The effects of meditation on length of telomeres in healthy individuals: A systematic review

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Research

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Abstract

Background: Meditation based practices have been suggested to result in many biological benefits which include reduction of attrition of telomeres, the protective nucleotide-protein complexes at termini of eukaryotic chromosomes. This systematic review evaluated the effects of meditation on telomere length (TL) in healthy adults.

Methods: Randomized controlled trials (RCTs) and Case-control studies (CCS) conducted to determine the effects of meditation on TL in healthy individuals, published up to July 2020 were retrieved by searching seven electronic databases (PubMed, Scopus, PsycINFO, Embase, Cochrane Library, CINAHL and Google Scholar). The methodological quality of RCTs and CCS was assessed using the Cochrane Collaboration Risk of Bias Tool and Joanna Briggs Institute critical appraisal checklist respectively. The data was synthesized narratively and the effect estimates of telomere length in the RCTs was synthesized using alternative methods as a meta-analysis was not conducted. The certainty of evidence was classified according to the GRADE system.

Results: A total of 1751 articles were screened. Five studies comprising two RCTs and three CCS were included in the final review based on the inclusion and exclusion criteria. The combined sample consisted of 615 participants with 41.7% males. Average age of participants was 47.7 years. One CCS and one RCT reported significant beneficial effects of meditation on TL while the two remaining CCS and the RCT showed positive effects of meditation on TL which were not significant. For all CCS and one RCT, the methodological quality was high while the remaining RCT was of moderate quality. The quality of evidence for the primary outcome was moderate in RCTs.

Conclusion: The present review adds to the existing evidence showing that meditation is potentially beneficial in reducing shortening of TL in healthy adults. However, strictly designed and well-reported RCTs with larger sample sizes are required to provide evidence of higher quality.

Systematic Review Registration: The protocol of this review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) database (registration number: CRD42020153977)

Background

Meditation is an ancient technique which promotes a sense of calm and heightened awareness and improves general physical well-being [1,2,3]. Most notably in Asian cultures, meditation is traditionally associated with achieving spiritual enhancement and higher mental states, while techniques incorporating these teachings have now become widely popular for building resilience to stressors of everyday life and illness [4]. Currently, the term “meditation” broadly refers to a number of varying techniques such as Breathing, Body-Scan, Walking, Zen, Vipassana, Loving-kindness (LKM), Mindfulness, and Concentrative meditation. In addition to promoting psychological well-being, a growing body of evidence has highlighted biological effects that may be brought upon by meditation that is beneficial in

health and disease. Thus, changes at cellular and molecular level, which may underpin these biological effects, have been the focus of many studies.

One such area of expanding interest is the association of meditation with cellular aging where the length of the telomeres may vary due to the effects of meditation. Telomeres are structures located at the termini of eukaryotic linear chromosomes comprising simple tandem repeats of DNA sequences bound by protective component proteins [5]. Telomere dysfunction, uncapping, and telomere loss can lead to cellular apoptosis, genomic instability, and cellular senescence [5]. The general DNA replication mechanism cannot copy the DNA to the very ends of the linear chromosomes, and with consecutive cell divisions this leads to attrition of chromosome ends [6]. Regulation of length of telomeres is affected by multiple factors, one of the most well recognized is telomerase, a specialized cellular ribonucleoprotein reverse transcriptase which counteracts attrition by synthesizing telomeric DNA. However, the tightly regulated nature of expression of telomerase in many types of human cells makes it unable to fully counteract the process of attrition and the overall effect is shortening of telomeres over time. In addition to being considered a biomarker of the natural aging process [7], short TL has been demonstrated to be a risk or prognostic marker in several disease conditions which are primarily associated with an age related onset [8,9,10,11,12,13,14,15]. Furthermore, previous studies have related shorter telomeres to both perceived stress and chronicity of stress [16] as well as elevated levels of catecholamines and cortisol [17], which also indicate a heightened stress response.

Meditation may bring about biological benefits by reducing psychological distress [18,19] and influencing gene expression and pathways central to regulating cellular oxidative stress [20]. Moreover, some studies have found that meditation may increase the activity of telomerase enzyme thereby counteracting telomere shortening [21,22]. Such purported benefits of meditation have also led to its effects being explored in a spectrum of diseases such as breast cancer [12,23], Alzheimer's disease [24], depression, anxiety, stress and adjustment disorders [25,26] with only some studies reporting a protective effect on telomere attrition [25,24,27]. A meta-analysis conducted on studies which compared a mindfulness based practice with a control condition in variable populations concluded that meditation based interventions may impact TL and that a longer duration of meditation practice may be conducive to telomere maintenance [28]. Another similar meta-analysis has shown that mindfulness meditation leads to increased telomerase activity in peripheral blood mononuclear cells [29].

However, the evidence of these analyses is influenced by the heterogeneous study populations and combined interventions where changes in TL may be influenced by other stress relieving activities or the presence of disease conditions which themselves may affect the process of telomere shortening. Further, novel data from interventional studies, describing the effects of meditation on TL have been recently published [30,31]. Therefore, a clear understanding of changes in TL conferred by meditation based practices in otherwise healthy persons would not only add to the knowledge on cellular aging and senescence but also strengthen the scientific basis of use of these complimentary approaches in the management of many chronic and inflammatory disease conditions.

Objective

This study systematically reviews and synthesizes the evidence from RCTs and CCS investigating the changes in TL in healthy adults who have followed meditation-based practices.

Meditation is an ancient technique which promotes a sense of calm and heightened awareness and improves general physical well-being [1,2,3]. Most notably in Asian cultures, meditation is traditionally associated with achieving spiritual enhancement and higher mental states, while techniques incorporating these teachings have now become widely popular for building resilience to stressors of everyday life and illness [4]. Currently, the term “meditation” broadly refers to a number of varying techniques such as Breathing, Body-Scan, Walking, Zen, Vipassana, Loving-kindness (LKM), Mindfulness, and Concentrative meditation. In addition to promoting psychological well-being, a growing body of evidence has highlighted biological effects that may be brought upon by meditation that is beneficial in health and disease. Thus, changes at cellular and molecular level, which may underpin these biological effects, have been the focus of many studies.

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Objective

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Method

The protocol of this review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) database (registration number: CRD42020153977). The review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocol (PRISMA) statement [32].

Criteria for considering studies for this review

Types of studies

Published RCTs and CCS on the effects of meditation on TL were selected for this review. Studies that used other study designs, reviews, and short reports were excluded.

Types of participants

Healthy adults, who were experienced/long-term meditators (in CCS) and those who received meditation training (in RCTs), regardless of gender and meditation technique were included. Studies conducted on participants with disease conditions such as cancer, Alzheimer's disease, infertility, obesity, depression, anxiety, stress, and chronic fatigue syndrome were excluded.

Types of intervention

RCTs, which used any form of meditation technique as the intervention, and CCS that recruited meditators (cases) who have practiced any form of meditation technique were included in this review.

Studies, which used other stress relieving non-meditative techniques such as Yoga and Qigong independently or in combination with meditation techniques were excluded.

Types of outcome measures

The primary outcome was TLs between meditators and controls in CCS and the TL difference between pre-post meditation interventions in RCTs. Secondary outcomes were mindfulness and psychological health related variables. Studies indicating ineligibility through available information were excluded.

Information sources

A systematic literature search was carried out for articles published in English using the following databases from their inception to 30 March 2020; PubMed, Scopus, PsycINFO, Embase, Cochrane Library, CINAHL and Google Scholar. Common Medical Subject Heading (MeSH) and free text terms adopted to each database were as follows: “Meditation” OR “Mindfulness” AND “Telomere length” OR “Telomerase” OR “Telomere” AND “Healthy individuals” (refer Table 1). The reference lists of eligible studies and previous reviews were scrutinized in order to further identify relevant original full text articles. In addition, relevant clinical trial registers as well as conference proceedings available through Google and Google Scholar were searched for other eligible unpublished studies. The search was updated in July 2020.

Table 1: Search strategy for databases

Search number	Query
1	"Meditation" AND "Telomere length"
2	"Meditation" AND "Telomere"
3	"Meditation" AND "Telomerase"
4	"Mindfulness" AND "Telomere"
5	"Mindfulness" AND "Telomere length"
6	"Mindfulness" AND "Telomerase"
7	"Healthy Individuals"
8	1 OR 4 AND 7
9	1 OR 6 AND 7
10	2 OR 5 AND 7
11	2 OR 6 AND 7
12	3 OR 4 AND 7
13	3 OR 5 AND 7
14	Limit 13 to RCT AND English
15	Limit 13 to CCS AND English

Data collection and analysis

A review author (NND) conducted the initial search and removed the titles which were clearly not relevant to this review. Remaining titles with abstracts were independently screened by two review authors (NND and NDS) for their eligibility for inclusion. Full texts were read in the studies which provided inadequate data in the abstract. Any clarifications and disagreements were discussed with a third reviewer (NS) and the decisions were documented. For the RCTs and CCS that appeared to be eligible, the full texts were obtained and examined to assess their relevance, based on the pre-planned criteria for inclusion.

Data extraction and management

Reviewers (NND and NDS) independently extracted data using a specifically designed data extraction form. Information extracted included first author, year of publication, country of the study, study design, study settings, participant characteristics, group comparison characteristics, sample size, intervention, outcome measures and technique used to measure the outcome.

Risk of bias assessment

All the included studies were assessed for methodological rigor by two independent reviewers (NND and NDS). The methodological quality of the RCTs were assessed using the Cochrane risk of bias tool [33] and the risk was assessed across the following seven domains: random sequence generation, allocation concealment, blinding of participants and personnel (checking for possible performance bias), blinding of outcome assessment (checking for possible detection bias), incomplete outcome data, selective reporting, and other biases. Three risk of bias categories i.e. low, high and unclear were set for each domain. Accordingly, overall bias was set for each study as high (if all categories were met), moderate (if two or more criteria were only partially met) and low (if all criteria were not met or only one criterion was met). The methodological quality of the CCS were analyzed according to the Joanna Briggs Institute critical appraisal checklist for CCS using ten criteria [34]. Each component of the checklist was rated with 0 to 1 mark as yes (mark = 1), no (mark = 0), unclear (mark = 0.5), or not applicable. The overall quality of the study was rated out of 10 and was set as low (≤ 3 marks), moderate (>3 and ≤ 7 marks) or high (>7 marks) in quality.

Data analysis and synthesis

A narrative analysis was employed to synthesize the evidence from CCS. While the two RCTs were considerably homogenous in study approach and primary outcome measures, a meta-analysis was not conducted primarily due to the limited sample size. The two RCTs comprised two and three sub-studies each which were considered likely to influence the findings if the results from the five comparisons were pooled using Review Manager Software (version 5.3). The analyses were complimented by computing the effect estimates for TL according to Synthesis Without Meta-analysis (SWiM) guidelines for alternative methods of combining results [41].

Results

The PRISMA flowchart detailing the steps followed in selecting the articles included in this review is shown in Figure 1. The initial literature search of seven databases resulted in 2,245 potentially relevant articles and after excluding the duplicates 1,751 articles remained. Through screening titles and the abstracts against the pre-set inclusion criteria, 134 full text articles were selected for review-in-detail. Review yielded only five peer-reviewed, full text articles: three CCS [35,36,37](30) and two RCTs [31,30] which met the full eligibility criteria. PRISMA checklist and the list of excluded publications and reasons for exclusion are provided in Appendix 1 (supplementary file 1) and 2 (supplementary file 2) respectively.

Description of studies

Characteristics of each study are detailed in Table 2 (Additional file 1). The selected studies were conducted in USA ($n = 2$), Spain ($n = 2$) and Germany ($n = 1$) and were published between 2013 and 2020.

Participants

As per criteria for this review, only studies conducted on healthy participants were included. The total number of healthy adult participants examined across all included studies was 615.

Case-control studies

The CCS included a total of one hundred and eleven participants with fifty-two meditators and fifty-nine controls and the sample sizes varied among 34 to 40. Meditators were recruited from Vipassana meditation centers and retreat centers in New England [36], Mindfulness program at the University of Zaragoza and Spanish Association of Mindfulness [37], and Soto Zen Spanish Buddhist community [35]. The mean age of the study population was 48.2 years with male participants comprising 63.46%.

Randomized controlled trials

Overall, the RCTs included 504 participants with 367 assigned to the meditation intervention groups and 137 assigned to the comparison groups where the sample sizes of the studies varied between 176 to 259 in interventional groups and 37 to 100 in control groups. Male participants comprised 40.43% out of the total sample. Participants were recruited from Durham and Orange County of North Carolina [30] and Berlin and Leipzig [31] with a mean age of 46.7 years.

Interventions

Case-control studies

These studies recruited long-term/experienced meditators who used three different meditation techniques: loving-kindness [36], mindfulness/observing thoughts [37], and Zen meditation [35] and the duration of the meditation experience of the meditators ranged from 4 years [36] to 10 years [35,37] with a mean of at least 60 minutes of practice per day [37,35]. One study did not mention the duration of a session but specified participants were those who practiced meditation daily [36].

Randomized controlled trials

One of the RCTs had used two types of meditation intervention groups: mindfulness meditation and loving kindness meditation and compared them with a monitoring waitlist control group [30]. The other RCT had used three different meditation intervention groups: the presence (breathing meditation technique with body-scan meditation technique), affect (loving-kindness meditation technique with affect dyad) and perspective (observing thought meditation technique with perspective dyad) and compared with a control group without any training [31]. All participants received 12 weeks of meditation training with a mean of 1.5 hours small group sessions and daily practice. In addition, one study had started the intervention with a three-day silent retreat and two core practices at home for approximately 30 min/day [31] while the other study had provided comparable resources for individual home practice [30].

The details of the interventions are summarized in Table 3 (Additional file 1).

Outcomes

Primary outcome

TL was reported as the primary outcome in all the studies. It was assessed using quantitative Polymerase Chain Reaction technique [31,36,30] or in situ hybridization technique [35,37] and reported as T/S ratio or in kilo-bases (kb), respectively. Details of the outcomes are shown in Table 4 (Additional file 1).

Secondary outcomes

Two CCS [37,35] had measured mindfulness and psychological health related variables between meditators and controls applying Mindfulness Attention Awareness Scale (MAAS), Five Facet Mindfulness Questionnaire (FFMQ), Hospital Anxiety and Depression Scale (HADS), the Self-Compassion Scale (SCS) and the Experiential Avoidance Questionnaire (AAQ-II). The MAAS comprises of 15 items to evaluate a core characteristic of dispositional mindfulness, which is open or receptive awareness and attention to the present moment. FFMQ consists of 39 items and it assesses observing (noticing or taking care of inner and outside experiences), describing (naming inner experiences with words), responding with awareness, and non-reactivity to internal experiences. HADS is used to measure the anxiety and depression via 14 items and SCS is a 24-item scale which is used to measure the self-compassion, self-kindness, common humanity and mindfulness. AAQ-II assesses the experiential avoidance through 7 items. One RCT computed the effect of meditation on emotions [30] using the modified Differential Emotions Scale which is used to measure ten positive emotions; amusement, awe, gratitude, hope, inspiration, interest, joy, love, pride, and serenity and ten negative emotions; anger, contempt, disgust, embarrassment, fear, guilt, hate, sadness, shame, and stress.

Risk of bias assessment

The methodological quality of the studies that were included is shown in Figure 2 and Table 5.

Table 5: Methodological quality of Case-Control Studies

<i>Alda et al., 2016</i>	Yes Marks = 1	No Marks = 0	Unclear Marks = 0.5	Not applicable
Were the groups comparable other than the presence of disease in cases or absence of disease in controls? (disease = meditation)	x			
Were cases and controls matched appropriately?	x			
Were the same criteria used for identification of cases and controls?	x			
Was exposure measured in a standard, valid, and reliable way?	x			
Was exposure measured in the same way for cases and controls?	x			
Were confounding factors identified?	x			
Were strategies to deal with confounding factors stated?	x			
Were outcomes assessed in a standard, valid and reliable way for cases and controls?	x			
Was the exposure period of interest long enough to be meaningful?	x			
Was appropriate statistical analysis used?	x			
<i>Hoge et al., 2013</i>				
Were the groups comparable other than the presence of disease in cases or absence of disease in controls? (disease = meditation)	x			
Were cases and controls matched appropriately?	x			
Were the same criteria used for identification of cases and controls?	x			
Was exposure measured in a standard, valid, and reliable way?	x			
Was exposure measured in the same way for cases and controls?	x			
Were confounding factors identified?	x			
Were strategies to deal with confounding factors stated?	x			
Were outcomes assessed in a standard, valid and reliable way for cases and controls?	x			
Was the exposure period of interest long enough to be meaningful?	x			
Was appropriate statistical analysis used?	x			
<i>Mendioroz et al., 2020</i>				
Were the groups comparable other than the presence of disease in cases or absence of disease in controls? (disease = meditation)	x			
Were cases and controls matched appropriately?			x	
Were the same criteria used for identification of cases and controls?	x			
Was exposure measured in a standard, valid, and reliable way?	x			
Was exposure measured in the same way for cases and controls?	x			
Were confounding factors identified?	x			
Were strategies to deal with confounding factors stated?	x			
Were outcomes assessed in a standard, valid and reliable way for cases and controls?	x			
Was the exposure period of interest long enough to be meaningful?	x			
Was appropriate statistical analysis used?	x			

Quality scores of the CCS ranged from nine to ten points. All three studies were high quality (score ≥ 7) but one study had inconsistencies between documented methodology and demographic data of cases and controls [37]. A meditator and two controls (7.5%) of one study were excluded from their analysis, due to presence of comorbidities and use of long term medications [35].

Randomized controlled trials

Overall one RCT could be considered to be of low risk of bias [30] while the other one had a moderate risk of bias due to inadequate information on allocation concealment and blinding [31]. Out of 362 participants, 64 dropped out (17.68%) in one study [31] due to study exclusions (n = 2), missing BMI (n = 2), missing leukocyte TL change (n = 14), blood sampling exclusion (n = 3), before first change (n = 13) and after an assignment (n = 30) while the other RCT did not have any dropouts as the investigators used previously collected samples.

Effects of intervention

Effect of the interventions are summarized in Table 4 (Additional file 1).

Primary outcome

Case control studies

One CCS showed significantly longer TL in meditators compared to controls [35] while another study showed that meditators have median relative longer telomeres than controls [36]. Furthermore, this study [36] reported significantly longer TL in women meditators than controls. The third CCS [37] showed positive beneficial effects of meditation on TL in cases but the difference when compared to controls was not significant.

Randomized controlled trials

One RCT did not show any effects of meditation on leukocyte TL. The other RCT which focused on two different techniques, showed a significantly lower decrease in the TL in loving-kindness meditation interventional sub-group. However this significantly lower decrease in TL was not observed in mindfulness meditation interventional sub-group.

Secondary outcomes

Effects of meditation on psychological health related variables

According to the mindfulness and psychological health related variables between meditators and controls, the measurements related to mindfulness such as attention and awareness, observing, describing, non-judging, resilience, self-compassion, and satisfaction with life suggested that expert/long-term meditators showed significantly beneficial results. Meanwhile, experiential avoidance, anxiety and depression levels were significantly lower in expert/long-term meditators [35,37]. The study which was

done on the effects of meditation on emotions [30] did not show any change in self-reported emotions after the intervention.

None of these studies reported any adverse effects of meditation practice.

Outcome synthesis and assessment of the certainty of the evidence

Meta-analysis for the outcomes of interest was not conducted due to the limited number of RCTs and the relatively small study population. However, following the guidelines regarding alternative methods for combining results, the effect estimates for TL was computed. The effect size with the 95% confidence interval (CI) is shown in Figure 3 and 4 for the RCTs and CCS, respectively. Certainty of the evidence was assessed based on the GRADE approach based on the study design, risk of bias, inconsistency, indirectness, imprecision and other considerations (Table 6). For the outcome of the CCS, the certainty of evidence was very low, mostly due to the nature of the study design and imprecision. Imprecision fell under the serious category since the investigators had used modest sample sizes. For the outcome of the RCTs, the certainty of evidence was moderate due to imprecision. Even though the CI of the 5 comparisons of the two RCTs overlapped, supporting the effect estimates of the individual comparisons, the CIs ranged across the line of no effect in all comparisons but one. Therefore, the grade of evidence was downgraded to serious.

Table 6: Certainty of the evidences

Certainty assessment							Certainty
of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	
	Observational studies	Not serious ^a	Not serious ^{b,c}	Not serious ^d	Serious ^e	None	⊕●●● VERY LOW
	Randomized trials	Not serious ^f	Not serious ^{b,c}	Not serious ^d	Serious ^g	None	⊕⊕⊕● MODERATE

- a. CCS are having a high risk of bias compared to RCTs. But when comparing only CCS together, all three CCS fall under low risk of bias.
- b. All the studies have shown a positive trend in the effectiveness of meditation on the TL.
- c. Heterogeneity of the studies was high since the studies have used different meditation techniques as interventions. But we considered all these techniques as sub techniques of meditation and hence we did not downgrade the grade of evidence.
- d. TL was assessed directly using standard methods.
- e. Modest sample sizes were used.

f. One study has shown unclear bias to allocation concealment, blinding of participants and personnel (performance bias), and blinding of outcome assessment.

g. Even though the sample sizes were adequate and CI were overlapped, the two ends of the confidence intervals ranged across the no effect line. Therefore, the grade of evidence was downgraded.

Discussion

We conducted a comprehensive systematic review to objectively assess the effects of meditation on TL of healthy persons. The current review demonstrated evidence from both observational and interventional studies that meditation and mindfulness practices were likely to reduce TL shortening. This study addresses the question of a qualitative and/or demonstrable effect of meditation related practices on telomere length shortening and cellular aging, which has lately generated wide interest due its potential applicability in both health and disease.

While this study also included CCS, which in general are considered to provide lower quality of evidence compared to RCTs, it is noteworthy that all three CCS included here were of high methodological quality according to defined criteria. As opposed to previous meta-analyses [28], rigorous criteria ensured that meditation based practices exclusively were used as the exposure/intervention in the studies included in our review, as use of multiple techniques within a group can confound effects of meditation alone. As the changes in TL were assessed only in healthy adults, the findings of our review are more likely to be applicable to the larger general population. Although the specific technique of meditation differed among the studies, these techniques are based on a few common underlying approaches such as maintaining attention on a chosen object, thought or activity and training to pay attention to the present moment.

There were no eligible studies done in Eastern countries which could be included in this review, but only those conducted in Western countries such as Spain and USA. However, the origin of these meditation techniques is mostly traced to Asian countries such as India, China, Thailand, and Sri Lanka [38]. The absence of reports from such countries might be due to unpublished studies, studies that have been published in non-indexed journals or they may have obtained negative results. Further, strong religious and spiritual connotations of meditation in these settings may make the practitioners of these techniques wary of collaborating with researchers who adopt a more scientific approach, which can contribute to the dearth of studies reported from these countries.

One of the main limitations of this study is lack of a meta-analysis. In a behavioural intervention of this nature where blinding of participants and researchers is generally not feasible, the conventional assessments may unduly downgrade the methodological quality of a study. One CCS included in this review had shown that the effect of meditation depends on gender where the female meditators had significantly longer telomeres than the comparison group. However, this gender dependent effect was not observed in the other two CCS. This observed effect may also be due to other factors which differed between the studies such as the duration of meditation practice or the technique that was used to measure the TL. Therefore, it is difficult to draw conclusions on the gender bias in effects of meditation on TL. The effects of meditation is dependent upon how well the participants have learnt and followed a

technique, which may be difficult to assess comprehensively and is an inherent limitation of all studies of this nature.

The results of this systematic review implied potential benefits of meditation on human TL. Meditation can be practiced in small groups or individually with or without an instructor and a small space is adequate for this purpose. The demonstrated benefits of meditation makes it suitable to be advocated as a healthy life style practice. However, further research is warranted to improve upon several aspects of the current knowledge. The frequency, duration and the precise technique of meditation practice varied across the studies that were reviewed. Thus, a pre-defined broad training plan would be a prerequisite to better investigate the effects of meditation on TL. Furthermore, as the TL reduces with increasing age, an age range should be pre-determined when recruiting the participants for such studies. Gender, lifestyle and ethnicity are some other confounding factors to be taken into consideration in designing these studies [39,40]. Selection of mediation naïve participants as controls in CCS and for both intervention and comparison groups in RCTs would negate any long-term effects of meditation on TL, which may otherwise bias the results. These groups should ideally not have engaged in any other relaxation practices, which have also been implicated in telomere health. Reliably identifying any potential benefits of one technique over another would be more challenging due to the inter-relatedness of these approaches and will require well-planned studies with clearly defined techniques and larger numbers of participants in each comparison group. The potential benefits of meditation on TL also calls for studies which evaluate these effects in a wider spectrum of disease phenotypes, especially when the onset of the condition is age related.

Conclusions

The findings of this review indicate that practice of meditation is likely to reduce TL shortening among healthy individuals. However, given the methodological limitations, future meticulously designed studies will be required to strengthen the evidence for the beneficial effects of meditation on TL before a strong recommendation can be made for adopting these techniques for modulating the process of cellular aging.

Abbreviations

TL – Telomere length

CCS – Case-control studies

RCT – Randomized controlled trials

PCR – Polymerase chain reaction

CI – Confidence intervals

MAAS - Mindfulness Attention Awareness Scale

FFMQ - Five Facet Mindfulness Questionnaire

HADS - Hospital Anxiety and Depression Scale

SCS - Self-Compassion Scale

AAQ-II - Experiential Avoidance Questionnaire

SWiM – Synthesis Without Meta-analysis

Declarations

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Authors' contributions

NND, NDS and NS conceived and designed the study. NND and NDS selected the articles. NS appraised the articles. NND, NDS, and NS extracted the data. NND and NDS assessed the methodological quality. NND synthesized the data and wrote the first draft of the manuscript. NND and NS interpreted the data and contributed to the writing of the final version of the manuscript. The authors read and approved the final version of the manuscript.

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Data Availability

The research data supporting this systematic review and meta-analysis are from previously reported studies and datasets, which have been cited. These prior studies (and datasets) are cited at relevant places within the text as references [30, 31, 35, 36, 37].

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interest

The authors declare no conflict of interest.

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Figures

Figure 1

PRISMA flow diagram of study selection for the systematic review

(a)

(b)

Figure 2

(a) Risk of bias graph and (b) summary of risk of bias of Randomized Controlled Trials

Figure 3

Summary of effect sizes and 95% confidence interval (CI) for telomere length in Randomized Controlled Trials

Figure 4

Summary of effect sizes and 95% confidence interval (CI) for telomere length in Case-Control Studies

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