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REVIEW

The Complex Interplay Between Sleep and Healthy Aging: A Scoping Review

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Background: The relationship between sleep and healthy aging is complex, involving changes in sleep patterns, architecture, and disturbances. Recognizing these changes is crucial for maintaining physical, cognitive, social, and psychological well-being in older adults. However, links between sleep parameters and aging outcomes remain unclear.

Objective: This review synthesizes current knowledge on associations between sleep parameters (duration, continuity, architecture, quality) and healthy aging outcomes, including physical health, cognitive function, psychological well-being, and social engagement.

Methods: Following the Arksey and O'Malley framework and Joanna Briggs Institute guidelines, this scoping review analyzed observational studies on healthy older adults. Sleep-related measures were examined without confounders from mental or physical illnesses.

Results: Twenty studies were included. Across cohorts, older adults consistently exhibited advanced sleep phases (bedtime ≈39 minutes earlier, wake time ≈76 minutes earlier) and reduced total sleep time (by approximately 2.4 hours vs younger adults). Both short and long sleep durations were associated with poorer aging outcomes, supporting a U-shaped relationship between sleep length and healthy aging. Sleep efficiency decreased by 13% and wake after sleep onset increased fourfold with age, particularly among women. Age-related reductions in slow-wave and REM sleep were linked to lower cognitive performance and altered mood regulation. Moderate daytime napping (<60 min/day) was generally associated with better sleep quality, whereas excessive napping correlated with reduced odds of "successful aging". Discrepancies between subjective and objective sleep assessments emerged, indicating that older adults may underreport sleep disturbances.

Conclusion: Gaps in understanding longitudinal sleep data, the mechanisms of sleep's impact on aging, and napping's role need further exploration. Future research could inform interventions for promoting healthy aging.

Keywords: sleep, objective sleep, subjective sleep, sleep quality, healthy aging, scoping review

Introduction

Sleep plays a fundamental role in maintaining overall health and well-being throughout the lifespan,[1] with its importance becoming increasingly pronounced as individuals age.[2,3] Healthy aging, often referred to as "resilient" or "successful" aging, is a multidimensional concept characterized by the maintenance of physical, cognitive, and social functioning, along with the preservation of psychological well-being in older adults.[4,5] Active aging, a complementary concept to healthy aging, emphasizes the continued participation of older individuals in social, economic, cultural, spiritual, and civic activities, regardless of physical capacity. Active aging constitutes one of the three core components of the Rowe and Kahn model of "successful aging",[6,7] which conceptualizes "better-than-average" aging as the confluence of three elements: i) avoidance of disease and disability, ii) maintenance of high physical and cognitive functioning, and iii)

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sustained engagement with life. Despite its popularity and widespread influence, this model has been criticized for its overly individualistic and biomedical orientation, which places limited emphasis on social and environmental determinants of aging.[8,9] This has led health institutions and organizations such as the World Health Organization (WHO) to broaden and expand the definition of aging. For instance, the WHO has defined active aging as the process of optimizing opportunities for health, participation, and security to enhance quality of life as people age. This aligns with the broader framework of healthy aging, which the WHO defines as the process of maintaining functional ability to enable well-being in older age. In recognition of the growing importance of this issue, the WHO has declared 2020–2030 the Decade of Healthy Ageing, focusing on fostering environments that promote both active and healthy aging.[5,10]

While aging is inevitably associated with changes in sleep patterns and architecture,[11] the extent to which these changes impact healthy aging outcomes remains a topic of ongoing research and debate.[10,12] Several key factors underscore the importance of examining the relationship between sleep and healthy aging. Firstly, advancing age is often accompanied by alterations in sleep duration, continuity, and quality, including a tendency towards more fragmented sleep, decreased total sleep time (TST), and alterations in sleep architecture characterized by reduced slow-wave sleep (SWS) and diminished rapid eye movement (REM) sleep.[13] These changes in sleep patterns are influenced by a myriad of factors, including physiological, psychological, and environmental variables,[14–16] and might also reflect the progressive modifications in the brain structure that para-physiologically accompany the aging process, which can have implications for the physical and cognitive health of older adults.[17–20] For instance, emerging evidence indicates that insufficient or disrupted sleep can adversely affect cognitive function through multiple converging biological pathways. These include altered prefrontal cortex activation leading to impaired executive control and attention, activation of systemic inflammatory and oxidative stress cascades, and disturbances in neuronal plasticity and cellular homeostasis.[21,22] Both population-based investigations and experimental animal models have demonstrated that these mechanisms may accelerate neurocognitive decline, highlighting sleep as a potential modifiable target for preserving brain health and functional aging.

Furthermore, an increasing body of scholarly literature suggests that the association between sleep and aging is not linear. For instance, a recent large-scale investigation on 13,569 participants in the US focusing on the concept of "phenotypic aging" (ie, the biological and functional decline reflected in physiological markers rather than just the passage of time captured by chronological age) provided compelling evidence that sleep duration exerts a strong influence on healthy aging, showing that both short and long sleep durations are associated with accelerated aging.[23] The potential influence of several endogenous (such as sex/gender) and external factors (including, above all, physical activity and exercise) can lead to a U-shaped relationship between sleep duration and phenotypic aging, as recently described in seminal population-based studies,[23,24] increasing the complexity of such an intricated interplay.

Moreover, sleep disturbances are prevalent among older adults, with conditions such as insomnia, sleep apnea, restless legs syndrome, REM sleep parasomnias, and periodic limb movement disorder becoming more common with aging.[25,26] These sleep disorders not only contribute to subjective complaints of poor sleep quality but may also exacerbate age-related declines in cognitive function, increase the risk of chronic medical conditions such as arterial hypertension, metabolic disorders, and diabetes, and impair the quality of life and well-being in older individuals.[27–29] Despite the recognition of the interplay between sleep and healthy aging, the complex relationships between sleep parameters and various domains of healthy aging outcomes are still largely poorly understood. Specifically considering the increasing burden of neurodegenerative diseases in the overall general population and its societal and economic impacts,[30] understanding the complex role that sleep may play as a protective factor is crucial in contemporary society.

Existing reviews have predominantly focused on pathological sleep conditions in relation to aging, thereby overlooking the complex spectrum of physiological sleep changes that accompany the aging process.[31–37] When addressing healthy older populations, these reviews have typically examined only a restricted set of sleep parameters (most often sleep duration or self-reported quality) and a narrow range of health outcomes, with particular emphasis on cognitive function. As a result, other key domains of healthy aging and the interplay between objective and subjective sleep measures have remained largely underexplored.

Given the breadth and complexity of the research question, a scoping review of the literature represents the most appropriate methodological approach, unlike a systematic review, which typically focuses on narrowly defined questions suitable for quantitative synthesis or meta-analysis. A scoping review can, indeed, offer a rigorous and systematic approach to collating and evaluating the available body of scholarly evidence, thereby providing valuable insights to elucidate the associations between sleep and healthy aging across various populations and settings, identifying gaps in knowledge, and informing future research directions and clinical interventions aimed at promoting optimal aging trajectories. This review aims to examine the current state of knowledge regarding the associations between sleep parameters, including sleep duration, continuity, architecture, and quality, and multiple dimensions of healthy aging, such as physical health, cognitive function, psychological well-being, and social engagement, by synthesizing findings from diverse epidemiological studies to provide a comprehensive understanding of how sleep influences healthy aging outcomes and to identify future research and clinical practice avenues for optimizing sleep and promoting successful aging in older adults.

Materials and Methods

Details concerning the methodology are reported in Table 1 as well as in the next sections.

Study Protocol

An a priori study protocol was devised following the "Joanna Briggs Institute" (JBI) recommendations.[38]

Methodological Framework

The Arksey and O'Malley framework,[39] a widely recognized methodological tool for conducting scoping reviews, designed to map the key concepts underpinning a research area and the main sources and types of evidence available, was leveraged. This framework involves several stages, including identifying the research question, identifying relevant studies, study selection, charting the data, and summarizing and reporting the results. As such, using this structured approach enabled the identification and analysis of the breadth of literature on sleep and healthy aging, as well as the identification of gaps in knowledge, understudied areas or areas with mixed findings, and future research directions.

Table 1 Search Strategy Adopted in the Present Review

Search Strategy Item	Details
Search string used	("normal aging" OR "normal ageing" OR "physiological aging" OR "physiological ageing" OR "healthy aging" OR "healthy ageing" OR "healthy old adult*" OR "health elderly" OR "healthy old men" OR "healthy women" OR "resilient aging" OR "resilient ageing" OR "optimal aging" OR "optimal ageing" OR "successful aging" OR "successful ageing" OR "noncomplaining old adult*" OR "noncomplaining elderly" OR "noncomplaining old men" OR "noncomplaining old women" OR "healthy ager*" OR "resilient ager*" OR "optimal ager*" OR "successful ager*") AND (sleep* OR "circadian rhythm*" OR nap OR napping)
Searched databases	MEDLINE via PubMed, Scopus, EMBASE, Web of Science
Inclusion criteria	P: ageing population, free from mental and physical diseases, noninstitutionalized E: not exposed to any intervention C: based on age groups, sex/gender, health status O: subjective and objective sleep S: original study
Exclusion criteria	P: young populations; animals E: exposed to interventions of any type C: not applicable O: others than subjective and objective sleep S: commentaries, technical reports, letters to editor, editorials, reviews, and study protocols
Time filter	None
Language filter	None

Literature Search

The search string utilized focused on various terms related to the process of aging and its association with sleep. The precise search string used is reported in Table 1. Four major scholarly electronic databases were searched, namely, MEDLINE via PubMed, Scopus, EMBASE, and ISI/Web of Science (WoS).

Moreover, target journals related to sleep, gerontology, aging, and the psychology of aging were hand-searched to ensure the inclusion of relevant studies and high coverage of the topic under study. Specifically, leading sleep science journals such as Sleep, Journal of Sleep Research, Sleep Medicine, and Nature and Science of Sleep were manually screened, given their centrality in publishing original research on sleep parameters, architecture, and quality across the lifespan. To capture the gerontology and aging perspective, we hand-searched Journal of Frailty & Aging, BMC Geriatrics, Maturitas, Journal of the American Geriatrics Society, and American Journal of Geriatric Psychiatry, which regularly feature studies on health, well-being, and aging trajectories. We also hand-searched journals related to the psychological/psychiatric correlates of sleep in aging (Biological Psychiatry, Journal of Psychiatric Research, Psychology and Aging, Journal of Psychosomatic Research, and Brain Research Bulletin). Finally, extensive cross-referencing was applied. The search was conducted from inception until September 26, 2024.

Inclusion and Exclusion Criteria

Inclusion/exclusion criteria were devised according to the PECOS mnemonic.[40] Only original observational studies involving non-institutionalized old individuals, aged sixty years and older, free from mental and physical diseases, meeting the criteria of healthy aging, were considered. Comparisons of any type (based on age groups, sex/gender, healthy versus diseased states) were considered. Outcomes were either objective or subjective sleep-related measures. Studies using animal models or focusing on middle-aged individuals were discarded. Investigations focusing on sleep disturbances and abnormalities were excluded if not including healthy controls. Interventional trials, including those administering central nervous system (CNS)-acting drugs, were not considered. Finally, commentaries, technical reports, letters to the editor, editorials, reviews, and study protocols were not deemed eligible for inclusion (Table 1).

Data Extraction

The following data were extracted independently by two authors (N.L.B. and D.B).: study, study country, study design, sample size, the definition of healthy aging employed in the study, tools for studying sleep, sleep-related parameters studied, sleep timing, sleep duration, sleep continuity and efficiency, sleep architecture, chronotype and circadian rhythms, subjective sleep (ie, sleep quality), comparison between objective and subjective measures, and key findings. A customized Excel spreadsheet was utilized.

Finding Reporting

The findings were reported in accordance with the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) Extension for Scoping Reviews (PRISMA-ScR) checklist.[41]

Results

The initial literature search yielded a pool of 7,694 items (2,587 from Embase, 1,766 from Scopus, 1,758 from PubMed/MEDLINE, and 1,583 from the ISI/WOS). After removing duplicates, 3,832 items were screened. After discarding irrelevant items based on the title and/or abstract, 107 results were analyzed in-depth. From the full-text assessment, 87 studies were excluded with reasons: 39 studies were excluded due to the study population, involving community-dwelling persons with comorbidities or other health issues, hospital-based patients, or institutionalized elderly not free from diseases, therefore not meeting the inclusion criterion of healthy participants. Eleven studies were excluded because they were methodological in nature, 22 studies were classified as interventional and thus excluded, and 15 studies were excluded as they explored outcome measures not of interest. Twenty studies[42–61] were finally included in the present review (Table 2). The study selection process is depicted in Figure 1.

Table 2 Major Features of the Studies Included in the Present Scoping Review

Study	Study Country	Study Design	Sample Size	Definition of Healthy Aging	Tools for Studying Sleep	Key Sleep-Related Parameters Studied	Key Findings
Nakazawa et al (1991)[48]	Japan	Cross-sectional	7 older adults (63.7±8.0 years) vs 7 younger adults (21.1±2.3 years)	Free from insomnia, physical, and mental diseases	Sleep diaries	Sleep timing, rectal temperature rhythms	Negative correlation between time of falling asleep and age (r=−0.8423, p<0.05). Advanced sleep phase in elderly
Dykierek et al (1998)[46]	Germany	Cross-sectional	42 elderly (64.4±7.5 years) vs 35 Alzheimer's patients (62.1±8.9 years) vs 39 depressed patients (67.7±9.8 years)	Free from narcolepsy and major sleep issues	PSG	Sleep architecture	Altered REM density, reduced stage 2 sleep in depressed patients, overall sleep architecture changes with aging
Hoch et al (1988)[53]	USA	Cross-sectional	23 healthy elderly (68.9±3.8 years) vs 20 Alzheimer's patients (71.6±4.9 years) vs 23 depressed elderly (70.1±5.6 years)	Free from sleep issues, physical, and mental diseases	PSG	Sleep architecture	All parameters differed except sleep latency. Stage REM borderline significant
Dodt et al (1994)[51]	Germany	Cross-sectional	20 elderly (mean age 78.4 years) vs 16 young controls (mean 24.9 years)	Fully self-sufficient, free from physical and mental diseases	PSG	HPA axis activity and sleep	Advanced bedtimes, increased ACTH and cortisol during sleep, and reduced SWS in the elderly
Spiegel et al (1999)[45]	Switzerland	Longitudinal	57 healthy older adults (63.5±3.7 years, follow-up with 30)	Free from physical, mental diseases	PSG	REM sleep characteristics	Higher REM density correlated with cognitive performance
Gori et al (2004)[58]	Italy	Cross-sectional	12 very old (85.4±7.8 years) vs 11 old (68.5 ±4.1 years)	Fully independent	PSG	Body movements	Very old group had more fragmented sleep, fewer body movements
Driscoll et al (2008)[60]	Australia	Cross-sectional	64 elderly men and women (mean age 79)	Free from sleep issues	PSG, sleep diaries, actigraphy	Sleep quality and health	Men had lower sleep efficiency, women spent more time asleep
Buysse et al (1992)[44]	USA	Cross-sectional	45 elderly (mean age 83.1) vs 33 younger adults (mean 24.9 years)	Free from major diseases	PSG, sleep diaries	Daytime napping	Elderly had more naps and fragmented sleep, reduced REM and SWS
Deantoni et al (2023)[42]	Belgium	Cross-sectional	60 seniors (average age 69)	Free from major diseases	PSG, actimetry, scales	Napping and circadian rhythms	Nappers had altered circadian rhythms, higher REM during daytime naps
Xin et al (2020)[50]	China	Cross-sectional	7469 participants	Rowe and Kahn's framework	PSQI	Daytime napping and successful aging	Long naps were associated with lower odds of successful aging

(*Continued*)

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Table 2 (Continued).

Study	Study Country	Study Design	Sample Size	Definition of Healthy Aging	Tools for Studying Sleep	Key Sleep-Related Parameters Studied	Key Findings
Campbell et al (2007)[61]	USA	Cross-sectional	50 healthy participants (mean age 46.5)	Free from major medical issues	PSG	Natural sleep patterns	Older subjects slept less per 24 hours, reduced REM sleep
Shi et al (2021)[47]	USA	Prospective cohort	12,304 women aged 70 and older	Based on cognitive, physical, and mental health	Self-reported	Sleep duration and healthy aging	Shorter and longer sleep durations linked to lower healthy aging odds
Liu et al (2016)[52]	China	Cross-sectional	5616 elderly (60+ years)	Rowe and Kahn's framework	PSQI	Sleep patterns	Poor sleep linked to lower successful aging ratio
Buysse et al (1991)[56]	USA	Cross-sectional	44 elderly vs 35 younger adults	Free from major diseases	PSG, PSQI	Self-reported sleep quality	Elderly had more arousals, higher AHI, and lower sleep quality
Danker-Hopfe et al (2006)[59]	Germany	Longitudinal	91 subjects (mean age 66.7)	Free from neuropsychiatric diseases	PSQI	Perceived sleep quality	Sleep quality stable over time, gender differences noted
Vitiello et al (2004)[57]	USA	Cross-sectional	150 elderly (67.5±0.5 years) vs 9 young men	Free from major diseases	PSG, PSQI	Gender differences in sleep	Women had higher sleep efficiency, elderly had less REM and SWS
Gkotzamanis et al (2023)[43]	Greece	Prospective observational	1226 older adults	Healthy Aging Index	Sleep Index II	Sleep quality and aging trajectories	Good sleep quality positively associated with healthy aging
Campbell et al (1989)[55]	USA	Cross-sectional	22 healthy elderly	Free from sleep issues	Self-reported	Circadian rhythms	Women woke up earlier, shorter sleep durations, gender differences in sleep satisfaction
Bliwise (1992)[54]	USA	Cross-sectional	38 elderly women	Free from sleep issues	PSG, questionnaires	Psychological determinants of sleep	Poor sleepers had more psychological symptoms, longer sleep latency, and lower total sleep time

Abbreviations: ACTH, Adreno-Cortico-Tropic Hormone; AHI, Apnea Hypopnea Index; HPA, Hypothalamic–Pituitary–Adrenal axis; PSG, Polysomnography; PSQI, Pittsburgh Sleep Quality Index; REM, Rapid Eye Movements (sleep); SWS, Slow Wave Sleep.

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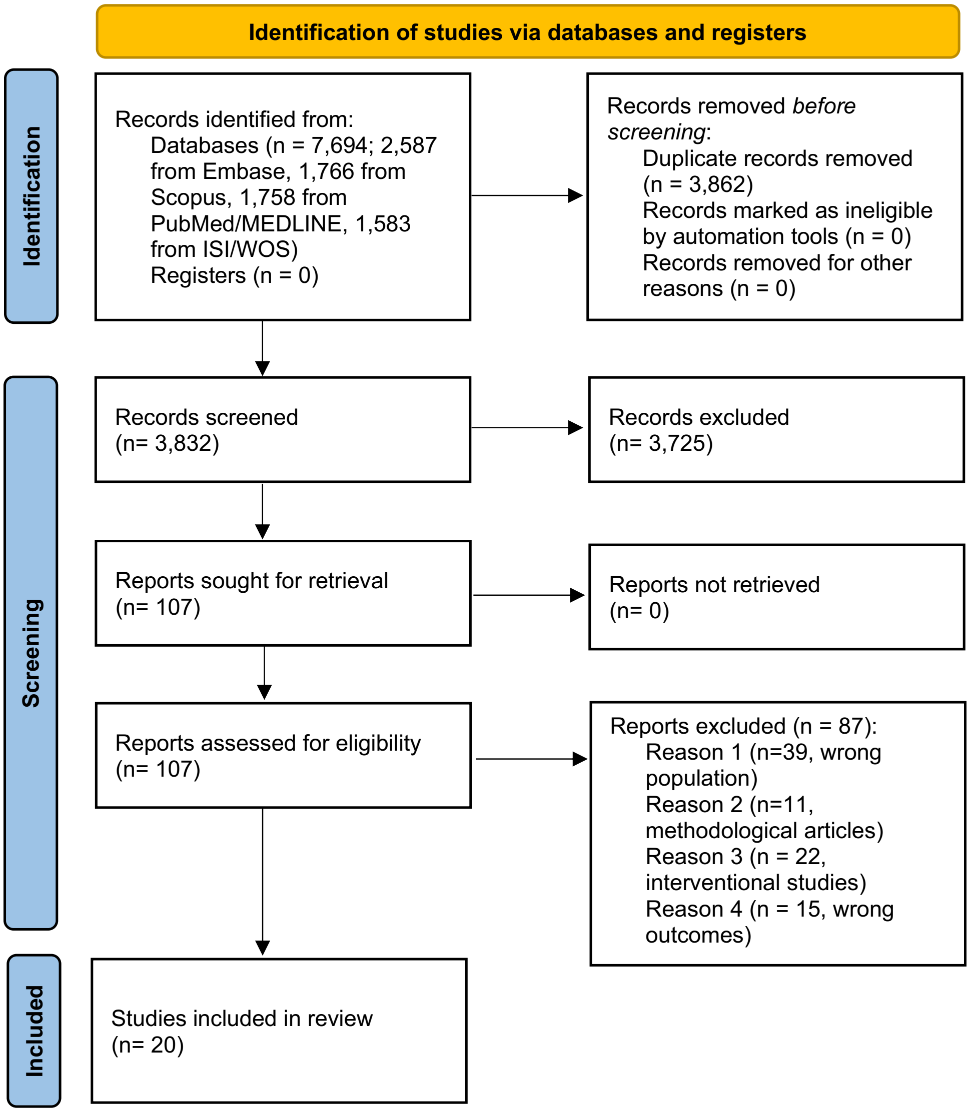

Figure 1 PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) flow diagram depicting the selection process.
Notes: PRISMA figure adapted from Tricco AC, Lillie E, Zarin W et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med.* 2018;169(7):467–473.[41]

Demographic Features

The average participant age in these studies ranged from 60 to 85 years, enabling us to examine the structure of sleep across a wide age range. In terms of gender distribution, both males and females were well represented. A few studies focused exclusively on women, while most studies featured mixed-gender samples. The sample sizes across the studies varied significantly, from small investigations involving as few as seven participants to large cohort studies including more than 7,000 participants. Altogether, the studies included more than 20,000 individuals from different geographic locations.

One study was conducted in Japan,[48] focusing on sleep timing and body temperature rhythms in healthy older (aged 63.7±8.0 years, 50–73 years) versus younger adults (aged 21.1±2.3 years, 18–24 years). Two studies were conducted in Germany,[46,51] exploring sleep architecture in healthy elderly, Alzheimer's, and depression patients, as well as HPA axis activity and sleep in the elderly, with a third[59] investigating perceived sleep quality and its temporal stability in the elderly.

Multiple studies originated from the USA, 44(p24),[47,53–56,61] including one[53] comparing sleep architecture in elderly, Alzheimer's, and depression patients, another[47] as part of the Nurses' Health Study focusing on sleep duration and healthy aging, while the others examine circadian rhythms, sleep quality, and gender differences in older adults.

Two studies were conducted in China[50,52] using data from the China Health and Retirement Longitudinal Study (CHARLS), investigating sleep patterns and successful aging, as well as the impact of daytime napping on healthy aging in the elderly. Two Italian studies focused on the role of stress hormones[49] and body movements during sleep in the elderly.[58] Australian researchers[60] assessed sleep quality and health in elderly men and women. Additionally, an investigation from Belgium[42] explored napping, circadian rhythms, and perceived sleep quality among seniors aged 69 years, as well as its temporal stability. Another study from Switzerland[45] examined REM sleep characteristics and their long-term impact on cognitive functions and aging. Finally, one study from Greece[43] focused on sleep quality and healthy aging trajectories in older adults.

Tools for Investigating and Measuring Sleep

Nine studies employed objective sleep assessment through polysomnography (PSG),[44–46,51,53,54,56–58] providing detailed information on sleep architecture, efficiency, latency, and stages. One study relied exclusively on subjective measures, using validated sleep-related questionnaires and patient-reported outcomes to capture perceived sleep quality and disturbances.[55] Three studies complemented objective assessments with sleep diaries,[44,48,56] allowing for the evaluation of daily sleep patterns, timing, and variability. The remaining investigations adopted multimodal approaches, integrating different assessment tools, such as PSG, sleep diaries, self-reported questionnaires, and/or actigraphy, to obtain a more comprehensive characterization of sleep behavior and quality in older adults.[42,52,60]

Sleep Timing

Six studies provided data on sleep timing.[44,48,51,54–56] All of these studies consistently reported an advanced sleep phase in older adults, characterized by earlier bedtimes and wake-up times compared to younger adults. This pattern was found to be consistent across various countries and cultures, including Japan, the USA, and Germany, regardless of study design. More specifically, negative correlations were observed between sleep onset time and age, with less pronounced but still notable correlations between final awakening time and age.[48]

In one study,[44] elderly participants went to bed approximately 39 minutes earlier and woke up around 76 minutes earlier than their younger counterparts. Gender-specific differences were also observed: despite similar bedtimes, women tended to wake up earlier than men (mean difference of 30 minutes), with the timing of peak body temperature closely linked to both bedtime and wake-up time.[55] Additionally, in a subset of older women, a relationship between perceived sleep quality and sleep onset was suggested, with poor sleepers tending to have a longer sleep latency compared to good sleepers.[54]

Sleep Duration

Nine studies provided data on sleep duration in the elderly.[47,48,50–52,54,55,57,61] One study[61] found that healthy older subjects sleep 2.4 hours less per 24 hours compared to younger individuals, suggesting that sleep duration decreases with age but stabilizes after the age of 60. Sleep quality is closely associated with TST, with poorer sleepers having shorter sleep durations compared to good sleepers,[54] though this trend was confirmed primarily in older women. A study comparing body temperature and circadian rhythm in a small sample of healthy 70-year-old individuals reported that women tended to sleep less than age-matched men (7.3 vs 7.8 hours), showing earlier sleep onset associated with a phase advance in the acrophase of body temperature, and a concomitant reduction in sleep quality.[55] Conversely, the study by Vitiello et al,[57] which analyzed both PSQI and PSG data in a larger cohort of older adults (late 60s), found longer total sleep time (TST) among women compared to men. It is noteworthy that the first study was conducted in 1994, whereas the latter was performed about a decade later and reported an overall reduction of approximately one hour of sleep in both sexes (6.4 hours in women and 6.1 hours in men).

Moreover, interesting relationships between sleep duration and aging trajectories were analyzed by a few studies,[47,50,52] which found that both shorter and longer sleep durations were associated with unhealthy aging, highlighting a non-linear (inverse U-shaped) relationship between sleep duration and aging. From a gender perspective, contrasting findings have been reported. One study revealed that women had longer TST,[57] while another observed that women had shorter sleep durations than men.[55]

Sleep Continuity and Efficiency

In the aging population, sleep is characterized by less continuity and efficiency, as confirmed by several studies,[44,54,57] which consistently found that older subjects spent more time awake during the night, with this effect being more pronounced in women.[54,56] Notably, these changes do not necessarily correlate with subjective complaint about sleep quality: one study[57] examining a cohort of 150 healthy older adults (mean age 67.5±0.5 years) using both objective (PSG) and subjective (PSQI) assessments confirmed a marked reduction in sleep efficiency (mean 82.2±0.7% vs 94.8±0.5%) and sleep continuity (WASO 64.3±3.1 min vs 15±2.9 min) in both sexes. Notably, women exhibited a greater discrepancy between objective and subjective measures, suggesting that conventional self-reported tools such as the PSQI may have limited predictive accuracy in detecting subclinical or latent sleep disturbances in this population.

Sleep Architecture

Several studies reported data on sleep architecture,[45,46,51,53,54,56,57,61] collectively highlighting the age-related effects and showing a general trend for a reduction of SWS and alterations in REM sleep among the elderly, with more fragmented patterns. Specifically, whilst SWS anomalies do not allow for a specific characterization of pathological aging, REM-related parameters and in particular REM density appear more specifically indicating unhealthy sleep, with REM density being a strong predictor of cognitive decline.[62] One study[51] found that aged subjects spent more time in stage 1 sleep, while time spent in stage 2 or SWS and in REM was reduced. From a gender perspective, aged men tended to spend more time in REM sleep than aged women, with shortened REM sleep latency observed in elderly men but not women. Another study[61] observed no differences in SWS between older and younger subjects but noted fewer REM sleep minutes in older subjects.

These changes in sleep architecture are paralleled by age-related changes in hormonal status. The increase of stress hormones, including cortisol, is paralleled by the profound decline of anabolic hormones dehydroepiandrosterone and its sulfate derivative (DHEA and DHEAS), testosterone, estradiol, growth hormone (GH), and insulin growth factor-1 (IGF-1) concentrations, resulting in a net increase of catabolic/anabolic ratio.[51] The main change of this hormonal imbalance affects the HPA axis activity and includes an altered function of hippocampal corticosteroid receptors. There is a profound relationship between these changes in HPA activity and the individual circadian rhythm.[51] Besides hormonal changes, other factors that might be involved in these profound changes in the sleep architecture include progressive cortical thinning, neurodegenerative processes, age-related retinal changes with subsequent limited exposure to light signals, progressive accumulation of waste materials within the brain parenchyma, and other processes.

Of note, changes in sleep architecture correlate with cognitive function, as reported by a longitudinal study with 14 years of follow-up,[45] which found that healthy old subjects with successful aging and good cognitive performances had longer REM latencies, higher REM density, and spent less time in REM sleep. Curiously, the authors also found that a greater number of NREM shifts were associated with healthy aging.[45]

Finally, gender differences also emerged as significant factors in understanding sleep architecture-related changes with age, with less SWS observed in healthy old men compared to women.[57]

Daytime Sleep and Napping

The frequency of diurnal naps significantly increases in later life, with 10% of adults and 25% older subjects reporting the occurrence of daytime naps.[63] Of note, across older age groups, roughly half of these naps are unplanned, suggesting an important link between napping and excessive daytime sleepiness.

Among the included studies, four reported data on daytime sleep and napping in the elderly.[42,44,50,52] One study[42] found no differences in daytime rest timing between nappers and non-nappers, with no differences in overall locomotor activity, although, as expected, nappers reported a higher daily nap frequency and had longer daytime rest periods. Nappers also exhibited higher sleep efficiencies and a greater proportion of REM sleep during daytime naps compared to nighttime naps, suggesting that napping may have a beneficial effect on sleep quality and efficiency. However, nappers also presented a decrease in the melatonin peak compared to non-nappers, suggesting that napping might influence an altered circadian regulation. Interestingly, napping does not seem to have an impact on the timing of melatonin peak onset in the investigated subjects.[42]

Whereas significant changes in the sleep onset and duration were observed in the elderly, with a general tendency towards an advanced circadian rhythm, no differences in the timing of daily naps among age groups could be found.[42] As such, while the 24-hour sleep duration may decrease with age, the propensity or preference for napping does not significantly change.

Finally, one study[51] suggested that longer daytime naps (over 60 minutes/day) were linked to reduced odds of achieving successful aging, suggesting a negative impact of excessive daytime napping on sleep quality and overall health.

Chronotype and Circadian Rhythms

Two studies[42,61] addressed chronotype and circadian rhythms in the aging population, offering insights into the patterns and implications of circadian preferences and biological rhythms in older adults. One study[61] consistently found that circadian sleep propensity was phase-advanced in older adults, with peak sleep tendency occurring 2–3 hours earlier. This study highlights the shift in circadian rhythms that accompanies aging, leading to earlier sleep and wake times. Another study comparing older subjects with and without daytime napping[42] observed no differences in Morningness-Eveningness Questionnaire scores between nappers and non-nappers, nor in the timing of melatonin peak between the two groups.

Sleep Quality

Several studies have explored sleep quality in the elderly.[44–46,48,51,53,56–58,60] Older subjects tend to report poorer sleep quality than younger individuals, with sleep quality correlating with the odds of successful aging. Elderly people reporting poor sleep at least five days per week have a lower likelihood of experiencing healthy aging.

Furthermore, subjective sleep quality, as seen by increased variability in Pittsburgh Sleep Quality Index (PSQI) scores, is comparable to objective sleep measurements: the elderly with poorer sleep quality are more likely to have a greater number of short arousals and a higher mean Apnea-Hypopnea Index.

Also, of note, sleep quality, as measured through the PSQI, exhibits satisfactory stability over time, with only minimal variations with time (around 0.1±2.5 points of variation after 16±5 months of follow-up), according to a longitudinal study analyzing 91 non-complaining subjects with a 16±5-month follow-up.[59] Notably, a high percentage of aged patients (26% of males and 34.5% of females) did not complain about any sleep disturbances, although they presented abnormal PSQI results (>5), probably reflecting an adaptation in the perception of disturbed sleep.

Finally, from the gender standpoint, one study[55] revealed gender differences in sleep satisfaction linked with the acrophase of peak body temperature, with women being phase-advanced by 1.25 h (mean value) compared to men, reporting a lower satisfaction rate, which suggests a close relationship between circadian changes and perceived sleep quality. In a study based on a sample of old women only,[54] it was noted that poor sleepers had later bedtimes, longer sleep onset times, and reported more psychological symptoms, such as anxiety and depression, highlighting the impact of psychological factors on sleep quality.

Comparison Between Sleep-Related Objective and Subjective Measures

Only three studies[54,56,57] performed a comparison between sleep-related objective and subjective measures, reporting contrasting findings. While one study[56] failed to compute significant correlations between objective and subjective features in the elderly, other studies[57] detect significant correlations between the subjectively perceived sleep quality, assessed through PSQI, and time in bed, TST, WASO, SE, and sleep latency.[54]

Discussion

The present scoping review systematically investigated the intricate, non-linear relationship between sleep and healthy aging, highlighting the multifaceted nature of sleep changes and their implications on aging trajectories and outcomes (pictorially depicted in Figure 2 and summarized in Table 1, fully reported in Supplementary Table 1).On the one hand, the synthesis of findings from diverse geographical regions, populations, and study designs emphasizes the universal relevance of sleep in the context of aging, underscoring, on the other hand, the need for a nuanced understanding of sleep in older adults. This is the first step to contextualize the findings related to sleep patterns, duration, continuity, architecture, and quality.

The review reveals consistent findings of an advanced sleep phase in older adults across different cultures, with earlier bedtimes and wake-up times. This pattern is linked to various factors, including gender, with women tending to

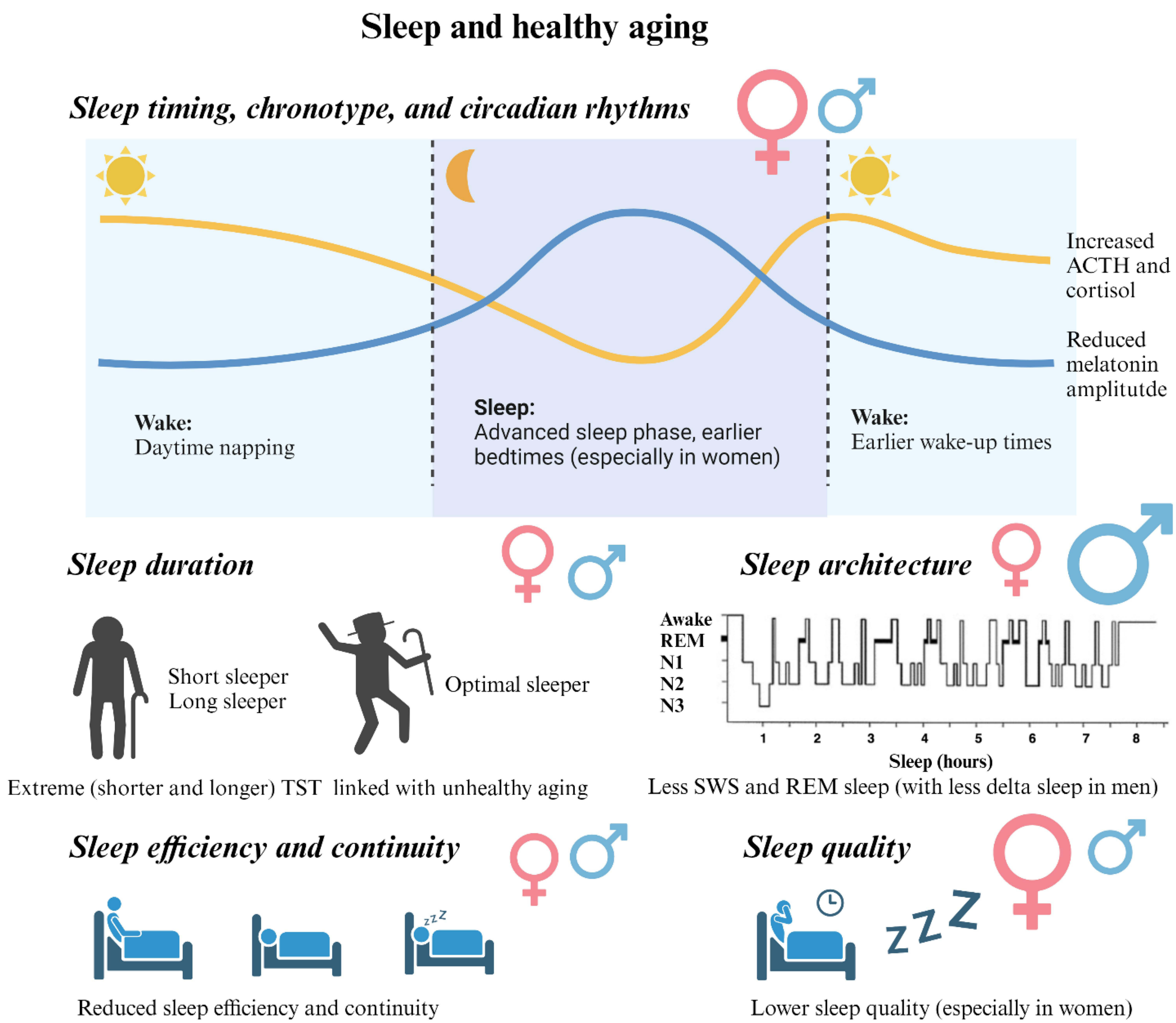

Figure 2 The relationship between sleep patterns, chronotype, circadian rhythms, and their impact on healthy aging, with specific insights into gender differences.

wake up earlier. A reciprocal relationship between sleep duration and sleep quality was also suggested, where poor sleepers presented with later sleep-onset. Noteworthy, the relationship between sleep duration and healthy aging outcomes indicates a U-shaped association, where both shorter and longer sleep durations can be detrimental, suggesting an optimal range conducive to healthy aging.

Sleep continuity and efficiency are found to decrease with age, with more pronounced effects in women, although findings on gender differences remain fuzzy. The impact of aging on sleep architecture is evident in the reduction of SWS and alterations in REM sleep, with potential implications for cognitive functions. The role of gender in these changes is also highlighted, with differences in REM sleep patterns and SWS between men and women.

Daytime sleep and napping emerge as significant aspects of sleep in older adults. Findings suggest that napping may improve sleep quality and efficiency. Additionally, napping has concomitant circadian implications. Furthermore, excessive daytime napping is linked to reduced odds of successful aging. Chronotype and circadian rhythms also shift with age, leading to earlier sleep and wake times, with implications for sleep propensity and circadian preferences, but also towards perceived sleep quality.

Finally, subjective sleep quality is a critical factor in healthy aging, with older adults often reporting poorer sleep quality compared to younger individuals. A higher tolerability for disturbed sleep with aging was also suggested, with an elevated percentage of non-complaining old subjects, especially women, with above-threshold PSQI results. This might also suggest the poor applicability of this screening tool among the elderly. The relationship between sleep quality and successful aging is underscored, with poor sleepers having lower odds of experiencing healthy aging. Gender differences in sleep satisfaction and the impact of psychological factors on sleep quality are also notable, pointing to the complex interplay between psychological well-being and sleep in older adults. The comparison between objective and subjective sleep measures reveals contrasting findings, indicating the need for careful consideration of both types of measures in sleep research among older adults, as previously mentioned. The lack of significant correlations in some studies suggests potential discrepancies between perceived and actual sleep quality, highlighting the complexity of assessing sleep in aging populations.

Knowledge Gaps and Future Research Directions

The present scoping review on the relationship between sleep and healthy aging reveals several critical gaps in the current literature, pointing to key areas for future research. These gaps not only highlight the need for a deeper understanding of specific aspects of sleep in the context of aging but also underscore the potential for developing targeted interventions aimed at enhancing sleep quality and, by extension, promoting healthy aging outcomes.

A first limitation encountered in summarizing the reviewed evidence is the heterogeneity of the older population samples studied and the definition of healthy aging, which spans from the use of disease-centered aging models, often focused on the presence of neurological disorders, to multidimensional ones. This means, considering such a wide age range, that the aging trajectories of the subjects included in these studies can be extremely variable, influenced by multiple interfering factors of a bio-psycho-social nature, and therefore, not so easy to study in relation to the effect of sleep and its properties.

Another relevant gap concerns longitudinal data on sleep patterns: there is, indeed, a notable scarcity of studies tracking sleep patterns over time in the same individuals. Such data would be of paramount importance to understand the trajectory of sleep changes with aging and their long-term impact on health outcomes. The underlying biological mechanisms linking sleep changes with aging processes also remain inadequately explored. Future research should aim to elucidate the pathways through which alterations in sleep architecture, duration, and quality impact physical, cognitive, and psychological mental health in older adults. Furthermore, the impact of daytime napping and its role in healthy aging is still not fully understood, with conflicting findings on its benefits versus potential drawbacks. Research clarifying the optimal duration and timing of naps could inform guidelines for healthy sleep practices in older adults.

Moreover, mixed findings on gender differences in sleep patterns, continuity, and architecture indicate a gap in gender-specific research. Detailed studies focusing on the distinct sleep needs and challenges faced by older men and women are needed to tailor interventions appropriately.

Another important limitation of our study relates to age heterogeneity among the included participants. Although it is plausible that differences in sleep quality and/or quantity may vary across age groups (for instance, between individuals in their 60s and those over 80), most of the included studies did not report sufficiently detailed age-specific data to enable such stratified analyses.

In terms of cultural and ethnic considerations, while the present review includes studies from diverse geographic locations, there is a need for more comprehensive research exploring societal and cross-cultural differences in sleep patterns and their implications for healthy aging, since the confounding effect of other determinants of healthy aging is not well addressed in the included studies.

Furthermore, several of the included studies were conducted many years ago, with key investigations dating back to the 1990s and early 2000s. Given the profound societal and technological transformations that have occurred since then, such as changes in lifestyle patterns, work schedules, exposure to artificial light and screens, and the pervasive influence of electronic devices, the sleep behaviors and environmental exposures of contemporary older adults may differ considerably from those observed in earlier cohorts. Consequently, the generalizability and current relevance of some of these findings should be interpreted with caution.

Additionally, we limited our observations to subjective findings and macrostructural changes in sleep architecture, although we acknowledge that aging is also accompanied by numerous and central alterations at the microstructural level. These include variations in cyclic alternating patterns (CAPs), SWS amplitude, and other electrophysiological features, which may play a pivotal role in shaping the cognitive and psychological consequences of disrupted or altered sleep in this population.

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Finally, the discrepancies between subjective reports and objective measures of sleep among older subjects highlight a gap in understanding the factors contributing to these differences and potentially suggest the need for the development and validation of more sensitive and contemporary assessment tools capable of accurately capturing sleep quality and related changes in advanced age. Further research could explore the reasons behind these discrepancies and their implications for sleep assessment and intervention.

Considering these evidence limitations and gaps found in the literature, the use of older population samples that are homogeneous in terms of age and aging trajectories, with stratification based on multidimensional models, could contribute to improving the methodological consistency of future studies aimed at investigating the role of sleep as a determinant of aging.

Clinical and Practical Implications

The findings of this scoping review hold significant implications for clinicians, public health stakeholders, and older individuals themselves. For healthcare providers, awareness of the physiological yet heterogeneous nature of sleep changes in aging is essential for distinguishing normal variations from early signs of pathological decline, particularly in cognitive and affective domains. Integrating objective assessments such as PSG or actigraphy with validated subjective tools could enhance diagnostic precision and guide individualized sleep management plans. Beyond descriptive observation, these results should be interpreted in light of the growing body of evidence on interventions for sleep improvement in older adults.[64] Behavioral and lifestyle-based strategies, mindfulness and relaxation practices, structured exercise programs, music therapy, and manual approaches like massage or acupuncture have shown measurable benefits on sleep onset latency, sleep efficiency, and WASO, while also enhancing psychological and functional outcomes.

For public health professionals, promoting these approaches through education, prevention, and accessibility programs could represent a sustainable and cost-effective strategy. Community-based initiatives encouraging regular sleep–wake schedules, exposure to natural light, and moderate physical activity may help maintain circadian stability and overall well-being. Furthermore, embedding sleep optimization within broader multimodal interventions, targeting mental health, cognitive preservation, and chronic disease prevention, could foster a comprehensive framework for active and functional aging.

Finally, for aging individuals, increasing self-awareness of sleep behaviors and adopting lifestyle modifications, including daily exercise, cognitive stimulation, and structured relaxation routines, can mitigate age-related sleep disruptions and preserve well-being. Digital self-monitoring tools and technology-assisted feedback may further improve adherence and empower older adults to actively manage their sleep health. Collectively, these insights underscore the necessity of translating emerging scientific knowledge into actionable, person-centered interventions that combine clinical assessment, behavioral therapy, and community engagement to support restorative sleep and healthier aging trajectories. To this end, a multidisciplinary approach based on the collaboration between sleep medicine experts and geriatricians could provide the decisive impetus for an increasingly comprehensive evaluation of sleep health in older individuals.

Conclusion

Overall, this review underscores the critical importance of sleep in the context of healthy aging, calling for a comprehensive approach to understanding and addressing sleep-related issues in older adults. Future high-quality, community-based research, leveraging longitudinal frameworks and employing multidisciplinary approaches that coherently combine and integrate insights from sleep science, gerontology, psychology, and technology, is needed to eventually develop comprehensive assessments and holistic interventions that address the multifaceted nature of sleep in aging.

This would pave the way for personalized sleep management in the aging population, investigating the potential for strategies that consider individual differences in sleep patterns, preferences, and responses to interventions. Data from studies could inform policy and public health initiatives aimed at promoting healthy sleep habits among older adults, considering the broader socio-economic and environmental factors influencing sleep.

By addressing these gaps and pursuing the suggested future directions, research can significantly advance our understanding of the complex relationship between sleep and healthy aging, ultimately leading to more effective strategies for promoting optimal sleep and aging outcomes.

Data Sharing Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Author Contributions

NLB: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Software; Validation; Visualization; Writing - original draft, Writing - review & editing; CM: Formal analysis; Writing - original draft; Writing - review & editing; PLR: Writing - original draft; Formal analysis; Writing - review & editing; AS: Formal analysis; Writing - review & editing; MCQ: Formal Analysis; Writing - review & editing; RL: Formal analysis; Writing - review & editing; FP: Conceptualization; Writing - review & editing; FB: Conceptualization; Writing - review & editing; DB: Formal analysis; Writing – review & editing; MS: Conceptualization; Writing - review & editing; MM: Conceptualization; Writing - review & editing; LP: Conceptualization; Writing - review & editing; GP: Conceptualization; Writing - review & editing; CF: Conceptualization; Validation; Writing - original draft, Writing - review & editing. All authors gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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