are not limited to a) Genetic theory of aging, b) Damage or Error theory, c) Dilman's Neuroendocrine theory, d) DNA damage theory, e) Free radical damage theory, f) Gene mutations, g) Cell divisions/telomere shortening, h) Cellular senescence and i) Antagonistic Pleiotropy [12–16]. Some of these causes may appear non-specific with regard to suitable interventions, because it is unclear which among them is more amenable to pharmacological intervention in order to reverse the aging process.

2. Factors that promote biological aging

While aging in itself is inevitable, there are ways to reduce or delay the pathological effects of aging. This involves looking at strategies to combat aging both at the cellular and/or genomic level and to see if any of the above mentioned triggers of aging are amenable to suitable drug interventions. Researchers propose at least seven highly intertwined processes that promote aging, thus providing a format for the identification of program mediators and therapeutic candidates. Deciphering these factors that are also responsible for age-associated diseases will be helpful in drug discovery efforts to decelerate aging [4,9]. Among these factors, one that has inspired a lot of excitement is metabolism, and researchers have been trying to understand why caloric restriction extends the life span in mice and other animals [17–21]. Metabolizing fewer calories could result in reduced oxidative damage or alternatively, absence of nutrients may trigger certain defense mechanisms that protect the body from decaying. Researchers have managed to identify several molecular pathways that govern metabolism. Modification of these pathways or their specific products through proper drug-based interventions, could one day mimic the life expanding effects of caloric restriction in humans without compromising on the food intake [16,19–23].

Another factor that is being thoroughly explored is the fallout from long term chronic inflammation. While several age-associated diseases involve the inflammatory process, long lived healthy individuals including centenarians are generally free from age-associated inflammatory diseases [24–26]. Interventions targeted to reduce chronic inflammation are being examined closely for their life enhancing effects [27–29]. Inflammation cannot be completely shut down as our bodies need the short term adaptive

inflammatory process to fight infections and ward off short term stress [30–32]. Thus, we need to better understand the inflammatory process at a molecular level to see if drugs can be developed that specifically target the aberrant pathways.

In addition, extension of lifespan in humans could also be achieved by lowering the rate of free radical induced-oxidative damage to tissues, replacement and/or rejuvenation of damaged tissues and cells, reversal of harmful epigenetic changes, or enhancing the telomerase activity [33–35]. Several experts are also developing strategies to combat multiple age-associated diseases at the same time [23,36].

Aging is a major risk factor for most chronic diseases and researchers agree that if we can address the issue of aging itself, we could potentially delay and diminish age-associated diseases all at once [11,12]. Researchers are looking at slowing down aging with the premise that a drug targeting the aging process will not only slow down aging but will also delay age-associated pathologies and diseases [37,38]. This approach is very attractive as researchers do not need to discover drugs to combat specific age-associated conditions like cancer, diabetes or dementia, but instead treat the aging process itself [4,9,37,38].

3. Therapies for a successful healthspan

- 1) The free-radical theory of aging suggests that antioxidant supplements, such as vitamin C, vitamin E, Q10, lipoic acid, carnosine, and N-acetylcysteine, might extend human life. However, despite several studies, it is not clear if β -carotene supplements and high doses of vitamin E extend life span or increase mortality rates [28,39,40].
- 2) Resveratrol is a sirtuin stimulant that has been shown to extend life in animal models, but the effect of resveratrol on lifespan in humans is unclear [41–44].
- 3) The anti-diabetes drug metformin has shown to extend the life of animals and the US-FDA has permitted a clinical trial to see if the life-extending benefits replicate in humans. If metformin turns out to be successful in delaying the aging process, a person taking metformin would be young at 90 [44–46].
- 4) Drugs like acarbose (a common drug prescribed for Type 2 diabetes), and anti-inflammatory drugs such as masoprocol and basic aspirin extend lifespan in mice, but these drugs can have multiple effects, and their mechanism of action is not clear. The fact that they tackle chronic inflammation could just be one piece of the puzzle, not the whole solution [47–49].
- 5) The most promising drug to combat aging has been rapamycin, an immunosuppressant often used in organ transplants. In addition to life span extension, rapamycin has an unbelievably wide range of effects in mice ranging from preventing Alzheimer's and cardiovascular disease to reducing cancer [44,50,51].
- 6) Non-drug therapies that extend lifespan include calorie restriction (CR). CR also retards age-related chronic diseases in a variety of species, including rats, mice, fish, flies, worms, and yeast. The mechanism through which this occurs is unclear [17–21].
- 7) Therapeutic cloning, body part replacement and stem cell research could one day provide a way to generate cells, body parts, or even entire bodies that do not decay [52–54]. Researchers have succeeded in growing artificial body parts in the lab, including nose, ears, tear ducts, bladders and blood vessels from human stem cells. The use of human stem cells for the purpose of cultivating organs, that can be transplanted into people, is another attractive approach to combat age-associated organ decay [55–58].

4. Ayurveda and science of aging

Jara also called as *Vardhakya* (aging) is defined as that which has become old by the act of wearing out. According to Ayurveda, *Jara*/aging is not a disease but a natural phenomenon like hunger, thirst or sleep. In the theory of natural destructions (*Swabhavoparamavada*), *Charaka* describes that there is a causative factor for the manifestation of a being but there is no cause for the cessation of this manifestation, since death following birth is a state of natural flow [59,60]. The term *Jara* denotes four entities: *Nityaga* which signifies continuation of consciousness, *Dhari* which denotes the factor(s) that prevent the body from *Jara*/aging, *Jeevitam* which represents the act of keeping alive and *Anubandha* that denotes transmigration of the body [59,60]. Accordingly, *Jara*/aging is influenced by factors affecting *Shareera* (physical), *Indriya* (emotional), *Satwa* (psychic level), *Agni* (metabolism) and *Bala/Ojas* (immunity). In addition, *Parinama* (cellular transformation), *Sharira vridhikara bhavas* (genotypic and phenotypic characteristics) and *Garbhahinivrittikara bhava* (pregnancy-induced fetal development and changes) also affect an individual's aging process [61–63].

Jara is accompanied by the process of decay and manifests in the form of various degenerative changes. Although these changes are natural (*Kalaja Vridhnavastha*-natural aging), they are not pleasant [62,64]. Everyone is aware that a person who has taken birth must grow and finally die, but nobody wants to grow old and certainly no one wishes to die. Humans in general consider aging and age-associated diseases as unnatural even though our choices and actions are responsible for the rapid biological aging. Misusing the five senses (*pancha tanmatras*) and bringing in disharmonious impressions through the five sense organs (*pancha jnanendriyas*), making incorrect choices that promote unhealthy transformation of the body and mind (*Parinama*), all trigger the disease process resulting in mental and physical suffering [65]. Mental and physical ill-health weakens *dhatu*s (homeostasis), resulting in *Akalaja vridhnavastha* (pathological aging) [61,62,66]. Ayurveda takes a holistic approach toward the maintenance of *dhatu*s, a state of equilibrium of normal anatomical, biological, physiological, mental and spiritual well-being [66,67]. Hence a balanced state (*sama*) of tissue (*dhatu*), energy systems (*Dosha*), heat of transformation (*Agni*) and metabolic wastes (*mala*) constitute homeostasis in Ayurveda that leads to healthy aging (*Sukhayu/Kalaja Vridhnavastha*) [66,68]. Some of the most important factors that affect *Jara*/healthy aging include:

Kala Parinama (time and transformation) is one the most important and potent factors that influences *Jara* or aging as it includes all creation in itself [69,70]. *Kala Parinama* refers to the physical and mental transformation that occurs as a function of time and as we age. Being out of harmony with the rhythms and cycles of nature can trigger unhealthy transformation and disharmonious changes, making the body vulnerable to disease and rapid aging [63,65,70]. *Kala* influences a human from conception till death and this time period is called *Ayush* (lifespan). Ayurveda divides *Ayush* into *Vaya* (various stages of life)—childhood (*Bala*-up to the age 16 years), adolescent/teenage (*vivardhamana*, 16–20 years of age), youth (*yuvana*, 20–30 years), matured individual (*sampoornata*, 30–40 years), aged individual (*parihani*, 40–60 years) and older adults (last stage of life-*Jirna* or *Vridhnavastha*) [61]. Owing to the influence of *Kala*, various changes occur in the body during these stages of life and hence the lifestyle adopted during each stage of this growth has a profound influence on the aging process.

Prakruti refers to the biological constitution (anatomical, physiological and psychological) of an individual. The *Prakruti* which is unique to each individual reflects the baseline characteristics of the individual including metabolism, mental makeup,

immunity, inherent strength and weakness and proclivities [67,70,71]. Thus, *Prakruti* determines an individual's capacity for transformation at the physical, mental and emotional levels owing to the interactions with internal and external stimuli all of which affect the aging process [63,72].

Doshas or biological energy systems determine the longevity at the cellular level. *Vata*, which is closely related to pranic life energy, governs all life functions and biological activity and is the energy of movement. *Pitta* governs digestion and metabolism. *Kapha* controls anabolism and is the energy of building and lubrication that provides the body with physical form, structure, and the smooth functioning of all its parts. Health and disease is a direct reflection of the status and interaction of the *Doshas* in the body that in turn provokes or delays the aging process [71]. Proper diet, exercise and a harmonious lifestyle can create a balance among these *Doshas* ensuring a healthy healthspan [59,61,62].

Subtle Doshas are subtle counterparts of *Doshas* and an elaboration of the mental and emotional aspects of the physical *Doshas* that also influence the *Jara*/aging process. The subtle counterparts of the biological *Vata*, *Pitta* and *Kapha Doshas* are *Prana* (subtle life energy), *Ojas* (subtle immunity) and *tejas* (subtle vitality/subtle fire or energy) that are necessary for smooth longevity [59,71,73]. *Prana* controls breath, sensory perceptions and the thought process and thus is responsible for mind-body coordination. *Tejas* represents the digestion and transformation of sensory impressions, intelligence, thoughts, perception and awareness that results in a suitable action. *Ojas* represents robustness, strength and vitality and is responsible for the auto-immune system and mental resistance against stress. The lifespan and healthspan of an individual has a direct correlation with the person's status and integration of *prana*, *tejas* and *Ojas* [59,71,73].

Ahara (diet) is another important factor that influences aging/*Jara*. A poor or defective diet (*GramyaAhara*) together with disharmonious lifestyle triggers the vitiation of any or all three *Doshas*, leading to pathological changes and reduced lifespan [74–76]. Poor dietary practices include among others, improper timing of food intake, eating meals late at night, incorrect choices of food, consuming stale, processed or highly refined food, cold foods, eating in a noisy environment, and eating in a stressed mental state. An over-abundance of calories and the highly refined foods together with poor eating practices may lead to increased inflammation, reduced control of infection, increased rates of cancer, increased risk for allergic disease and reduced immunity (*Ojas*). These changes coupled with altered enthusiasm, insomnia, and lethargy can result in failure to live out the complete lifespan [74,75,77].

Achara (routines) refers to the physiological machinery that controls the circadian rhythm or the 24-h body clock and is another component that has an important role in the aging process. According to Ayurveda, the health of all living beings is governed by an internal clock that runs on a 24-h, light–dark cycle in conjunction with the sun and earth's movement. Ayurveda provides several guidelines about the operations of the body clock in terms of time and season-based routines called day routines (*dinacharya*), night routines (*ratricharya*) and seasonal routines (*ritucharya*) [63,76]. These guidelines include optimal times to arise and sleep, breathing routines, elimination, bath, massage, exercise, diet, study, travel, and other pursuits. Ayurveda recommends healthy and harmonious lifestyle routines to sustain and maintain the synchronicity of the circadian rhythm that results in good health, vitality and immunity, all of which delay biological aging [63,76]. Modern medicine recognizes these internal clocks as the circadian rhythms that are intimately tied to our health, well-being and the aging process. In humans, these biological clocks or circadian rhythms anticipate various activities throughout the day, from

waking up to sleeping and eating. In addition, these clocks regulate hormone levels, body temperature, and metabolism.

Jatharagni (digestive fire) not only regulates the digestion, absorption and assimilation of food but also has a profound influence on the lifespan and healthspan of an individual. *Jatharagni* is the root of all the digestive fires in the body [78,79]. *Jatharagni* serves as the central digestive fire and is the representation for all metabolic functions in the body. This includes the digestive function, cellular metabolism, sense perception, thought function and transformation of mental and emotional impressions [80–82]. If *Jatharagni* is too weak, the digestion of food is compromised resulting in malabsorption and accumulation of toxins (*ama*). If *Jatharagni* is too strong, it burns out the associated tissues resulting in tissue degeneration. Thus, the state of *Jatharagni* influences the aging process [80–82].

5. Ayurvedic recommendations for a successful healthspan

Unlike the modern medicine approach of seeking pills and supplements or replacing body parts to extend the healthspan of the individual, Ayurveda relies on a comprehensive program that includes dietary, lifestyle, behavioral and psychological intervention for extension of healthspan. The rationale for such a broad therapeutic intervention is to restore the normal balance and functioning of all the systems simultaneously at the level of the body, mind and emotions. The entire approach is a customized and individualized approach that covers the scope of all treatment procedures to enhance the healthspan of the individual and includes the following:

5.1. Diet and conscious eating

The philosophy of conscious eating (*Ahara Vihara*) is emphasized in the Ayurvedic texts. According to Ayurveda, our personality is determined by what, when, where and how we eat. Ayurveda insists that conscious eating favors optimal digestion that directly and swiftly corrects imbalances and, in doing so, prevents diseases, ends suffering and delays the aging process. Ayurveda recommends the importance of eating a wholesome, constitution-specific diet and being in tune with nature while eating, as it influences and impacts our digestion, metabolism and lifespan [83]. In realizing the close connection to nature through eating, the relationship with food becomes a sacred experience. The sun represents the fire element and in the physical body this is reflected as the process of transformation of the food by the heat of the digestive juices (*Jatharagni*) [84]. Thus, when the sun is at its peak, digestion is stronger and optimal. Ayurveda recommends eating the largest meal during the midday hours and smaller meals in the morning and evening to prevent the metabolism from going awry.

Nutritionists and other researchers are also realizing the importance of relationship between the timing of feeding, metabolism, weight regulation and aging [85,86]. In an interesting case study demonstrating a relationship between the timing of feeding and weight regulation, 420 individuals were grouped into early eaters (lunch before 1500 h) and late eaters (lunch after 1500 h) [87]. Late lunch eaters lost less weight and displayed a slower weight-loss rate during the 20 weeks of treatment suggesting that eating late may influence the success of weight-loss therapy [87]. While the strength of the study was its relatively large sample size and numerous biomarkers and genetic indicators, the work was mostly observational and requires further interventional studies to demonstrate the causality of this observation. Thus, time-bound meals may not only prevent weight gain and onset of other digestive related problems, but also enhances the healthspan of the individual [84,85,87].

In addition to the timing of food intake, the quality of food consumed and its impact on growth, metabolism and development of an individual, is also of considerable interest to health care professionals [88]. Furthermore, nutritionists are also closely looking at maternal diet and its impact on fetal growth and metabolism. While maternal undernutrition is a major factor contributing to adverse pregnancy, over indulgence of poor quality food during pregnancy is also a contributing factor for adverse metabolic outcomes in the offspring later in life [89–91]. Several research studies have now revealed a strong link between in utero nutrition and disease outcomes later in life termed as “maternal nutrition–offspring metabolic disease cycle”. According to these studies, prepregnancy maternal nutrition affects fetal metabolism and growth, child growth during the preschool years and increases risk for metabolic disease in adult life [89–91]. In a retrospective study involving 174 women, researchers concluded that women receiving poor diets had a greater incidence and recurrence of fetal neural tube defects than women eating a nourishing diet. In addition, dietary counselling was effective in reducing the incidence of fetal neural-tube defects [92]. One mechanism that links poor maternal diet to metabolic diseases is diet-induced differential regulation of microRNA. Researchers who sought out to understand why a poor maternal diet increases the risk of developing diabetes in the offspring, found that miR-483-3p was produced at higher levels in individuals who had experienced a poor diet in their mother's wombs than those who were better nourished [93]. High levels of miR-483-3p resulted in the suppression of a protein called GDF3. GDF3 is responsible for fat metabolism and low levels of GDF3 are associated with low birth weight and metabolic deficits [93]. Thus, poor quality foods and irregular eating habits are posing new challenges to which our bodies poorly adapt resulting in unforeseen health problems, confirming the importance of proper diet and nutrition at all stages of life to ensure a disease-free lifespan.

5.2. Sleep

Sleep (*Nidra*) is one of the main pillars of good health in Ayurveda, and is as important as diet in sustaining a quality healthspan [94–96]. Sleep can be influenced by age, lifestyle, daily routines, diet and environment [94–96]. Ayurveda cautions that poor sleep patterns can be debilitating as it triggers age-associated pathological conditions that can hasten the aging process. Research studies indicate that insufficient sleep can disrupt circadian rhythms that results in negative health outcomes, including obesity, cardiovascular disease, and cognitive impairment [97,98]. In a study involving 26 participants, researchers exposed the subjects to 1 week of insufficient sleep (sleep-restriction) followed by 1 week of sufficient sleep [99]. Following each condition, whole-blood RNA samples were collected from each participant for transcriptome analysis. The analysis revealed that 711 genes were differentially regulated by insufficient sleep. Genes affected by insufficient sleep were predominantly associated with circadian rhythms, sleep homeostasis, chromatin modification, inflammation, immune and stress responses, oxidative stress and metabolism [99].

Poor sleep quality not only disrupts the circadian rhythms but also triggers metabolic diseases including diabetes, obesity, and cardiovascular disease. In a large, well-conducted meta-analysis study, researchers systematically combined the results of cohort studies that investigated an association between sleep duration, incidence of type 2 diabetes and death from any cause [100,101]. Most of the participants were over 60 when they participated in the study, and the different studies varied in length between four and 25 years. The major conclusion from this study was that poor sleep quality predicted the risk of development of type 2 diabetes. In addition, sleeping less than 6 h a night was associated with an

increased risk of early death [100,101]. These studies not only highlight the close connection between sleep, circadian rhythm and metabolism but confirm the Ayurvedic concept of sleep being a pillar of life that endows the body with strength, complexion and healthy growth that continues throughout life. The research findings are in agreement with Ayurvedic's emphasis on good quality sleep as a staple of optimal health and longevity.

5.3. Regular routines

For health and optimum healthspan, Ayurveda recommends a set of daily routines (morning, noon and night) of self-care. These guidelines include time of waking and sleeping, elimination, hygiene, massage, mindfulness practices, diet, work, and travel all during the course of the day and night. The routine calls for optimal times to awake, sleep, oral care, care of eyes, nose, ears and skin. Routines also include cleansing procedures, bowel habits, yoga, breath practices and massage. These daily observances were encouraged in order to maintain the synchronicity of circadian rhythms with time of the day, night and seasons (*dinacharya*, *ratricharya* & *ritucharya* respectively) and to help ward off all acute or chronic conditions that have a deleterious influence on the aging process [61–63,76,96,102]. These Ayurvedic concepts of daily routines have had major implications for health research and helped establish a growing field of science called chronobiology. Scientists are only now beginning to understand the importance of routines, biological clocks and circadian rhythms and their role in aging, well-being and morbidity. Researchers studying chronobiology have noticed that increased longevity and improved health can be achieved by time-bound routines. Furthermore, disturbances in the circadian rhythm can trigger fatigue, disorientation, insomnia and increased susceptibility to cancer [103,104]. Similarly, frequent long distance travels, shift work, jet lag, eating late in the night or sleep disorders destabilize the close coordination between the biological clock, circadian rhythms and the environment that has a serious impact on overall health and lifespan [103–105].

5.4. Panchakarma

Periodical detoxification, purification, and rejuvenation therapies classified as panchakarma therapies in Ayurveda, are highly recommended as they provide the strength and nourishment to the deeper tissues (*Dhatu*s) and pacifies age-associated health issues. Oleation and fomentation therapies are important as they neutralize the *Vata*-triggered coldness and dryness that accompany aging. Panchakarma therapies ensure rapid blood circulation, continuous cerebral blood flow and efflux of toxic matter through increased lymphatic drainage [106,107].

A recent study on the cellular effects of panchakarma revealed changes in several metabolites across many pathways [108]. The study involved 65 healthy male and female subjects who participated in a 6-day panchakarma-based Ayurvedic intervention that also included herbs, vegetarian diet, meditation, yoga, and massage [108]. Significant reductions in 12 phosphatidylcholines and other metabolites including amino acids, biogenic amines, acyl-carnitines, glycerophospholipids and sphingolipids were observed in the panchakarma group compared to the control group. The significant alterations in plasma metabolites are consistent with metabolic changes in the gut microbiota and host metabolism that promote general health and well-being [108]. Similar studies with a larger sample size, longer follow-up period and suitable outcome measures are warranted to confirm the broad ranging effects of panchakarma therapies in delaying the aging process.

5.5. Abhyanga

Regular oil massage (*Abhyanga*) with warm oil that is often infused with the individual's constitution-specific herbs is beneficial for maintaining good health and to delay age-associated pathological changes. *Abhyanga* can be incorporated as a daily routine as it restores the balance of the *Doshas* and enhances well-being and longevity [96,106,109,110]. *Abhyanga* is also recommended for CNS conditions including brain-related injuries, dementia and mental stress. Significant brain functional activation changes together with increased cerebral blood flow were observed in participants who received oil massage. Massage reduced the levels of stress-related hormones with a concomitant increase in circulating lymphocytes and regional cerebral blood flow [107,111]. Researchers are of the opinion that application of medicated oil followed by a gentle massage could relax the tight junctions between endothelial cells in the CNS vessels and facilitate the entry of solutes and other components into the CNS. In another pilot study involving 20 healthy subjects (10 male and 10 female) that underwent a 1-h *Abhyanga*, subjects showed clinically significant reduction in subjective stress experience. Furthermore, a significant reduction in heart rate in all subjects and lowered blood pressure in prehypertensive subjects were also observed [112]. Further studies with a large sample size involving normal adults and adults with age-associated pathologies are needed to confirm the impact of oil massage in delaying the aging process and reversing age-associated pathological changes.

5.6. Mindfulness practices

A daily practice of yoga, meditation and pranayama (breath practices) helps to delay the aging process. The results from a meta-analysis study clearly show that the above mentioned yogic practices enhance muscular strength and body flexibility, improve respiratory and cardiovascular function, promote recovery from addiction, reduce stress, anxiety, depression, and chronic pain, improve sleep patterns, and enhance overall well-being and quality of life [113,114]. These combined practices facilitate the transport of oxygenated blood to various organs and body tissues, eliminates waste, and improves proper coordination of the body, mind and emotions. These practices sustain equanimity of the physical, mental and emotional body, thereby fostering a longer health span [63,96].

5.7. Sadvritta

Sadvritta could be defined as moral reasoning, code of ethics or good conduct and is required to guide daily living and maintain a balanced state of mental and physical life. It includes guiding principles of proper conduct that helps to reflect on the importance of an individual's life extending beyond the single individual. Sadvritta allows the individual to examine one's values, interpersonal and social behavior. Cultivating these ethical regimens help to strengthen mental health and sustain the balance between an individual's mind and body [115–117]. Selfless service/action that is rendered without any personal expectation for the service provided is one of those ethical regimens. Selfless service requires for an individual to perform any service without any expectation, and also remain unaffected by the results of such service [116,117]. The individual also needs to cultivate a loving attitude towards the selfless task irrespective of the outcome.

In a longitudinal ~50 year study involving high school graduates, researchers caught up with over 3000 individuals and found that those individuals who had performed selfless service regularly lived longer compared to those who did not render any selfless service

[118]. Additionally, participants who volunteered only for compassionate reasons achieved the most health benefits compared to those who performed the service purely for personal gain or self-growth. The researchers concluded that while selfless service provided a longer health span and reduced mortality rates, those same benefits were lost if the main motive for performing selfless service was for personal gain or self-growth [118]. The findings of the research study confirm the Ayurvedic concept of Sadvritta and suggest that ethical regimens and good conduct stabilize body-mind function, help to ward off mental disorders, and helps to overcome life's challenges that accompany the aging process.

6. Conclusion

While there are various steps to manage the aging process, the modern medicine approach is different from the Ayurvedic approach. While neither approach is superior or inferior, the paramount difference lies in how both these sciences address the aging process. A subset of researchers consider aging itself to be a disease because, 1) aging is associated with an accumulation of cellular and molecular changes that impair normal physiology, 2) impairment of normal physiological functioning of cells, tissue, organs and bodily systems, in turn triggers age-associated diseases, and 3) aging itself is a risk factor for other diseases [11,12]. Anti-aging approaches would therefore require an ideal disease-free physiological state at a certain age and a “to-do” list of drug interventions to keep the individual as close to that ideal state as possible. If aging is viewed as a disease as some researchers do, than the most logical approach would be to overcome the aging process with drugs like metformin, resveratrol, masoprocol, rapamycin and others. However, a drug approach de-emphasizes the enormous potential of disease prevention through lifestyle changes as the entire aging process is viewed in mechanistic and reductionistic terms that involve manipulating a specific pathway or molecules with powerful drugs [119,120]. In contrast, a systems approach is designed to address multiple pathogenic mechanisms and optimizing the therapeutics for each of those targets [119,120]. The past few decades of genetic and biochemical research have revealed an extensive network of molecular interactions involved in the aging process, suggesting that a systems approach or a network-based therapeutics approach, rather than a single target-based approach, may be feasible and potentially more effective for delaying or reversing the aging process.

Ayurveda considers aging as a natural and inevitable process and offers time-tested therapies for healthy aging. Ayurveda professes the principles of harmonious living and being in tune with nature, universal consciousness, environment, and individual constitution. Healthy aging would therefore require for the individual to bring in harmonious impressions, incorporate healthy lifestyle practices and routines that promote good health and well-being, and encourage healthy transformation of the body and mind through harmonious choices and actions. Unfortunately, lack of systematic safety and efficacy studies or proof-of-concept trials have relegated these Ayurvedic concepts of aging to a conceptual model. Thus, it is imperative that these concepts are revisited and re-examined to generate best research evidence that support these underlying principles, addresses causality, and minimizes bias and chance effects [121–123]. An important application of the Ayurvedic program described above is that a multi-component lifestyle system may serve as a platform on which these anti-aging drugs targeted to the patient's risk factors and that is likely to fail as a monotherapeutic, may succeed as key components of a “whole” therapeutic system. Thus, a combinatorial approach incorporating the best of modern medicine and Ayurvedic principles will ensure adding life to years and years to life.

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Conflict of interest

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