Review Article

Implication of Asana, Pranayama and Meditation on Telomere Stability

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Abstract

Telomeres, the repetitive sequences that protect the ends of chromosomes, help to maintain genomic integrity and are of key importance to human health. Telomeres progressively shorten throughout life and a number of studies have shown shorter telomere length to be associated with lifestyle disorders. Previous studies also indicate that yoga and lifestyle-based intervention have significant role on oxidative DNA damage and cellular aging. However, very few publications investigate telomere stability and its implication from the point of view of asana, pranayama, and meditation. In this context, a review was conducted to systematically assess the available data on the effectiveness of asana, pranayama, and meditation in maintaining telomere and telomerase. Literature search was performed using the following electronic databases: Cochrane Library, NCBI, PubMed, Google Scholar, EMBASE, and Web of Science. We explored the possible mechanisms of how asana, pranayama, and meditation might be affecting telomere length and telomerase. Moreover, results showed that asana and pranayama increase the oxygen flow to the cells and meditation reduces the stress level by modulating the hypothalamic–pituitary–adrenal axis. Summing up the result, it can be concluded that practice of asana, pranayama, and meditation can help to maintain genomic integrity and are of key importance to human health and lifestyle disorders.

Keywords: *Asana, lifestyle diseases, meditation, pranayama, telomere maintenance*

Introduction

Over the past several years, it has become increasingly clear that alterations in telomere integrity can directly impact human health. At the molecular level, telomeres are long sequences of noncoding, six-nucleotide-long tandem repeat of "TTAGGG" DNA bases that are located at the terminal ends of all vertebrate chromosomes, including those of humans.[1] Telomeres have been compared with the plastic tips on shoelaces, since they can keep chromosomal ends from fraying and fusing to each other, which would destroy or interfere genetic information. There is loss of telomere repeats with successive cell divisions, and telomere length in a somatic cell may thus reflect the replicative history of that cellular lineage. When the telomere length becomes critically short, it can no longer protect the cell's DNA, leaving the cell at risk for serious damage. Telomere length is maintained by telomerase or an alternative lengthening of telomere mechanism[2] by cells. However, these maintenance mechanisms are active/expressed only by embryonic cells, stem cells, or cancer cells. Normal somatic human cells repress their expression immediately after birth.[3,4] Meanwhile, critical telomere shortening leads to telomere and chromosomal instability which promotes genomic rearrangements that impinge upon disease-relevant pathways.[5] Excessive telomere elongation, too, promotes the formation of partially single-stranded telomeric DNA circles which too can compromise the chromosomal stability. Thus, a fine balance between various telomere length control pathways dictates telomere stability.[6]

Under physiological conditions, such unstable telomere has been associated with diseases linked with aging and stress exposure, including diabetes mellitus, obesity, heart disease, chronic obstructive pulmonary disease, asthma, cancer, as well as psychiatric illnesses, such as depression, anxiety, posttraumatic stress disorder, bipolar disorder, and schizophrenia.[7-12] Smoking, exposure to pollution, lower physical activity, psychological stress, and unhealthy diet significantly increase the oxidative burden and the rate of telomere

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shortening.[13] However, recent studies also indicate that better lifestyle choices which reduce oxidative stress might affect telomerase activity and prevent excessive shortening of telomere length, leading to delayed onset of age-associated diseases and increased lifespan. A number of interventions have been studied to determine their influences on telomere stability as indices for promoting health and longevity. Among them, yoga seems to provide comprehensive benefits by delaying or reversing accelerated pathological manifestations of diseases. Yoga is an ancient mind–body practice which includes meditation, breathing practices, asanas, philosophy, cleansing practices, and deep relaxation. There are many different yoga styles, including Iyengar, Svaroopa, Viniyoga, Kripalu, Kundalini, and Himalayan. Yoga is derived from Sanskrit root "yuj" meaning "to control" or "to unite." Many asanas in yoga aim at reducing toxic buildup of reactive oxygen species (ROS) and consequent damages from oxidative stress.[14] It is believed that regular practice of yoga brings about a decrease in stress levels and improved antioxidant status[15] by establishing natural harmony and functional balance between various organ systems, leading to better health and a feeling of well-being. Yoga has traditionally been viewed as a relatively safe form of exercise that can be practiced by people of varying health status and is therefore emerging fast as an effective alternative and complementary medicine discipline.[16]

In spite of the positive effects of yoga which have been demonstrated through disease-specific outcomes, basic understanding of the mechanism in terms of modern sciences is not very clear. However, there is evolving evidence that regular practice of asana, pranayama, and meditation stabilizes telomeres. Thus, the purpose of this review is to investigate the efficacy of yogic interventions on telomere length maintenance and its implications on health and disease.

Methods

The literature search was performed using the following electronic database: Cochrane Library, PubMed, Google Scholar, EMBASE, and Web of Science. The search terms used contained: "telomere length" AND "yoga." The articles which met the following criteria were included in the current review: (i) Studies that were published in English, (ii) articles had to be peer reviewed, and (iii) clinical trials that used asanas, meditation, or pranayama as an intervention and telomere length and/or telomerase activity, as end points, were selected and analyzed. These searches resulted in a record of 660 peer-reviewed articles which we screened. This screening identified 12 studies that met the inclusion criterion of employing a randomized controlled trial to assess the effects of asana, pranayama, and meditation on telomere length and telomerase activity.

Impact on telomere length

Telomere length is an important biological variable that can influence a variety of disease-related complex traits as well as host–environment interactions such as drug and nutritional responses.[17] Although reduction in oxidative stress has been shown to improve telomere length of patients with various pathologies including depression, obesity, hypertension, asthma, type II diabetes, and cancer, only few studies were found which studied the impact of asana, pranayama, and/or meditation on telomere length in various pathologies. Most studies measure telomere length in peripheral blood mononuclear cells (PBMCs) by quantitative polymerase chain reaction. In this method, the average telomere length is estimated by comparing the amount of amplification product of telomere repeats (T) to that of a single-copy gene (S). Although the method yields only a relative measure and not base pair estimate of telomere length, it is most frequently used by investigators due to its high throughput.[18]

Ornish *et al*.[19] conducted a pilot study involving 35 individuals with localized prostate cancer to explore the relationship between comprehensive lifestyle changes and telomere length. The participants were divided into two groups – the intervention group had to follow comprehensive lifestyle changes compared to the control group. Men in both groups underwent active surveillance for 5 years. The intervention group with ten patients embarked on lifestyle changes which involved gentle yoga-based stretching, breathing, and meditation. However, data on specific type of asana performed or exact yoga schedule of the individuals are not included in the article. At the end of the study period, relative telomere length in PBMC of the patients increased approximately 10% from baseline by a median of 0.06 telomere to single-copy gene ratio (T/S) units in the lifestyle intervention group, but in the control group, telomere length was nearly 3% shorter, difference $P = 0.03$).

Studies by several groups including that of Banerjee *et al*. have shown an association of radiation-induced telomere damage in breast cancer patients.[20] In a subsequent study, Banerjee *et al*. found that postradiotherapy DNA damage in the form of telomere shortening in the yoga group was slightly less compared to control groups after radiotherapy. The study was done on 68 participants randomized to yoga and supportive therapy for 6 weeks. The intervention included pranayama for 90-min duration followed by Yoga Nidra.[21] This is also similar to the findings of Carlson *et al*.,[22] who found that an 8-week mindfulness-based stress reduction program maintained the telomere length in the intervention group, whereas it was found to decrease for control participants.

However, Lengacher *et al*.[23] did not observe any difference in the telomere length ($P = 0.92$) in a cohort of breast cancer patients who participated in a 6-week mindfulness-based

stress reduction program though a steady increase in telomerase activity was found. Participants attended 6 weekly 2-h sessions in which a trained psychologist led them in (a) sitting meditation (an awareness of bodily sensations, thoughts, and emotions while focusing on attention to breathing); (b) body scan (observing any sensations in the body from the head to the toes while focusing on attention to breathing); (c) gentle Hatha; and (d) walking meditation (increases awareness during walking).

Krishna *et al*.[24] analyzed the leukocyte telomere biology and its relation with homocysteine, malondialdehyde (MDA), and oxidative stress in yoga practitioners. Their prospective case–control study included 15 yoga practitioners aged 30–40 years with minimum of 2 years' yoga practice (yoga group) and matched sedentary healthy general population with no medical problems (control group, n = 18). Individuals with chronic hypertension, known cardiovascular disease, and any other systemic diseases were excluded from the study. Yoga group practiced asana, pranayama, and meditation. Leukocyte telomere length was shorter in control group than in yoga group ($P < 0.001$). The authors also found higher oxidative stress biomarkers, MDA, and homocysteine, in control group compared to yoga group ($P < 0.001$). This suggests that in people who practice yoga regularly, systemic oxidative stress is lower and leukocyte telomere length is well preserved compared to those who have a relatively sedentary lifestyle despite lack of any medical disorders. Again in this publication, data on specific type of asana performed or exact yoga schedule of the individuals were not included. In general, asanas, pranayama, and meditation activate the DNA damage response pathway to repair genomic damage and improve genomic stability.[25] Further, it maintains the telomere length through regulation of telomere metabolism which contributes to genomic stability and reduction in telomere attrition.[22]

The studies led by Tolahunase *et al*.[26,27] analyzed the impact of yoga and meditation-based lifestyle intervention on cellular aging and longevity of apparently healthy individuals. End point markers were telomere length in PBMC, DNA damage marker-8-hydroxy-2′-deoxyg uanosine (8-oxoG), oxidative stress marker-ROS, and total antioxidant capacity. This prospective, open-label, single-arm exploratory study enrolled apparently healthy individuals to receive yoga and meditation-based lifestyle intervention for a 12-week period. The key inclusion criteria were male or female aged 30–65 years and leading unhealthy modern lifestyle. The key exclusion criteria were inability to perform the yogic exercises due to any physical challenges. The program included sessions 5 days per week for 12 weeks. Each session included a set of a sanas, pranayama, and meditation for approximately 90 min. The asanas included loosening practices (warm up) for 5 min followed by Shavasana, Uttanpadasana, Pawanmuktasana, Prone Makarasana, Bhujangasana, Salabhasana, sitting Vakrasana, Ardha-Matsyendrasana, Vajrasana, standing Tadasana, Vrikshasana, and Ardhachakrasana for 2 min each. The asanas were followed by relaxation by performing Shavasana for 5 min. This was followed by pranayama or breathing exercises which included Nadishodhana, Bhramri, Shitkari, Shitali, and Brahmamudra which lasted for about 20 min. There was significant improvement in the biomarker levels assayed by the authors in comparison to the values at baseline. The mean levels of 8-oxoG and ROS were significantly lower ($P < 0.01$ and $P < 0.0001$, respectively). The authors did find an increase in the mean level of telomere length, but the finding was found to be insignificant ($P = 0.069$).

Dada *et al*. also studied the role of yoga and meditation in decreasing seminal oxidative stress and oxidative DNA damage.[28] They hypothesized that oxidative DNA damage of sperm is a possible etiological factor in childhood cancer. Therefore, decreasing the DNA damage in sperm by yoga and meditation could decrease the incidence of childhood cancers. A total of 131 fathers of children with retinoblastoma (nonfamilial sporadic heritable) and 50 controls (fathers of healthy children) were recruited from a tertiary center in India. Sperm parameters as per the WHO 2010 guidelines and ROS, DNA fragmentation index, 8-oxoG, and telomere length were estimated at day 0 and after 3 and 6 months of intervention. The intervention lasted for 2 h each day for 6 months, comprising theory and practice of yoga. Mean relative sperm telomere length of fathers of children with retinoblastoma was shorter as compared to that of controls (0.35 ± 0.021 vs. 0.38 ± 0.027; $P > 0.01$) though the difference was not significant. Similarly, the seminal mean ROS levels ($P < 0.05$), sperm DNA fragmentation index ($P < 0.001$), and 8-oxoG ($P < 0.01$) levels were significantly higher in fathers of children with retinoblastoma, as compared to controls. After yoga intervention, favorable changes were observed within 3 months. After 6 months of intervention, the levels of ROS, DNA fragmentation levels, and 8-oxoG were significantly reduced ($P < 0.05$).

Hoge *et al*.[29] examined the relative telomere length in a group of individuals experienced in loving-kindness meditation (LKM), a practice derived from the Buddhist tradition which utilizes a focus on unselfish kindness and warmth toward all people and control participants who had done no meditation. Among women, the LKM practitioners had significantly longer relative telomere length than controls ($P = 0.007$), which remained significant even after controlling for body mass index and past depression.

Thimmapuram *et al*.[30] administered 12-week "Heartfulness Meditation" program on burnout, emotional wellness residents, faculty members, and nurses at a large community teaching hospital. The intervention involved heartfulness meditation practice wherein the participants

were asked to simply tune in to their hearts and be open to any experience that they may have. Upon experiencing wandering of mind, the participants were advised to gently redirect toward the heart. This was recommended in the morning for 20 min and at night for 5 min before going to sleep. Participants also used the same technique at least once per week in group meditation led by a heartfulness trainer for 30 min. In the evening, practice lasting 15 min, participants were asked to imagine that stress and heaviness ("impurities and complexities") were leaving the body through the back in the form of smoke or vapor. These impurities and complexities were to be replaced by a flow of purity, lightness, and freshness. Participants were asked to not dwell on those things they were expunging, but to simply brush them off. In the subset of individuals aged 24–33 years, there was a statistically significant increase in telomere length in meditators ($P = 0.036$, $n = 17$). This result was not seen in age-matched controls ($P = 0.539$, $n = 9$).

Impact on telomerase

Telomerase is a RNA-containing enzyme that synthesizes telomeric DNA onto the ends of chromosomes, thereby maintaining the integrity of the genome in embryonic stem cells and in proliferating progenitor cells derived from quiescent normal stem cells. Over the long term, high telomerase likely promotes improvement in telomere maintenance, and telomerase activity is an indicator of telomere maintenance capacity contributing to genomic stability. In normal tissue cells, telomerase is carefully regulated so that it is not continuously expressed, whereas cancer cells almost universally and constitutively express telomerase.[31] The levels of telomerase in the articles discussed here were checked in PBMC.

The study led by Tolahunase *et al*.[26] which evaluated the impact of cellular aging in apparently healthy individuals found telomerase activity to be significantly increased ($P < 0.05$) in the yoga intervention group. The intervention included a set of a sanas, pranayama, and meditation for approximately 90 min for 12 weeks. The group also found similar results in another study involving a 31-year-old man with class I obesity (body mass index, 29.5 kg/m^2). The patient was asked to perform a series of asanas, pranayama, and meditation for approximately 1 h for 3 months. After the interventional period, the activity of telomerase increased, and a sustained reduction in oxidative stress markers, such as ROS and 8-oxoG, as compared to baseline levels was seen.[32]

Similarly, in the study led by Ornish *et al*.,[19] there was a slight increase in telomerase activity (expressed as natural logarithms increased from 2.00 [standard deviation (SD): 0.44] to 2.22 [SD: 0.49; $P = 0.031$]) from baseline within a 1 month of comprehensive interventional program. However, at 5 years, telomerase activity had decreased from baseline by 0.25 (−2.25 to 2.23) units in the lifestyle intervention group and by 1.08 (−3.25 to 1.86) units in the control group ($P = 0.64$). However, Lengacher *et al*. observed a steady increase in telomerase activity in a cohort of breast cancer patients over 6 weeks of mindfulness-based stress reduction program and 12 weeks after the completion of the program wherein the participants were requested to formally meditate for a minimum of 15–45 min per day and allocate 15–45 min per day for informal practice (deliberate awareness of and attention to being mindful of routine activities and events such as eating, weather, driving, walking, and interpersonal communications).[23] Epel *et al*., too, observed a significant increase in telomerase activity in the regular meditation group within 5 days of enrollment. The study was a prospective cohort trial comparing the effect of meditation to being in a relaxed, vacation-like environment for a week.[33] This indicates that in yoga and meditation interventional groups, the regulatory mechanisms involved in the maintenance of telomerase activity are better modulated.

In another study by Lavretsky *et al*.,[34] 39 dementia caregivers with mild depressive symptoms were enrolled in a randomized pilot study to examine the effects of brief daily yogic meditation on mental health, cognitive functioning, and telomerase activity. The participants were asked to perform Kundalini yoga and Kirtan Kriya meditation and compared to passive relaxation with listening to instrumental music for 12 min per day for 8 weeks. Kundalini yoga focuses on breath and movement of body, working predominantly on the pituitary glands and nervous system.[35] At the end of the study period, the meditation group showed 43.3% improvement in telomerase activity compared to 3.7% improvement in the relaxation group. The interventional group also showed lower levels of depressive symptoms and greater improvement in mental health and cognitive functioning compared to the relaxation group. Similar results were found in a randomized mindfulness-based intervention of 47 overweight/obese women by Daubenmier *et al*. which reported an 18% increase in telomerase activity compared to controls.[36] Participants enrolled in another 3-week mind–body intervention study also showed a two-fold increase in telomerase activity after a mind–body intervention in 108 participants enrolled in a study.

Possible Mechanisms of Asana, Pranayama, and Meditation on Telomere Length and Telomerase

Advanced age is a known risk factor for a number of chronic diseases. However, as opposed solely to chronological age, "biological" age, which is determined both by physiology and chronology, appears to be a key factor related to the development of ultimate pathology and this, in turn, has been related to a cumulative burden of oxidative stress.[37] Telomeres have been postulated as a universal biological clock that shortens in parallel with aging in cells.[38] Telomere length shortening mainly

occurs during cell division due to the inability of the DNA replication machinery, specifically DNA polymerase, to synthesize in a 3′-5′ direction leading to the incomplete replication of the lagging strand.[39] The rate of telomeric erosion over time is determined partially by genetic factors and partially by environmental factors.[40]

The rate of telomere length shortening can be accelerated significantly by oxidative stress that promotes the gradual or sudden loss of sufficient processes required to maintain proper telomere length.[41-43] ROS produced during oxidative stress can produce modified DNA bases (mainly 8-oxoG) and single-strand DNA breaks anywhere in the genome. The presence of 8-oxoG inhibits telomerase activity and decreases the binding of telomeric proteins to the telomere sequence, leading to the disruption of telomere length, maintenance, and function.[44] 8-oxoG can base pair with adenine as frequently as with cytosine and during DNA replication, GC to TA transversions lead to mutations that have been associated with pathological states such as cancer and aging.[45] Human 8-oxodG-DNA glycosylase, the primary enzyme responsible for the excision of 8-oxoG, introduces a chain break in a double-stranded oligonucleotide specifically at an 8-hydroxyguanine residue base paired with cytosine.[46] Various studies have shown that repair of all DNA double-strand breaks is highly error prone.[47] There is also evidence that telomeric DNA is deficient in the repair of single-strand breaks, in contrast to the majority of genomic DNA.[48] Hence, when the 8-oxoG lesion is not repaired correctly, it induces single- or double-strand breaks and GC-TA mutation, which may lead to genomic instability.[49] Since there is high concentration of "G" nucleotides in telomere repeats, telomeric DNA sequences are a preferred target for oxidative damage which along with low or negligible telomerase activity in normal cells can accelerate telomere length shortening.

Central to asanas and pranayama is diaphragmatic breathing which is the act of breathing deeply into the lungs by flexing the diaphragm rather than the rib cage.[50] The basic mode of respiration used in yoga practice is slow, smooth breathing using the diaphragm rather than respiratory muscle of chest. The literature on the mechanism of diaphragmatic breathing exercises is scarce but probably involves either reduced generation of ROS or increased stimulation of enzymes for rapid breakdown of ROS or both. In studies involving yeast, increased oxygen consumption was shown to decrease the production and release of ROS.[51] Asanas involving diaphragmatic breathing can increase alveolar gas exchange and ventilatory distribution and improve submaximal and maximal oxygen consumption.[52] Hence, pranayama can alter the perceptions and mental responses to both external and internal stimuli, slow down reactivity, and reduce ROS production. The superoxide anion O_2^- is the main ROS produced in cells. The enzyme superoxide dismutase (SOD) converts this superoxide to hydrogen peroxide, which is then removed by glutathione (GSH) peroxidase or catalase, thus preventing the accumulation of ROS. Bhattacharya *et al*. conducted a study to assess the effect of yogic breathing exercises (Vipassana) on ROS levels. The free radicals and SOD levels were measured before the study and at the end of the study. The levels of SOD increased and that of free radicals decreased in the study group as compared to the control group.[15] Similarly, Martarelli *et al*. also observed an increase in antioxidant levels in intervention group performing 40 min of diaphragmatic breathing.[50] Jatuporn *et al*. observed a statistically significant increase in plasma total antioxidants, plasma Vitamin E, and erythrocyte GSH in patients with coronary artery disease who were undergoing yoga exercise intervention.[53]

ROS is produced through a variety of mechanisms including enzymatic reactions and/or auto-oxidation of several compounds, such as catecholamines and hydroquinone. Different exogenous stimuli, such as the ionizing radiation, ultraviolet rays, tobacco smoke, pathogenic infections, environmental toxins, and exposure to herbicide/insecticides, are also sources of *in vivo* ROS production.[54] Lipids are a primary target for oxidation by ROS. Among the many different primary products of lipid peroxidation is MDA which has been widely used for many years as a convenient biomarker for lipid peroxidation of omega-3 and omega-6 fatty acids.[55] There is also increasing evidence that telomere length negatively correlates with MDA levels in yoga group. Ingole *et al*.[56] studied the effect of Vipassana intervention on serum MDA levels and observed that before and after Vipassana practice, the mean serum MDA levels in the participants reduced from 3.1 ± 0.67 to 2.51 ± 0.55. Mahagita observed that long-term transcendental and Zen meditation reduced lipid peroxidation and biophoton emission.[57] Similarly, levels of catecholamines are decreased after meditation.[58] Thus, there is reduced availability of substrates which undergo auto-oxidation to produce ROS, with regular practice of yoga. This in turn is manifested as reduced lipid peroxidation, reduced cellular injury, and slow shortening process of telomere length.[24]

Since asanas involve slow and steady muscle stretch, it allows for effortless, easy, and comfortable maintenance of the posture, allowing various muscle and joints to stretch smoothly without any resistance. This static but passive stretching of the muscles and ligament affords sufficient time to stimulate the circulation around various tissues and organs. This also causes effective and easy removal of waste products of the metabolism from the body.[59] Hence, a sanas itself reduce oxidative stress and prevent toxic buildup of metabolites in the body, which ultimately reduces molecular damage to cells.

Discussion

Results of the present systemic review indicate a positive association between markers of cellular aging and disease with intervention programs involving yoga and meditation.

Determining the causal underlying cellular and molecular processes that deteriorate with age and lead to increased disease susceptibility and frailty is critical in order to meet the growing health-care needs of human populations. Estimation of biomarkers that predict biological aging rather than chronological age has been considered a better marker for functional impairments, chronic diseases, and mortality. Moreover, recent molecular studies suggest the use of telomere length and telomerase as a marker of cellular and biological aging.[60] A delicate balance is sustained by normal cells in preserving telomere length and telomerase. Any imbalance in this regulatory mechanism causes telomere length shortening which has been implicated as a causative factor for accelerated age-related diseases. Yoga is an ancient workout form that has been implicated in improving cellular longevity. However, not much is known about the regulatory pathways for telomere length maintenance that are modulated by regular practice of yoga.

The results of this review highlight the positive effects of yoga intervention on telomere length. The study suggests that the impact is mediated through upregulation of enzymes that degrades ROS and thereby prevents the accumulation of ROS in cells. ROS is produced as a normal product of cellular metabolism. In addition, there is an increased production of ROS related with adoption of modern lifestyle practices due to unmanaged chronic stress. Yoga practices help in the management of stress and stress-induced disorders through downregulation of the hypothalamic-pituitary-adrenal (HPA) axis response to stress and regulation of the sympathetic nervous system.[61] This in turn reduces the oxidation of guanine bases of DNA. Since telomeric sequence is particularly rich in guanine bases, it is more susceptible to oxidative damage. Besides, DNA repair is inefficient at telomeric ends. Together, this results in accelerated shortening of telomere length which is manifested as aging-related chronic diseases.

A major limitation of this review is that only few clinical trials have been found in the literature. Even the sample size of the study is low. The study by Dada's group is the only one detailing the yoga protocol that the intervention group followed. Although the results from the study are encouraging, the results are not comparable due to lack of control group. In spite, interventional programs incorporating yoga and meditations seem to have a buffering effect on lifestyle-induced oxidative stress, oxidative DNA damage, and biological aging.

Implications in health and disease

Oxidative stress refers to a serious imbalance between oxidant production and antioxidant defense, for which the generation of oxidizing substance is beyond the detoxifying capacity of cells resulting in damage of target molecules such as DNA, protein, and lipid structure, and it is involved in the pathogenesis of many diseases, for example, cancer, cardiovascular disease, diabetes mellitus, Alzheimer's disease, and Parkinson's disease.[62,63] Unmanaged chronic stress speeds up the aging process through telomere length shortening, which itself is a risk factor for cancer and other age-related chronic diseases.[64] The underlying mechanisms for such effects are complex and involve chronic activation of the sympathetic nervous system and HPA axis. Sustained elevation of hormones released from these pathways can result in diverse effects, including stimulation of inflammation and immune system.[65] These underlying signaling pathways offer opportunities for designing new therapeutic approaches for disrupting the effects of stress

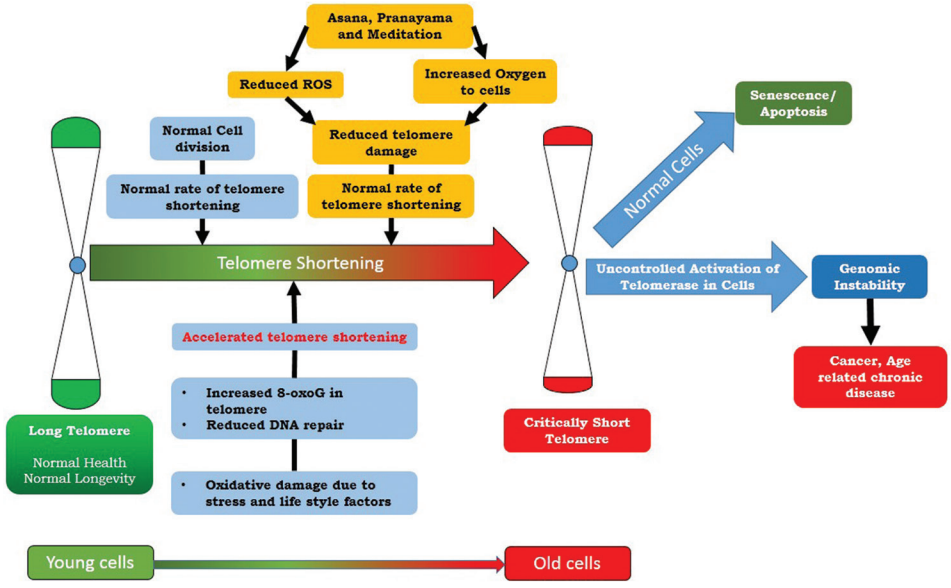

Figure 1: Mechanism for protection of telomere length through yoga

biology on disease biology and include bio-behavioral and pharmacological approaches. Yoga is one such approach.

Conclusion

Rapid telomere length shortening may indicate a very high cellular activity. In addition to cell division, factors causing telomere length shortening include DNA damage, inflammation, and oxidative stress. Telomere length is maintained by telomerase enzyme. However, telomerase activity is undetectable in normal cells and its activation upon detection of critically short telomeres helps cells to escape from senescence. Thus, critically short telomeres contribute to genomic instability and are associated with lifestyle diseases. Moreover, the results of this review highlight the positive effects of yoga intervention on telomere length – a major biomarker of cellular aging in maintaining genomic integrity and promoting cellular longevity [Figure 1]. However, these findings are limited to a small number of trials and relatively small sample sizes. More rigorous randomized controlled trials of healthy controls and specific disease states are needed.

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Conflicts of interest

There are no conflicts of interest.

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