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# The relationship between sleep quality and quality of life in aging: a systematic review and meta-analysis

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**Abstract**

This study examined the available literature concerning the association between sleep quality and quality of life (QoL) in autonomous older people with no sleep disorders. A systematic review and meta-analysis were conducted on studies identified in the PsychInfo, PubMed and Scopus databases that examined the associations between QoL and sleep quality in older adults. Our systematic literature search identified 23 studies concerning a total of 21,092 participants (range of mean ages: 58-79 years). The results showed that self-reported sleep quality, but not objective sleep quality, correlated positively with QoL with a moderate effect size (for self-reported sleep quality, the overall estimate of the average effect size was a Pearson’s *r*=.28 [95% CI: .34, .23]; for objective sleep quality, it was*r*=.01 [.12, -.09]). This also applied to the main domains of QoL concerning physical and psychological health, social relationships and environmental aspects (the estimated average effect sizes ranged from Pearson’s *r*=.13 to *r*=.35). These findings highlight the influence of sleep quality, and particularly of self-reported sleep quality, on QoL (as a whole and in its specific domains) in older adults with normal aging and no insomnia. This influence should therefore be investigated systematically when examining QoL.

**Keywords:** Aging; Quality of Life; Sleep; Meta-analysis

## Introduction

Sleep occupies a large part of our lives, and sleep quality is a fundamental indicator of an individual's health and day-to-day functioning throughout the lifespan (Grandner, 2012; Buysse, 2014).Sleep problems and negative changes in sleep patterns and quality can have a harmful influence on various life/health domains, such as physical and mental health and daytime functioning (Cavuoto et al., 2016; Hughes et al., 2018),affecting individuals' overall self-reported quality of life (QoL; WHO, 2004). They are associated with a higher risk of developing various poor health outcomes, including organic diseases such as cancer (Song et al, 2020) or diabetes mellitus (Yaggi, Araujo, & McKinlay, 2006), or cognitive and functional disorders such as mild cognitive impairment or Alzheimer's disease (D'Rozario et al., 2020), all of which are more common in older adults.

It is wellknown that aging is also characterized by a greater risk of developing chronic health conditions that interfere with older adults' functioning in daily life. The physical and physiological changes that go with aging become more predominant in advanced age (Ward, Schiller, & Goodman, 2014), and can raise the risk ofindividuals developing not only vulnerabilities and limitations on theirfunctional independence, but also of developing sleeping problems - such as a greater difficulty initiating and maintaining sleep (Mander, Winer, & Walker, 2017), as often reported by older adults. As the chronic diseases more common in older adults, even if they are aging normally (National Institute on Aging, the National Institutes of Health, 2011), are frequently associated with both sleep disturbances and various negative health outcomes (Wai & Yu, 2020; Zhang, & Zhao, 2007, Neikrug &Ancoli-Israel, 2010; Stepnowsky&Ancoli-Israel, 2008), the link between sleeping poorly and subsequently experiencing a worse subjective QoL may change, and become stronger as people grow older.On the other hand, it is still unclear whether and to what degree a better-quality ofsleep could sustain a better QoL in community-dwelling older people with no diagnosed sleep disorders.There is a need to clarify the importance of sleep to the everyday QoLof older adults by concurrently examining factors moderating this relationship, such as age (which has not been done in the available literature). The present systematic review and meta-analysis thus aimed to estimate the magnitude of the relationship between sleep quality (measured objectively and subjectively) and QoL in the community-dwelling elderly.

Many older adults report changes in their sleeping patterns and circadian rhythms, which can affect their sleep quality, often starting in middle age and increasing as they get older (Espiritu, 2008; Martin &Ancoli-Israel, 2008; Ancoli-Israel, 2009). We know that the prevalence and severity of diagnosed sleep disorders such as insomnia, sleep apnea syndrome or periodic limb movements markedly increase in older age (Neikrug &Ancoli-Israel, 2010; Stepnowsky&Ancoli-Israel, 2008), often in combination with neurodegenerative conditions such as dementia (e.g., Min &Slattum, 2018). Among the changes in sleep with older age there are objectively-measurable shorter periods of slow wave sleep (SWS) and rapid eye movement (REM) sleep, a longer sleep onset latency (SOL) and more episodes of waking after sleep onset (WASO), and an increase in the lighter stages of sleep (Ohayon, Carskadon, Guilleminault, &Vitiello, 2004; Manderet al., 2017). Though these changes in sleep structure are part of the aging process (Ohayon et al., 2004; Ohayon et al., 2017), objectively-recorded sleep parameters and self-reported sleep problems are often variously associated with health status and daytime functioning, especially in older people (Hughes et al., 2018). For instance, an objectively-recorded poor sleep quality, including short sleep duration or other changes in sleep structure as mentioned above, has been associated with poor daytime functioning (Goldman et al., 2007; Spira et al., 2012), and nursing home placement (Spira et al., 2012).Self-reported poor sleep quality – when individuals do not feel rested on waking and generally satisfied with their sleep (Buysse, 2014) - is associated with a greater recourse to healthcare (Kaufmann et al., 2013), and greater functional dependence in older adults (Spira et al., 2014). The detrimental effects of self-reported and objectively-measured poor sleep quality on older adults' health and daytime functioning often differ, however, in people with insomnia (Kay, Buysse, Germain, Hall, & Monk, 2015), especially when they are elderly (Neikrug &Ancoli-Israel, 2010; Stepnowsky&Ancoli-Israel, 2008). A better way to examine sleep quality in older age is to consider this construct as an individual's changing behavior in relation to various sleep parameters, which can be measured using both objective and subjective methods to generate us complementary information. No studies have yet produced a comprehensive summary of the relations between objective and subjective sleep quality in association with the QoL of older people with no known sleep disorders or other chronic diseases. It is also worth mentioning that sleep quality and sleeping difficulties are assessed using a variety of subjective (e.g., questionnaires or sleep diaries) and objective methods (e.g., actigraphy or polysomnography) that can have a different, but complementary role for the purpose of examining the relationship between sleep quality and QoL in older people. This means that an integrative review of studies using objective and subjective sleep measures of sleep quality is needed to:i) identify which reliable, valid and informative measures and protocols should be included in assessments of sleep health; and ii) better estimate the contribution of different aspects of sleep quality to older adults' QoL, also from a practical/applied perspective.

The World Health Organization (WHO) defines quality of life (QoL) as a complex multidimensional construct (Lawton, 1991; Bowling et al., 2015; WHO, 2004) that encompasses our perceptions of various life domains in relation regarding our goals, expectations, standards and concerns (WHO, 2004). QoL is not merely a question of health or the burden of disease, which basically concerns health status, clinical symptoms, or functional abilities (Karimi & Brazier, 2016), it is also an estimation of the quality of other relevant life domains (WHO, 2004). QoL derives from a personal assessment of such various and multifaceted domains (Skevington,Lotfy, & O'Connell, 2004; WHO, 2004) as our: physical health (e.g., physical pain, medical treatment, energy for daily activities); psychological health (e.g., emotional resources, cognitive capabilities, self-esteem); social relationships (e.g., satisfaction with personal and social relationships); and environment (e.g., features of the home, opportunities for and participation in leisure activities).

Because sleep quality affects different life domains (especially those related to health), it is among the factors that have been examined when characterizing older adults' QoL (e.g., Schubert et al., 2002).

A significant body of research, reviews and meta-analyses (e.g., Min &Slattum, 2018) has confirmed the relationship between sleep quality and QoL in older adults with sleep disorders (Schubert et al., 2002). For healthy-aging older adults with no neurodegenerative disorders (though they may have some chronic diseases), and with no insomnia or other sleeping disorders, this relationship between sleep quality and QoL has been less thoroughly examined. This is rather surprising, since clarifying this relationship could generate applied and clinical information to help promote active aging, which is among the WHO's priorities (Agenda 2020-30; WHO, 2020). The present study aims to fill this gap. The few studies on the matter found that autonomous older adults with a self-reportedly worse sleep quality (i.e., presence of sleeping difficulties but not insomnia) also had a worse QoL. This was true of their QoL as a whole, and in its physical and psychological domains (Olds et al., 2016; Grossman, Shrira, & Bodner, 2016; Rashid, Ong, & Wong, 2012; Lo & Lee, 2012; Uddin, Soivong, Lasuka, &Juntasopeepun, 2017; Driscoll et al., 2008), or social and environmental aspects (Tel, 2013). On the other hand, older adults' objective sleep parameters do not appear to be related to their QoL (Driscoll et al., 2008).

Although existing evidence extensively supports the relationship between sleep quality and QoL in clinical samples of older people with sleep disorders like insomnia, or with neurodegenerative disorders, considerably less attention has been paid to elucidating this link in autonomous, active, older adults in the general population (the WHO's definition of active aging can also include people with chronic diseases [WHO, 2002]). There is now a sufficient (and growing) body of research showing that sleep quality has a fundamental influence on health and everyday life functioning for active and healthy-aging older people too. The available evidence (Olds et al., 2016; Grossman et al., 2016; Rashid et al., 2012; Lo & Lee, 2012; Uddin et al., 2017; Driscoll et al., 2008) would suggest a significant association between self-reported sleep quality and QoL, and all its main domains, in actively aging people with no sleep disorders. As mentioned before, a review of all the various measurements used in studies assessing sleep (be it self-reported and objectively-measured) and QoL instruments in older adults has also become necessary.It is still unclear, however, whether and to what degree self-reported and/or objectively-recorded sleep quality relateto QoL in older people with no diagnosed sleep disorders.

Surprisingly, no systematic reviews or meta-analyses on the relationship between sleep quality and QoL (and its domains) in older adults with no known sleep disorders or neurocognitive impairments have ever been conducted to summarize the findings, and examine the strength of this association. This was the main aim of the present study.

Reviewing previous research, the literature appears highly heterogeneous in terms of the methods used to assess sleep and QoL in older people, and it not always focused on these two health constructs. Previous studies show that the strength of the correlations between sleep and QoL (and across different life domains) changed when sleep quality was measured subjectively or objectively. As stressed earlier, no systematic reviews or meta-analysis to date have produced a complete picture of this relationship in healthy-aging older people. The present study thus also tried to fill a knowledge gap concerning subjective and objective sleep measures, and their relationship with QoL, by providing an integrative summary of the results obtained in the aging literature when these two types of measure were used to examine the associations between sleep quality and QoL.

Therefore, themain objective of the present study was to run a systematic review and meta-analysis to assess the relationship between sleep quality and QoL in autonomous, active older adults with or without any chronic diseases, but with no sleep disorders (e.g., sleep apnea or insomnia). We focused on: (i) studies assessing QoL (and its domains) and both self-reported and objective measurements of sleep quality; and (ii) the relationship identified between sleep quality and older adults' overall QoL. We also examined: (iii) the moderating effects of the different QoL domains (physical and psychological health, social relationship, and environmental), and of age. This last factor was considered, as mentioned earlier, because aging is associated with a rising prevalence of chronic diseases that mayinfluence both sleep quality and QoL, thus potentially increasing the shared variance between the latter two factors in older adults. Here again, no studies have addressedthis issue using age as a moderator to try and catch its complexity, and the changes occurring at different levels (i.e.,general health, physicalor psychological states, and so on). Given these premises, age could be expected to moderate the relationship between sleep and QoL in healthily-aging people as well, but this role of aging *per se* has yet to be investigated in detail. This study therefore aimed to test whether the effects of a poor sleep quality on older adults' QoL (and its domains) differs as a function of age.

## Methods

### *Study eligibility criteria*

The present systematic review and meta-analysis were performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis statement (PRISMA; Moher et al., 2015; Liberati et al., 2009). A systematic literature search was conducted, considering studies correlating QoL, and the main domains of QoL (i.e., psychological and physical health, social relationships, and the environmental domain) with self-reported and objective sleep quality in active, autonomous older adults aging normally, with no sleeping disorders.

All the studies considered met the following *a priori* inclusion criteria: i) participants: normally- or healthy-aging, autonomous adults over 50 years old with no clinical sleep disorders (e.g., insomnia or sleep apnea), and no diagnosed mood or psychiatric disorders, cognitive impairments or signs of incipient dementia; ii) measures of interest reported: QoL (and its domains) and sleep quality, specifying the self-reported and objective sleep parameters considered; and; iii) any type of study design (see Table 1S). The lower age limit of 50 years was chosen partly because marked changes in sleeping patterns and sleep quality tend to occur from this age onwards (Espiritu, 2008; Martin &Ancoli-Israel, 2008; Ancoli-Israel, 2009). Another reason was because people may retire already in their fifties in some countries (OECD, 2018; Nogueira et al., 2018). To note, only two studies used in our analysis included a sample of adults aged 50 and older. The weighted mean age of the samples considered was 68.97 years, however. Our exclusion criteria concerned: i) clinical populations (e.g., older adults with chronic diseases and/or conditions); and ii) single animal studies, single case studies, qualitative studies, books, commentaries, or meta-analyses and reviews (see Table 1S).

***Search strategy and data collection***

A comprehensive literature search for relevant peer-reviewed articles was undertaken in April 2019, and updated in December 2019, using three electronic databases - Scopus, PsychInfo, and PubMed - and considering publications in English, Spanish, Portuguese, and Italian. There was no limitation on the date of publication (up until November 2019). The search strategy was based on the following terms: (“sleep” OR “quality of sleep” OR “sleep quality” OR “sleep difficult*” OR “insomnia”) AND (“older adult*” OR “healthy older adult*” OR elderly OR “healthy elderly” OR “elderly people” OR “ageing” OR “normal ageing” OR “normal aging”) AND (“quality of life”). Specifically for PubMed, broad search terms were combined with quick search and medical subject headings (MeSH): (“aged” OR “aged”[mh] OR “old”) AND “quality of life”[mh] AND “sleep”[mh]). The complete search algorithm with the keywords for each database is available from the authors on request.

To include all available information useful for the purposes of the present systematic review and meta-analysis we also checked all potentially eligible studies to search for any sub-sample of healthy elderly people (i.e., in the case of experimental studies including at least one healthy control group), or samples with broad age ranges (i.e., the adult lifespan), but reporting separate statistics for the elderly. Then, we coded all useful information (see below for coding of the effects) or contacted the corresponding authors to obtain an estimate of the relationship between sleep quality and QoL in the healthy older adults involved in such studies. This approach also enabled us to reduce the publication bias.

All potential references identified were input in the Zotero citation management software (Roy Rosenzweig Center for History and New Media, 2016) and deduplicated. After the literature search, three independent reviewers were involved in the study selection and assessment processes. Two review authors (ES, LM) independently screened the titles and abstracts of the articles retrieved for eligibility. Data were extracted independently by these two reviewers, recording: authors and year of publication; demographic characteristics of the samples (mean age, proportion of females); QoL measures; sleep quality measures (i.e., self-reported and/or objective); and the proportions of "poor sleepers" (if applicable) (see Table 1). Any disagreements were discussed until a consensus was reached.

***Quality assessment on the studies included (risk of bias)***

The methodological quality of each eligible study was examined using an adaptation of the Joanna Briggs Institute Critical Appraisal Checklist for assessing the risk of bias (see Munn, Moola, Riitano, &Lisy, 2014). As the present study focused on the relationship between QoL and sleep quality in older adults, we adapted the checklist, identifying five main criteria for critical appraisal of the following potential sources of bias: i) the inclusion criteria for selecting participants; ii) details of the subjects and the study setting; iii) the instruments used to assess QoL (e.g., scales or questionnaires); iv) those used to measure sleep quality; and v) the adequacy of the statistical analysis for estimating the relationship of interest for the purposes of the present study. As an example of this fifth criterion, we considered whether reporting the correlations of interest (correlation matrix) was associated with a lower risk than deriving them from another effect size. In accordance with the JBI Reviewers' Manual (Joanna Briggs Institute, 2016), and before any critical appraisal of the single studies, a scoring system was agreed by all three reviewers. The following cutoffs were adopted: (i) the risk of bias was "low" if studies scored a "yes" on more than 70% of the items; (ii) it was "moderate" if the answer was "yes" for between 50% and 69% of the items; and (iii) it was high if the items scored as "yes" were less than 49%. Two authors of this review

(LM, ES) independently rated each study for significant bias as low, moderate, or high risk on each item. In the case of disagreements, a third author (ET) examined the data included by the other two reviewers (see Table 2S). A quality assessment was subsequently used as a moderator of the association between sleep quality and QoL, to see whether studies with a different risk of bias led systematically to different estimates of the effects.

***Statistical analysis***

**Coding of the effects**

As a first choice, Pearson's correlations between measures of sleep quality (self-reported and objectively measured) and QoL (and its domains) were coded as the effect sizes of interest for each study. Where QoL was measured using a self-report tool (e.g., WHOQOL-Bref; Skevington et al., 2004) and different correlations were available for the tool's subscales, these were coded instead of the global score because they were useful for a subsequent moderation analysis. For studies not reporting the correlations of interest, the corresponding authors were contacted to ask for an *ad hoc* analysis. When correlations were unavailable and could not be retrieved from the authors, we estimated the effect sizes from other indicators. Standardized regression coefficients, where reported, were coded as an alternative to correlations. Since our literature search also revealed several studies that used a categorical approach to defining sleep quality and QoL, effect sizes could also be derived from standardized differences (e.g., Cohen's *d*), and odds ratios (including those calculated from contingency tables). Specifically, we considered cases in which participants were grouped by sleep quality (e.g., "good vs poor sleepers" -without diagnosed sleep disorders- based on a median split or another cutoff in the distribution, or complaints about sleep, or subjectively-judged unsatisfactory sleep quality), and QoL (e.g., based on a median split). Though these effect sizes use different metrics, they all represent estimates of how sleep quality relates to QoL in the general older adult population (the object of our systematic review and meta-analysis), and they were converted into Pearson's correlation using the formulas suggested by Borenstein et al. (2009) before computing the meta-analytical estimates.

Each effect size was coded on a different row of the dataset, considering: type of effect, e.g., correlation, standardized difference, odds ratio; type of sleep quality measure, i.e., subjective or objective (and further specifying the objective measures: TST, SE, SOL, and waking after sleep onset [WASO]); type of QoL measure (its subscales were coded, if available). For effect sizes derived from group comparisons, the group definition criteria were coded (i.e., "good vs poor sleepers", with criteria or cutoffs, along with the number of participants in each group. Since there is no universally-adopted overall index of objective sleep quality, we considered all the objective sleep parameters commonly measured using actigraphy and polysomnography (see Table 2S). Where available, descriptive statistics (means, standard deviations) of the two groups' QoL were coded, as they served to calculate the between-group standardized difference (using Hedge's g formula, as proposed by Schwarzer, Carpenter, &Rücker, 2015).

The data extraction and data coding for the meta-analytic process was conducted entirely by the three authors of the review. The first rater (LM, a Ph.D. student at the time) obtained the necessary data from the studies considered. Then the second rater (ES, a Ph.D. student at the time) checked all the data extracted to confirm their accuracy. A third rater (ET, a postdoctoral researcher at the time) expert in research methodology for the psychological sciences handled all of the data coding for the calculation of the effect sizes of the relationships of interest. In the event of disagreements or discrepancies, the coding was decided by consensus among all the authors of the study.

**Analytical plan**

Our analytical strategy followed the guidelines of Borenstein et al. (2009), and Schwarzer et al. (2015). The R software (R Core Team, 2019), version 3.6.2, was used for all analyses, employing the "metafor" package (Viechtbauer, 2010) in R for the meta-analysis. This package implements functions that fit multivariate/multilevel random-effects models for meta-analysis, with or without moderators, using maximum likelihood estimation. A random-effects approach was adopted because it enabled us to deal with the predictably considerable heterogeneity among the studies being analyzed. The studies were treated as the random effects (see Borenstein et al. 2009, for the advantages of a random- over a fixed-effects approach). Briefly, a random-effects approach does not assume there is only one true effect size underlying all studies in a meta-analysis. Instead, it assumes that different studies reflect different underlying true effect sizes (due to different group compositions, instruments used, or other unknown moderators). Random-effects meta-analytical models thus aim to estimate the average value of the distribution of the true effect sizes.

Most of the studies reported more than one effect size for the same sample of participants, because several measures of QoL were used, for instance. Multilevel modelling (implemented in the "rma.mv" function of the "metafor" package in R) was used to deal with the resulting structure of dependencies among effect sizes, with observed effect sizes treated as observations clustered in studies. The covariance structure among the effect sizes was computed using the "clubSandwich" package (Pustejovsky, 2019) in R, assuming a correlation of .70 between effects within the same study. A sensitivity analysis conducted using any alternative correlation between .30 and .90 showed negligible variations in the final estimates. All effect sizes were converted into Fisher's Z scales before computing the meta-analyses. Effect sizes other than correlations were converted using the Borenstein et al. (2009) conversion schema, which also served to calculate the variances of the effects.

The risk of publication bias (i.e., the selective reporting of effects based on their significance) could be excluded *a priori* on theoretical grounds, as most of the studies did not focus on correlating QoL with sleep quality (or any other information from which the correlation was computed for our purposes) as the primary effect of interest. We nonetheless tested for publication bias for the sake of completeness. First we used the funnel plot with the "trim and fill" method (Duval, 2005), which adjusts the estimates based on the asymmetry observed in the distribution of the effects in the funnel plot, assuming that this asymmetry is due to underreporting of non-significant results in studies on small samples. The "trim and fill" method cannot be used on multilevel models because it cannot deal with dependencies among effects, so we applied it directly to the observed effects. Then we conducted the precision-effect test and the precision-effect estimate with standard errors (PET-PEESE; Stanley, 2017) test, which consists of two conditional meta-regressions in which the standard errors (PET) or variances (PEESE) are entered as moderators of the effect size. Despite some limitations, especially when the number of studies is small and there is marked heterogeneity, the PET-PEESE method has been shown to provide more reliable estimates than conventional meta-analyses in the presence of publication bias in psychological research (Stanley, 2017).

Meta-regressions were fitted to examine possible moderators of the relationship between QoL and sleep quality. The factors entered in the analysis included:  mean age of the sample (where it was available, or could be estimated; it varies only between-sample); QoL domain (physical, mental, social, and environmental; it varies mostly within-sample); type of effect size (correlation or group comparison; it varies only between-sample); and a study's risk of bias (low, moderate, high; it varies only between-sample). The latter two factors were considered only for methodological reasons. For the relationship between QoL and objective sleep quality, the same factors were considered (although not all the moderators could be meaningfully analyzed due to the very limited number of studies reporting this relationship), with the addition of type of sleep measure (SE, SOL, TST, WASO; it varies mostly within-sample). For better clarity, the moderating roles of the mean age of the sample and the risk of bias are presented in separate subsections in the Results section.

Finally, we tentatively corrected the estimated effect sizes for attenuation (e.g., Salkind, 2010). When measure reliability is not perfect (as in virtually any field of psychological research), the variables include some degree of random noise. The correlations between them are therefore always attenuated to some extent compared with the correlations between the underlying constructs. The proposed formula for correcting correlations for attenuation is (Salkind, 2010; cf. Spearman, 1904):

$$r_{xy} = \frac{r_{x'y'}}{\sqrt{r_{x'y'} * r_{y'y'}}}$$

where $r_{xy}$ is the true correlation between the underlying constructs; $r_{x'y'}$ is the correlation between the observed indicators x and y; and $r_{x'x'}$ and $r_{y'y'}$ are the reliabilities of the indicators x and y, respectively. We therefore coded the reliability indexes (Cronbach's alpha) of all the standardized scales, as explained in their respective manuals. Unfortunately, sleep quality was measured with single-item scales in many studies, which made the reliability assessment very difficult. Single item, self-report measures of general QoL and sleep quality may nonetheless have a good reliability in terms of test-retest stability. For example, Atroszko et al. (2015) reported coefficients of .86 for QoL and .81 for sleep quality in a large sample of university students. These values do not necessarily reflect the loading of any single-item scale on the latent construct, however. Rather, plausible loadings in structural equation modelling could be between .40 and .70. Since the issue of disattenuation was complex, it is examined in a separate section in the Results, where we calculated a series of plausible meta-analytical corrected estimates.

***Results of the literature search***

The results of our literature search are illustrated in Figure 1. A total of 2879 records remained after removing duplicate articles. Screening of titles and abstracts identified 192 eligible studies, which were reduced to 23 studies on the basis of our inclusion/exclusion criteria (see Tables 1 and 3).

***Characteristics of the studies included***

**Study design and participants**

The 23 independent studies analyzed in this systematic review and meta-analysis concerned a total of 21,092 participants considered for the present study (weighted mean age 68.97; range of mean ages across studies: 58-79 years). Twenty-one of the studies were cross-sectional, 2 were prospective, 2 were longitudinal, 1 was a randomized clinical trial, and 1 was a case-control study. Three of the last of these types of study were independent studies that included sub-samples of older adults obtained from "control groups" of healthy participants (i.e., Reynolds et al., 2010; Gooneratne et al., 2007; Li et al., 2014). The studies were conducted in several countries around the world: 11 in Asian countries, 6 in Europe, 5 in the Americas, and 1 in Australia (see Table 2S).

**QoL measures**

Self-report questionnaires were used to assess QoL in 22 studies, while 1 used a single *ad hoc* question posed by the authors (see Table 1). The most often used questionnaires were the World Health Organization Quality of Life questionnaires (WHOQOL-100 [WHO, 1998]), used in 1 study; the WHOQOL-Bref (Skevington et al., 2004), used in 8, which measure general QoL and its physical and psychological health, social relationships, and environmental domains; and the Short Forms of the Medical Outcome Survey (Ware &Sherbourne, 1992) - the SF-36 in 7 studies, and the SF-12 in 1 - which measure health-related QoL and its domains of physical and mental health. Since the above-mentioned measures also examine domains of QoL (i.e., physical and psychological health, social relationships, and the environmental domain), we included the associations between these separate domains and self-reported and objective sleep quality in older adults in our meta-analyses (see below). Another 3 studies used the Euro QoL-5 Dimensions, a standardized tool developed by the Euro QoL Group (1996) to measure QoL in terms of mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Though all these self-report questionnaires have been validated for use in healthy populations, the only one to have been validated specifically for assessing QoL in older people is the CASP-19 (Control, Autonomy, Self-Realization and Pleasure; Hyde et al., 2003), which was only used in 2 studies (see Table 1).

**Measures of self-reported and objective sleep quality**

The tools used to assess sleep quality included self-report questionnaires, *ad hoc* questions posed by the authors, and objective sleep measures. Among the self-report questionnaires, the PSQI (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) was the most widely used (in 10 studies). Other studies used: the Insomnia Severity Index (ISI; Bastien, Vallières, & Morin, 2001; 1 study); the Athens Insomnia Scale (AIS; Soldatos, Dikeos, &Paparrigopoulos, 2000; 1 study); the Sleep Disturbance Questionnaire (SDQ; Douglass et al., 1994; 1 study); and the Jenkins Sleep Scale (JSS; Jenkins et al., 1988; 1 study). All these questionnaires have been validated for both healthy and clinical populations, but none of them were specifically devised to assess sleep quality in older people. The remaining studies examined sleep quality using single *ad hoc* questions posed specifically to compare sleep quality in good versus poor sleepers (7 studies).

Four studies used objective methods to assess elderly people's sleeping patterns: using actigraphy (7 days of recordings) in 2 studies, and polysomnography (overnight recording) in 2. These studies examined the following objective sleep parameters: total sleep time (TST); sleep onset latency (SOL); waking after sleep onset (WASO); and sleep efficiency (SE); and comparisons could be drawn between the measures obtained with actigraphy and polysomnography. Details of each study are summarized in Table 1.

***Overview of the coded effects***

A total of 119 effect sizes were coded for the 23 studies. The median number of effects coded per study was 2 (range: 1 to 28, mean = 5.17) (see Table 3). Of all these effects, 101 were correlations, and 18 were group comparisons (including 15 standardized differences, and 3 odds ratios). Of the 23 studies, 14 reported at least one correlation. All 9 studies for which group comparisons were coded were of the "good vs poor sleeper" type. All but one of the studies included effect sizes involving self-reported sleep quality. Only 4 studies (Castro et al., 2013; Driscoll et al., 2008; Kume et al., 2017; Sella et al., 2021) included available effects involving objective sleep quality. As concerns QoL measures, 14 studies reported effects involving the physical health domain of QoL, 14 reported effects involving the psychological/mental domain, 7 involved the social domain, and 6 involved the environmental domain. The mean age of participants could be retrieved or estimated for all except 3 studies (Grossman et al., 2016; Li et al., 2014; Sun et al., 2015).

***Associations between QoL and self-reported sleep quality***

A total of 22 studies and 49 effect sizes could be used to estimate the relationship between QoL and self-reported sleep quality. The overall estimate suggested a medium average effect size, Pearson's $r$=.28, $p$< .001, [95% CI: .34, .23]. The estimated standard deviation of true effects across studies was rather large, $\tau$=.13 (which suggests that 95% of true effects varied between r = .50 and r = .03). Unsurprisingly, heterogeneity was significant, Q(df = 48) = 1632.27, $p$< .001. The forest plot shown in Figure 2 was obtained to clarify the distribution of the estimated true effects. Unlike commonly-reported forest plots (which descriptively depict the observed or aggregate effects), Figure 2 shows the distribution of the estimated random effects of the studies (i.e., best linear unbiased predictions, BLUPs; Pinhero& Bates, 2000), extracted from the multilevel model. There were too many single effect sizes (k=49) to report in a single forest, but the series of single effect sizes aggregated by study (using the formula suggested by Borenstein et al., 2009, p.227-228) can be found in Table 1. For easier readability, the BLUPs are arranged in order from the strongest to the weakest.

The funnel plot in Figure 3 concerns the publication bias. The distribution of the observed effect sizes is very heterogeneous at all levels of precision (vertical axis), but there was clearly no concentration of effects with a low precision and larger-than-average size (i.e., in the bottom left part of the plot). The "trim and fill" method consequently did not suggest that any effects were missing on the right of the funnel plot, thereby excluding a publication bias. In fact, it suggested that there might even be six effects (or two studies, when the same analysis was performed on the effects aggregated by sample) missing from the left of the funnel plot, which would slightly adjust the overall estimate towards an even larger (rather than smaller) effect. This had minimal impact on the estimated effect size ($\Delta r < .03$), however, and it reflects an especially large heterogeneity of the effect size among the high-powered studies, while the few studies with smaller sample sizes also provided modest effect size estimates. Such slight asymmetry was not corrected for, because it clearly reflects heterogeneity, not publication bias (which would lead to an overestimation, not an underestimation, of the effect size). The PET-PEESE test further confirmed the lack of a publication bias. The PET model left a significant intercept, so the PEESE model was applied. The latter showed a non-significant coefficient for the variance as the moderator, B = 4.43, p = .13, and the bias-adjusted estimated effect size remained unchanged, r = .28, p < .001.

As for the moderators, type of QoL domain emerged as a significant moderator of the relationship, $\chi^2(3) = 235.47$, $p < .001$. The Pearson's coefficient estimated for the correlation between self-reported sleep quality and the physical health domain of QoL was *r*=.35 [.42, .27], *p*< .001; for the psychological/mental health domain it was *r*=.21 [.29, .13], *p*<.001; for the social relationships domain it was *r*=.13 [.22, .03], *p*=.01; and for the environmental domain it was *r*=.17 [.27, .06], *p*=.002. The correlation with self-reported sleep quality was therefore significant for all four main domains of QoL, and the magnitude of these correlations ranged from small to moderate, with evident but not very large variations.

Lastly, although the average effect sizes were not identical when they were coded directly from correlations or derived from group comparisons (i.e., "good vs poor sleepers"), there was no evidence of any substantial variation in the estimates in the two cases. When type of effect size (correlation vs group comparison) was tested as a moderator, it did not reach significance, $\chi^2(1)=1.15$, *p*=.28, and the estimated difference in effect size between the two cases was negligible, *B*=.07, *p*=.28 (the effect size was slightly weaker when derived from group comparisons rather than directly from correlations).

***Associations between objective sleep parameters and QoL***

The relationship between QoL and objective sleep quality could only be estimated from 4 studies (Castro et al., 2013; Driscoll et al., 2008; Kume et al., 2017; Sella et al., 2021), involving a total of $k$ = 70 effects. Although the total k was large, the small number of studies involved restricts the reliability of the results. The overall meta-analytical estimate was not significant, however, and was practically zero, Pearson's r = .01, p = .82, 95% CI (.12, -.09). The CI is quite narrow, suggesting that the effect is either nil or negligible. The estimated standard deviation across the four studies (σ) was zero. This does not necessarily mean there was no heterogeneity across the studies, but only that the estimated BLUPs of the four specific studies involved were identical. Since the estimated mean effect was virtually nil, there was no point in assessing the publication bias. The "trim and fill" method was nonetheless applied, and did not suggest that any effects were missing in the funnel plot. As only four studies were involved here, and the overall relationship of interest was virtually zero, calculating any moderating effect would have virtually no informative value. When computed anyway, the results were as follows. The meta-analytical estimates varied to a negligible degree for the different objective sleep measures considered: for SE, $r$ = .00; for SOL, $r$ = .03; for TST, $r$ = .03; for WASO, $r$ = .00 (with all ps> .14). The same happened for the different QoL domains, as the estimated effect size varied between r = .05 and r = -.02 (all ps> .33).

***The effect of age on the associations between QoL and sleep quality***

To establish whether and to what degree aging can moderate the relationship between QoL and sleep, age was used as a moderator variable in a subsequent analysis.

*Self-reported sleep quality*: the mean age of the sample was not significant and the estimated variation in effect size (Fisher's Z) with each additional year of age was positive but negligible, $\chi^2(1)$=.63, $p$=.43, B=.002.

*Objective sleep parameters*: mean age did not emerge as a significant moderator for each association between objective sleep parameters and older adults' QoL, $\chi^2(1)$=2.42, $p$= .12 (the estimated variation in effect size with each additional year of age was again positive but very small, B=.006).

These results should be interpreted with caution, however, because they are based on the mean age of samples across only 22 studies for self-reported sleep quality, and 4 studies for objective sleep parameters.

## ***Quality assessment of the studies included in the analysis***

On independent quality assessment of the studies considered, 13 studies (57%) were judged to be at “low” risk of bias, 9 (39%) at “moderate” risk, and only 1 at “high” risk of bias. Then we examined whether the risk of bias emerging from our quality assessment was systematically associated with different estimates of the relationships of interest. To do so, we considered “risk of bias” as a moderator. As in the previous analysis on the role of age, the analysis was limited to the overall estimate of the relationships, without further investigating interactions with other moderators, because this risk of bias was a between-study factor.

*Self-reported sleep quality*. Among the 22 studies involved in the overall analysis, 12 were classified as being at “low” risk of bias, and 10 at “moderate-to-high” risk. Our quality assessment of the studies did not significantly moderate the estimated relationship between QoL and sleep quality, $\chi^2(1)=.14$, $p=.71$ (in both cases, the estimated correlation was much the same: $r=.27$ in studies at “low” risk, and $r=.30$ in studies at “moderate-high” risk of bias; $p< .001$).

*Objective sleep parameters*. All three studies involved in the estimation of this relationship were classified as being at “low” risk of bias, so no moderation analysis could be conducted in this case.

Table 2S shows the outcome of the quality assessment on the results of the studies included in our analysis.

## ***Reliability of measures and correction for attenuation***

Due to the further complication of considering reliability for objective measures of sleep quality, we limited this analysis to the relationship between self-reported sleep quality and QoL. For the QoL measures, the reported reliability coefficients ranged between .68 and .94 (mean and median were both .81), while for the self-reported quality of sleep measures they ranged between .72 and .90 (mean and median were both .83). With these values, the correction for attenuation formula increased the effect sizes (Pearson's r) by an average of 23%.

Unfortunately, however, only 12 studies reported effect sizes for which the reliability coefficients were available for both the QoL and the self-reported sleep quality measures. In some of these studies - and all the others (13 studies in all) - at least one measure (usually sleep quality) was measured with single-item scales.

When it was rerun on the corrected effect sizes for the above-mentioned 12 studies, the meta-analysis estimated an overall mean effect size of r = .28 [.36, .20], which represents a 22% increase over the corresponding meta-analytical estimate computed on the same set of effect sizes without any disattenuation, r = .23 [.30, .17]).

Reliability measures were not available for single-item scales. We assumed that they could range between .40 and .70, as this range could include the correlations between single-item scores and true underlying constructs, and they may be plausible loadings on latent factors in structural equation models. Inputting these values enabled us to rerun the meta-analysis on all 23 studies under plausible assumptions. The overall mean meta-analytical estimates ranged from r = .35 [.42, .28] (representing a 26% increase over the estimate without disattenuation, r = .28) to r = -40 [.48, .32] (representing a 43% increase).

## Discussion

The present systematic review and meta-analysis aimed, for the first time to our knowledge, to fill a serious gap in the literature concerning the contribution of sleep quality - be it self-reported or objectively measured - to QoL in autonomous, community-dwelling (active) older adults with no sleeping disorders. It summarizes the literature on the relationship between sleep quality and QoL in normal aging. As we know that aging coincides with increasingly large and varied changes in health (i.e.chronic conditions)and life domains, including sleep patterns and quality, we also conducted a moderator analysis of age (specifically, of the mean age of the sample). Given the applied and clinical importance of this issue, an overarching review was also conducted to see which measures and questionnaires should be recommended for assessing sleep and QoL in aging.

The findings from the literature review identified 23 studies on the associations between sleep quality and QoL and its main domains (physical and psychological health, social relationships, and environmental) in older people. Twenty-two of these studies included the relationship between self-reported sleep quality and QoL, while4 also investigated the relationship between objective sleep quality parameters and QoL. Our findings show that self-reported sleep quality correlated positivelywith QoL in the population under investigation (see Table 1), with an overall medium effect -Pearson's $r$=.28. There was a considerable heterogeneity across the true effect sizes estimated in the various studies, however (Figure 2). Correcting for attenuation suggested that the true relationships between the latent constructs were likely to be 20-40% stronger (depending on the assumptions regarding the single-item measures). Our findings are in line with previous reviews of a deterioration in health-related aspects of QoL among older adults with sleep disorders (for systematic reviews and meta-analyses, see: Wai & Yu, 2020; Min &Slattum, 2018; Neikrug &Ancoli-Israel, 2010; Shi et al., 2018). This would confirmthat a perceived good sleep quality (i.e., fewer sleeping difficulties) can influence the overall QoL perceived by older people, even if they have no sleep disorders (Sella et al., 2021).In the present study, a self-reported good sleep quality was also found positively correlated with all four domains of QoL, with significant, small-to-moderate estimated effects (ranging from Pearson's $r$=.13 to $r$=.35). Here again, all these relationships may well be stronger after disattenuation, when referred to the latent constructs. In line with previous reviews on the effects of clinical sleep disorders on various health outcomes relating to older adults' QoL (Wai & Yu, 2020; Min &Slattum, 2018; Shi et al., 2018), our results extend what we know about how a self-reported good sleep quality is associated not only with a better perceived QoL in the physical and psychological health domains, but also in the social relationships and environmental domains. Our finding is compatible with the idea that there could be a two-way relationships between the constructs of sleep quality and QoL. In other words, an individual's personal assessment of their physical and psychological health (e.g., the burden of chronic physical or cognitive difficulties), or of their social life and living conditions (e.g., the quality social networks, or health and social care) could be influenced by how people judge their sleep quality, and vice versa. Further longitudinal research will be needed to understand how these factors relate to one another over time, and to ascertain the directionality of the relationship. Such a pattern of findings nonetheless clarifies the role of sleep quality in this target population that had not been examined before (to our knowledge, at least).

As for objective sleep measures, the meta-analyzed data from the only 4 studies identified point to virtually null associations between objective sleep quality parameters (measured using actigraphy or polysomnography) and QoL (see Table 1S and 1). Our results confirmed as much for all the objective sleep parameters considered here, i.e., TST, SOL, SE and WASO (see Table 1S and 1). It is nonetheless worth noting that sleep quality was differently associated with QoL, depending on whether self-reported or objective sleep measures were considered. These results, showing that subjective and objective sleep measurements do not necessarily correlate with the same health factors, are in line with previous sleep research on young and older people with insomnia (or other health issues) (Carskadon et al., 1977; Lauderdale et al., 2008; Akerstedt et al., 2002). Our results extend this picture to autonomous older adults with no known sleeping disorders, supported by the different association with QoL seen in our sample, which was significant and moderate for self-reported sleep quality and QoL, but null for objectively-measured sleep parameters. This might be due to differences between the two sleep quality measures. The objective sleep measurements focused only on sleep at the macro level (NREM-REM sleep cycles, for instance) and at the micro level (the sleep-wake process, for instance) (Mander et al., 2017), while subjective sleep assessments encompass a variety of issues, such as how a disturbed or unsatisfactory night's sleep affects everyday living by making people less enthusiastic to get things done, or drowsy during the day. The impact of the latter issues on QoL can only be assessed subjectively. That said, given the very small number of studies considered, and the different aspects of sleep they examined, our findings concerning objective measures of sleep quality and their interpretation will need to be confirmed by future studies. These results point to the need, for applicative purposes, to choose with care which assessment tools to use when examining sleep quality and QoL in aging, at least when active older adults with no sleeping problems are concerned.

As for the role of age, we hypothesized that it could be a moderator of the relationship of interest because of the growing impact of age-related changes on sleep quality, and the increasing risk of chronic conditions, as well as the greater heterogeneity of such changes across individuals with aging. In our sample, age did not significantly moderate the relationship between QoL and sleep quality, however. This result confirms previous reports that aging *per se* is not the main factor to consider in explaining how self-reported sleeping difficulties might relate to QoL in active, autonomous older adults with no diagnosed sleep disorders (Luca et al., 2015; Sella et al., 2021). More specific factors relating to the aging process (such as multiple chronic diseases) may moderate this relationship, but this was not the focus here. Future studies should examine the interaction between sleep quality and QoL taking such other factors into account.

Our review also identified a marked heterogeneity in the methods and tools used to assess QoL and sleep quality (see Table 1 for details), with some studies even using a single question to assess both QoL and self-reported sleep quality. We also examined the methodological assessment of each study (risk of bias) (see Supplemental material, Table 2S). The frequent use of single-item measures goes to show that reliable and valid tools or protocols for assessing these two constructs are not always used. This makes some of the reported results difficult to interpret reliably (see Table 1). Our moderation analysis nonetheless suggested that the risk of bias did not substantially affect the meta-analytical estimates, as far as the relationship between QoL and self-reported sleep quality was concerned at least. Given that sleep quality and QoL are both complex and multifaceted constructs, future studies shouldmake an effort to use only psychometrically sound multi-item measures to better capture specific aspects of them. We found the studies investigated here at only low-to-moderate risk of bias (apart from one study judged to have more severe methodological weaknesses; see Table S2), but they showed a marked heterogeneity of methodological approach. It is worth adding that our systematic literature review also enabled us to quantitatively control for the risk of bias, confirming that our findings were robust overall. The majority of studies included in this review relied on self-report measures for both sleep quality and QoL, raising the risk of inflated correlations – and more generally of an issue with the validity of the measures – due to methodological bias (e.g., method bias, Podsakoff, MacKenzie, & Podsakoff, 2012). We are convinced that the risk of this methodological bias is a marginal concern in the studies that we reviewed, however. This risk is related especially to a number of task conditions, including: ambiguous items; complex syntax or abstract wording of questions; double-barreled questions; incomplete labeling of response scale points; and the absence of reverse-scored items (Podsakoff et al., 2012). Considering the scales used most frequently to measure QoL and sleep quality in the studies reviewed here, none of these risks were of substantial concern.

Despite these interesting results, there are some limitations of this study that need be mentioned. First, we did not consider specific dimensions of self-reported sleep quality (e.g., subjective sleep efficiency or sleep onset latency), so our findings need to be interpreted with caution. Future studies should examine the associations between older adults' QoL and specific dimensions of self-reported sleep quality, also considering the impact of chronic health conditions not envisaged here(as we were unable to code them all). Second, although we only included samples of older people without any sleep disorders in our analyses (based on our eligibility criteria), it may be that some of these older adults had undiagnosed or prodromal symptoms of sleep disorders. These limitations should be taken into account when interpreting our findings. The strength of the present study lies, on the other hand, in that it is the first to shed a little lighton the relationship between sleep quality and QoL, and on the sleep quality measurement tools appropriatefor assessing older adults with no sleep disorders or neurodegenerative conditions. They might reveal theoretical and applied implications (at the publichealth and clinical level)by:i) confirming and elucidating the relationship between sleep and QoL in older age; ii) improving our understanding of the health profiles of older adults with no diagnosed sleep disorders, especially as regards the role of subjectively-reported sleeping difficulties; iii) shedding light on the fallout of sleeping difficultieson healthily-aging older adults' QoL. Then, although the relationship between sleep quality and QoL in older people is largely correlational at the present time- improving sleep quality through systematic education on sleep hygiene (e.g., avoiding caffeine and smoking, promoting aerobic exercise), and lifestyle modification approach (Irish, Kline, Gunn, Buysse, & Hall, 2015), could also have far-reaching effects on older adults' QoL.

In conclusion, our systematic review and meta-analysis indicate that self-reported sleep quality has a crucial role in older adults' perception of their QoL as a whole, and its main - physical and psychological health, social relationships, and environmental domains, whereas objectively-measured sleep quality has a minimal influence on QoL. From the applied and clinical perspectives, our findings point to the importance of also and more systematically assessing self-reported sleep quality, and of making the effort to develop and administer evidence-based training to promote good sleep quality in older adults.

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*Figure 1*. Flowchart of the study selection procedure.

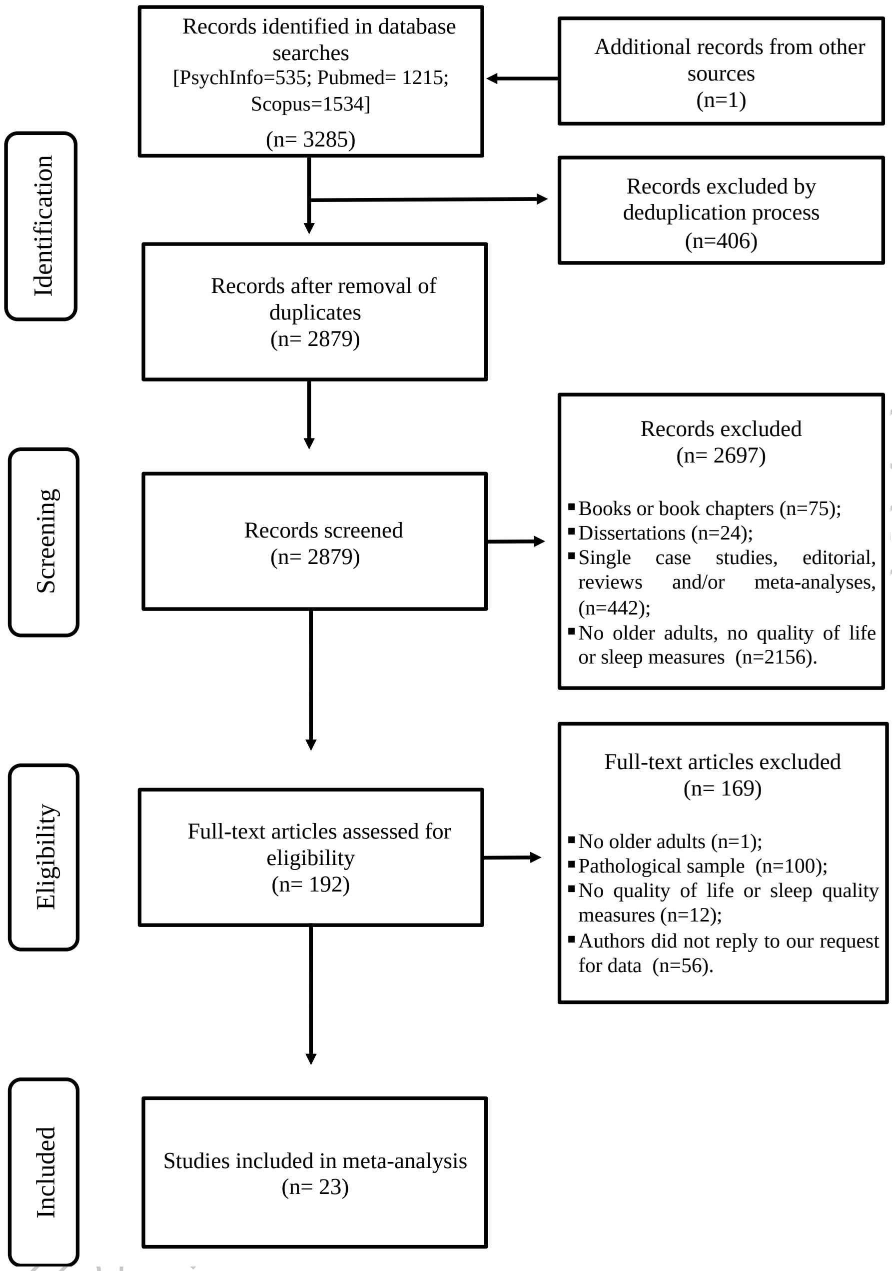
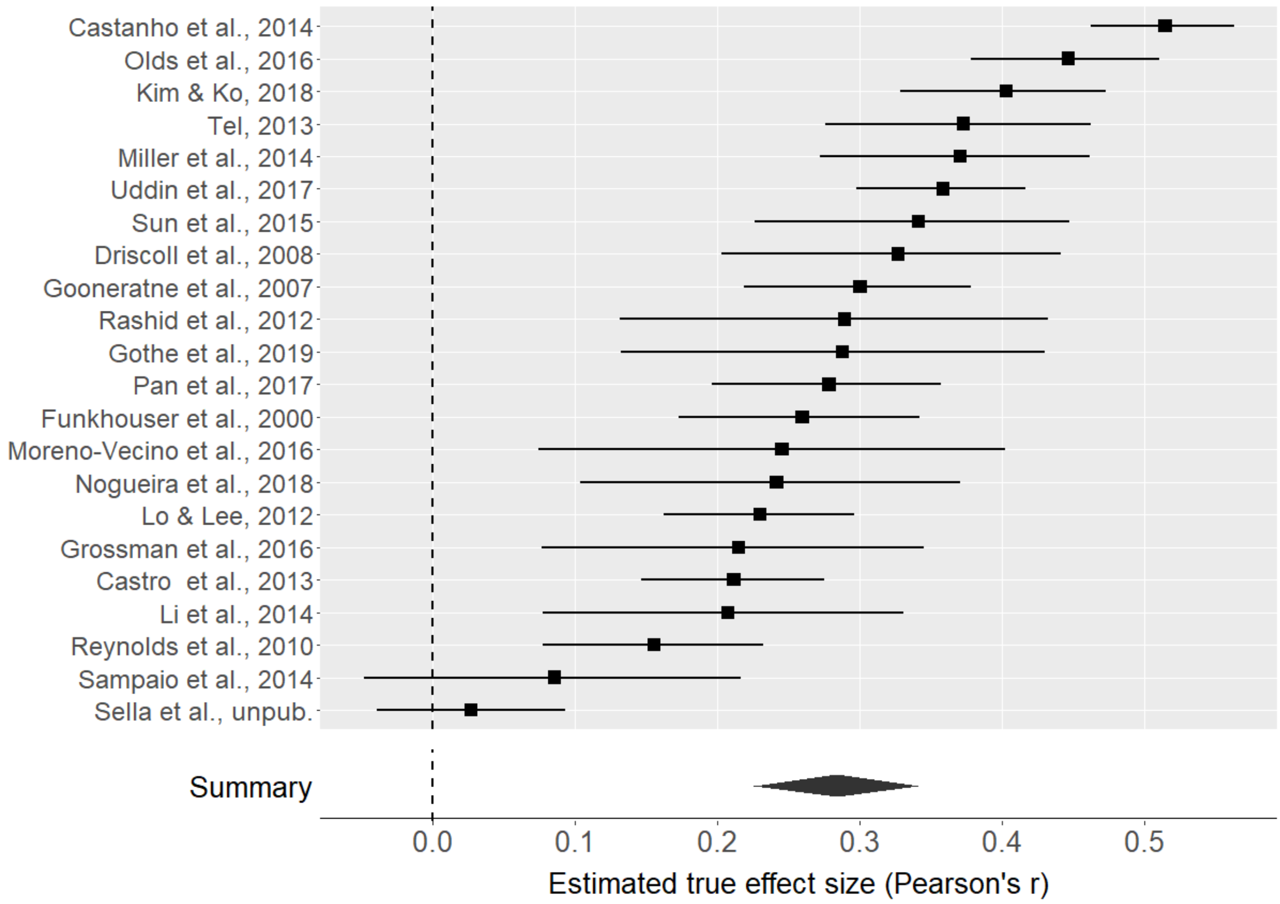
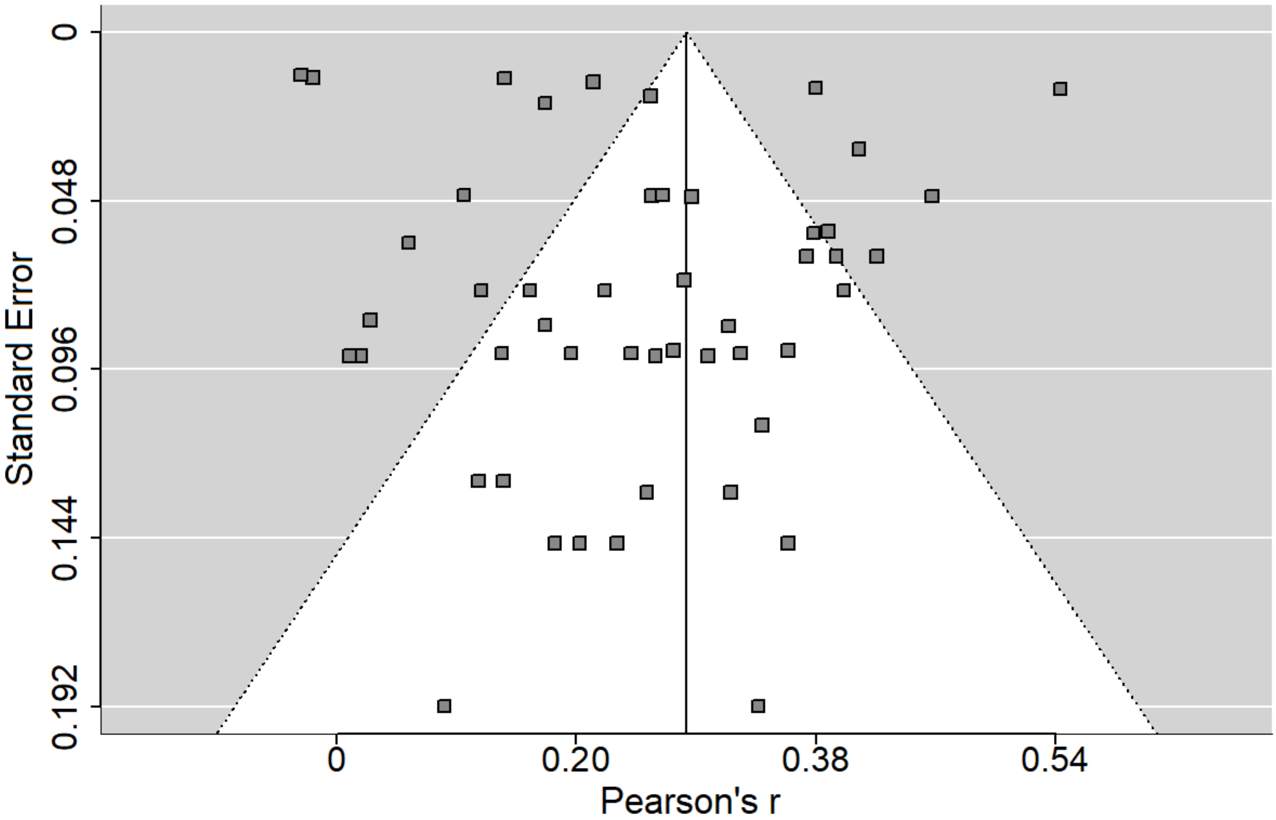



*Figure 2*. Forest plot showing the estimated best linear unbiased predictions (BLUPs) of random effects for the meta-analytical model on self-reported sleep quality. Error bars represent 95% CIs of the random effects. The summary diamond represents the overall meta-analytical estimate with its 95% CI.




*Note*. The BLUPs represent the estimated true effect sizes underlying each study according to the meta-analytical model, not the observed, or combined, effect sizes by study (which can be found in Table 1).

*Figure 3*. Funnel plot of all effects of interest for self-reported sleep quality.




*Note*. The gray squares represent the observed effect sizes. The x axis represents the effect size (converted from Fisher's Z into Pearson's r for an easier interpretation). The y axis represents the standard error. The white funnel is centered on the overall mean effect size, and it indicates the width of the 95% CI of an estimated effect as a function of its standard error.

***Table 1.*** Summary of findings from studies on the association between sleep quality and quality of life in older adults.

| Types of studies | | | Sample characteristics | | | | | Sleep quality | | | Quality of life | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Sleep quality groups | | | | |
| **Study** | **Study design** | **Country** | **Total participants involved in the study** | **N** | **Females** | **Age** | **Measures of sleep quality** | ***Poor sleepers*** | ***Good sleepers*** | **Measures of QoL** | **Key findings** | **Aggregate effect size*** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| Sampaio et al., 2014 | Cross-sectional study | Japan | 145 | 145 | 78 | M$_{age}$=73 y ±2.02 | *Self-reported sleep quality:* single *ad hoc* item (“good” vs “poor sleep quality”) | √ | √ | SF-36 | Good sleepers had a better QoL, overall and in the physical health domain | .12 |
| Nogueira et al., 2018 | Cross-sectional study | China | 451 | 451 | 355 | *Age range:* 50–85 y (estimated average: 72.2 y) | *Self-reported sleep quality:* three *ad hoc* items (“good” vs “poor sleep quality”) | √ | √ | WHOQOL-Bref | Good sleepers had a better QoL in the physical health domain | .23 |
| Grossman et al., 2016 | Longitudinal study | Israel | 8582 | 1808 | 55.5% | M$_{age}$=63.71 y ±8.97 | *Self-reported sleep quality* single item taken from the EDS (“good” vs “poor sleep quality”) | √ | √ | 12 items originating from the CASP-19 | Good self-reported sleep quality coincided with a better QoL | .17 |
| Rashid, et al., 2012 | Cross-sectional study | Malaysia | 151 | 151 | 82 | *Age range:* 60->80 y | *Self-reported sleep quality:* PSQI | | | WHOQOL-Bref | Better self-reported sleep quality coincided with a higher QoL | .32 |
| Tel, 2013 | Cross-sectional study | Turkey | 187 | 187 | 97 | M$_{age}$=72.51 y ±5.21 | *Self-reported sleep quality:* PSQI | | | WHOQOL-Bref | Self-reported good sleep quality coincided with a better QoL in the physical, psychological, social, and environmental domains. | .38 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sella, Cellini, & Borella, 2021 | Cross-sectional study | Italy | 50 | 50 | 33 | $M_{age}$=70.40 y ±7.43 | *Self-reported sleep quality:* PSQI<br>*Objective sleep quality:* actigraphy | | | WHOQOL-Bref | Self-reported good sleep quality, and better self-reported sleep efficiency both coincided with a better QoL | .05 |
| Kim & Ko, 2018 | Cross-sectional study | Korea | 203 | 203 | 132 | $M_{age}$=76.26 y ±6.77 | *Self-reported sleep quality:* ISI | | | EQ-5D | Less severe sleep disturbances coincided with a better QoL | .41 |
| Miller, Wright, Ji, & Cappuccio, 2014 | Longitudinal study | United Kingdom | 8789 | 5062 | 161 | Age range: 50 y and over (two independent samples with estimated $M_{age}$ = 57.8 and $M_{age}$ = 73.4) | *Self-reported sleep quality:* three *ad hoc* items ("good" vs "poor sleep quality") | √ | √ | CASP-19 | Good sleepers had a better QoL | .38 |
| Lo & Lee, 2012 | Cross-sectional study | China | 301 | 301 | 254 | $M_{age}$=76.08 y ±7.59 | *Self-reported sleep quality:* PSQI | √ | √ | SF-36 | Self-reported good sleep quality coincided with a better QoL | .21 |
| Pan et al., 2017 | Cross-sectional study | China | 5555 | 5555 | 53.7% | $M_{age}$=68.10 y ±6.6 | *Self-reported sleep quality:* single item on self-reported sleep quality ("good", "intermediate", "poor") | √ | √ | EQ-5D | Self-reported good sleep quality coincided with a better QoL | .27 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Olds et al., 2016 | Cross-sectional study | Australia | 124 | 124 | 63 | $M_{age}$=62.3 y ±4.3 | *Self-reported sleep quality:* single item on self-reported sleep quality ("very good", "good", "bad", "very bad") | | | SF-36 | Better self-reported sleep quality coincided with a higher QoL, overall and in the physical and mental health, and social domains | .41 |
| Kume at al., 2017 | Cross-sectional study | Japan and Thailand | *Japanese sample:* N= 37 | 37 | 22 | $M_{age}$=74.3 y ±6.3 | *Objective sleep quality:* actigraphy | | | WHOQOL-Bref | A higher objective sleep duration coincided with a better QoL (albeit with small effect size) | .09 |
| | | | *Thai sample:* N= 44 | 44 | 33 | $M_{age}$=72.93 y ±6.17 | | | | | | |
| Castro et al., 2013 | Cross-sectional study | Brazil | 1101 | 135 | NA | $M_{age}$=66.01 y ±0.46 | *Self-reported sleep quality:* PSQI<br>*Objective sleep quality:* PSG recordings | | | WHOQOL-Bref | Self-reported, or objectively-measured good sleep quality coincided with a better QoL (albeit with small effect size) | .07 |
| Sun et al., 2015 | Cross-sectional study | China | 3714 | 3714 | 3540 | *Age range:* ≥65 y and over | *Self-reported sleep quality:* single item on sleep quality (good vs poor) | √ | √ | SF-36 | Self-reported good sleep quality coincided with a better QoL in the physical health domain | .33 |
| Moreno-Vecino et al., 2017 | Cross-sectional study | Spain | 463 | 463 | 463 | $M_{age}$=74.59 y ±5.2 | *Self-reported sleep quality:* 4 items of | | | EQ-5D | Self-reported good sleep quality | .20 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | JSS | | | | coincided with a better QoL | |
| Gothe et al., 2019 | Cross-sectional study | United States | 247 | 247 | 169 | $M_{age}$=65.40 y ±4.6 | *Self-reported sleep quality:* PSQI | | | SF-12 | Self-reported good sleep quality coincided with a better QoL in the physical and mental health domains | .26 |
| Uddin et al., 2017 | Cross-sectional study | Thailand | 280 | 280 | 139 | $M_{age}$=65.81 y± 4.37 | *Self-reported sleep quality:* AIS | | | WHOQOL-Bref | Self-reported good sleep quality coincided with a better QoL | .38 |
| Castanho et al., 2014 | Cross-sectional study | Portugal | 120 | 120 | 57 | $M_{age}$=65.20 y± 8.80 | *Self-reported sleep quality:* PSQI | | | WHOQOL-Bref | Self-reported good sleep quality coincided with a better QoL, overall and in its separate domains | .34 |
| Funkhouser et al., 2000 | Cross-sectional study | Switzerland | 61 | 61 | 42 | $M_{age}$=71.62 y±5.46 | *Self-reported sleep quality:* SDQ | | | WHOQOL-100 | A lower self-reported sleep quality coincided with a worse QoL overall and in its separate domains | .09 |
| Reynolds et al., 2010 | Randomized clinical trial | United States | 64 | 30 | 15 | $M_{age}$=78.9 y ±3.0 | *Self-reported sleep quality:* PSQI | | | SF-36 | A lower sleep quality coincided with a worse QoL in the physical and | .18 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | mental health domains | |
| Goonera tne et al., 2007 | Case-control study | United States | 154 | 78 | 30 | $M_{age}$=74.8 y ± 6.5 | *Self-reported sleep quality:* PSQI | | | Single item on self-reported QoL (lower scores meant a worse QoL) | Self-reported good sleep quality coincided with a better QoL | .29 |
| Li et al., 2014 | Cross-sectional study | Taiwan | 903 | 94 | 33 | *Age range:* 65–75 y and over | *Self-reported sleep quality:* single item on sleep quality (no sleep disorders vs sleep disorders) | √ | √ | SF-36 | Good sleepers had a better QoL | .17 |

*Note.* PSQI: Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989); JSC: Jenkins Sleep Scale (Jenkins, Stanton, Niemcryk, & Rose, 1988); ISI: Insomnia Severity Index (ISI; Bastien, Vallières & Morin, 2001); AIS: Athens Insomnia Scale-5 (Soldatos, Dikeos, & Paparrigopoulos, 2000); SDQ: Sleep Disturbance Questionnaire (Douglass et al., 1994); SF-36: Medical Outcome Survey (MOS) - Short Form (SF)-36 (Stewart, Hays, & Ware, 1988); EQ-5D: EuroQoL - 5 Dimension (EQ-5D; EuroQoL G, 1990); WHOQOL-B: World Health Organization Quality of Life (WHOQOL-BREF; WHO; 1998); CASP-19: Control, Autonomy, Self-realization, and Pleasure questionnaire.
*Where multiple effect sizes were reported within the same study, we show them as aggregated using the formula suggested by Borenstein et al. (2009, p.227-228).

## Supplemental Material

## The relationship between sleep quality and quality of life in aging: a systematic review and meta-analysis

***Summary of the content:***

**PART 1 – Additional tables**

**PART 2 – Analyses on the relationship between sleep duration and quality of life**

**References (supplemental)**

**PART 1 – Additional tables**

***Table 1S.*** Summary of eligibility criteria, with definitions

| Study variables | | Description |
|---|---|---|
| *Type of participant:* | | |
| | Older adults | Older participants (with no psychiatric or neurodegenerative disorders, and no diagnosed sleeping disorders);<br>age > 50 years old;<br>gender: male and female. |
| *Reported measures of interest:* | | |
| | Quality of life* | Personal assessment of overall perception of various life domains in relation to goals, expectations and beliefs, standards, and concerns, given the culture and value systems (WHO, 2009). Lower overall QoL scores were treated as unfavorable. |
| | • Psychological/Mental health | Personal assessment of positive and negative feelings, self-esteem, body image, personal beliefs, and mental abilities. Lower scores in this domain of QoL were treated as unfavorable. |
| | • Physical health | Personal assessment of daily activities, energy and fatigue, mobility, and presence of pain. Lower scores in this domain were treated as unfavorable. |
| | • Social relationships | Personal assessment of relationships with family and friends, social support, and sexual activity. Lower scores in this domain were treated as unfavorable. |
| | • Environmental factors | Personal assessment of characteristics of physical environment, transport, health and social care, and economic resources. Lower scores in this domain were treated as unfavorable. |
| | Sleep quality | |
| | • Self-reported sleep quality | Overall score based on the assessment of aspects of self-reported sleep quality, such as feeling rested on waking and satisfied with one's sleep as a whole. Lower self-reported sleep quality was treated as unfavorable. |
| | • Objective sleep parameters^ | |

| | | |
|---|---|---|
| | Total sleep time (TST) | Period of time spent awake after nocturnal awakenings, assessed using objective measures. A lower TST was treated as unfavorable. |
| | Sleep onset latency (SOL) | Length of time taken to accomplish the transition from full wakefulness to sleep, assessed using objective measures. A longer SOL was treated as unfavorable. |
| | Waking after sleep onset (WASO) | Total number of awakenings during the night, estimated using objective measures. More time spent awake was treated as unfavorable. |
| | Sleep efficiency (SE) | The ratio of total time spent asleep to the total time spent in bed after sleep onset. A lower ratio was treated as unfavorable. |
| *Study search* | | All types of study design (e.g., observational, cross-sectional, longitudinal, mixed methods), except for single animal studies, single case studies, and qualitative studies. |

*Note.* *QoL and its main domains according to the WHOQOL-B (WHO, 2009); ^Comparative measures across different objective sleep measurements (i.e., polysomnography and actigraphy).

***Table 2S.*** Risk of bias, assessed with an adapted version of the Joanna Briggs Institute Critical Appraisal Checklist for Analytical Cross-Sectional Studies (Moola et al., 2017). Authors' judgments for each study are included.

| ***Study*** | ***Q1*** | ***Q2*** | ***Q3*** | ***Q4*** | ***Q5*** | ***Risk of bias*** |
|---|---|---|---|---|---|---|
| Driscoll et al., 2008 | Y | Y | Y | Y | Y | Low |
| Sampaio et al., 2014 | Y | Y | N | Y | N | Moderate |
| Nogueira et al., 2018 | NC | Y | N | Y | N | High |
| Grossman et al., 2016 | NC | Y | N | Y | Y | Moderate |
| Rashid et al., 2012 | NC | Y | Y | Y | Y | Low |
| Tel, 2013 | Y | Y | Y | Y | Y | Low |
| Sella et al., 2021 | Y | Y | Y | Y | Y | Low |
| Kim & Ko, 2018 | Y | Y | Y | Y | Y | Low |
| Miller et al., 2014 | Y | Y | N | Y | Y | Low |
| Lo & Lee, 2012 | Y | Y | Y | Y | Y | Low |
| Pan et al., 2017 | Y | Y | N | Y | Y | Moderate |

| | | | | | | |
|---|---|---|---|---|---|---|
| Olds et al., 2016 | Y | N | NC | Y | Y | Moderate |
| Kume at al., 2017 | Y | Y | Y | Y | Y | Low |
| Castro et al., 2013 | Y | Y | Y | Y | Y | Low |
| Sun et al., 2015 | Y | Y | N | Y | Y | Moderate |
| Moreno-Vecino et al., 2017 | Y | Y | Y | Y | Y | Low |
| Gothe et al., 2019 | Y | Y | Y | Y | Y | Low |
| Uddin et al., 2017 | Y | Y | Y | Y | Y | Low |
| Castanho et al., 2014 | Y | Y | Y | Y | N | Moderate |
| Funkhouser et al., 2000 | Y | Y | NC | Y | N | Moderate |
| Reynolds et al., 2010 | Y | Y | Y | Y | N | Low |
| Gooneratne et al., 2007 | NC | Y | Y | N | Y | Moderate |
| Li et al., 2014 | Y | Y | N | Y | N | Moderate |

*Note.* Q1: Were the criteria for inclusion in the sample clearly defined? Q2: Were the study subjects and the setting described in detail? Q3: Was sleep quality measured with a valid and reliable instrument? Q4: Was quality of life measured with a valid and reliable instrument? Q5: Were appropriate statistics reported for the effect size of interest?
Assessment= Y: yes (low risk of bias); N: no, or NC: not clear (high risk of bias); NA: not applicable.

**PART 2 – Analyses on the relationship between sleep duration and quality of life**

Total sleep duration gradually declines from birth to older age, with changes typically occurring in an individual's circadian rhythms and sleep architecture (e.g., Mander, Winer, &Walker, 2017; Li, Vitiello, & Gooneratne, 2018). It has been demonstrated that sleeping habits are considered an important factor for older adults' health and quality of life. An excessively short or long sleep duration - under 5 or over 10 hours (Hirshkowitz et al., 2015) - has been linked to adverse health outcomes (Itani, Jike, Watanabe, & Kaneita, 2016; Jike, Itani, Watanabe, Buysse, & Kaneita, 2018), and a worse QoL in older adults (Faubel et al., 2009; Lo & Lee, 2012; Mesas et al., 2010; Magee et al., 2011). This section focuses on the estimated effects of sleep duration on older adults' overall QoL, and on the moderating roles of the subdomains of QoL (physical and psychological health, social relationship, and environmental domains) and of age on these associations.

***Search strategy, data collection, and coding effects***

Available data on the proportions of groups with a "short sleep duration" were extracted. We specifically considered cases in which participants were grouped by QoL (e.g., based on median split). The groups were classified in terms of participants' reported sleep duration, defined as: "optimal" (mean 7-9 hours) or "suboptimal" (less than 6 or more than 9 hours on average) in the light of previous literature on the hours of sleep considered appropriate (e.g., Hirshkowitz et al., 2015). For the effect sizes derived from group comparisons, the group definition criteria were coded using criteria or cutoffs ("optimal vs suboptimal sleep duration"), and specifying each group's reported sleep duration along with the number of participants in each group.

**Results**

As explained in the paper, 170 eligible studies emerged from our literature review. Four of them considered the relationship between sleep duration and QoL, and met our inclusion/exclusion criteria. These studies were coded for the purpose of "optimal" vs "suboptimal" sleep duration group comparisons (Faubel et al., 2009; Lo & Lee, 2012; Mesas et al., 2010; Magee et al., 2011) (see Table 3S).

***Characteristics of the studies included***

The four independent studies analyzed in this section concerned a total of 34,549 participants (weighted mean age 74.77; range of mean ages across studies: 70-90 years). Two studies were cross-sectional, and two were prospective.

To measure QoL, three studies used the Medical Outcome Survey (MOS)–Short Form (Ware & Sherbourne, 1992; the SF-36), while one used a single question ("In general, how would you rate your overall quality of life?" - Magee et al., 2011). For the sleep duration measure, three studies adopted a single question ("How many hours do you usually sleep per day" - Mesas et al., 2010; see also: Magee et al., 2011; Faubel et al., 2009) and one used the PSQI (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) (see Table 3S).

**Table 3S**. Summary of study findings on the association between sleep duration (optimal vs suboptimal) and quality of life in older adults

| Types of study | | | | Sample characteristics | | | Sleep quality | | | Quality of life | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Study** | **Study design** | **Country** | **Total participants involved in the study** | **N** | **F** | **Age** | **Measures of sleep quality** | **Sleep duration groups** *Optimal, 7 to 8 h* | *Suboptimal, ≤ 6 or ≥ 9 h* | **Measures of QoL** | **Key findings** |
| Mesas et al., 2010 | Prospective study | Spain | 3820 | 3820 | 2177 | $M_{age}$=71.8 y ±7.9 | *Self-reported sleep quality:* sleep duration (hours spent asleep) | | | SF-36 | More than 9 hours, or less than 6 hours of sleep coincided with a worse QoL in the physical health domain<br><br>Less than 8 hours of sleep coincided with a worse QoL in the mental |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | health domain |
| Magee, Caputi & Iverson, 2011 | Cross-sectional study | Australia | 63480 | 28117 | NA | *Age range:* 55–95 y old | *Self-reported sleep quality:* sleep duration (hours spent asleep) | √ | √ | Single item on self-reported QoL (good vs poor QoL) | More than 9 hours, or less than 6 hours of sleep coincided with a worse self-rated QoL, overall and in the health domains |
| Faubel et al., 2009 | Prospective study | Spain | 2311 | 2311 | 1319 | $M_{age}$=72.3 y ±7.7 | *Self-reported sleep quality:* sleep duration (hours spent asleep) | √ | √ | SF-36 | Excessively short or long sleep duration coincided with a worse QoL in the physical and mental health domains |
| Lo & Lee, 2012 | Cross-sectional study | China | 301 | 301 | 254 | $M_{age}$=76.08 y ±7.59 | *Self-reported sleep quality:* PSQI | √ | √ | SF-36 | A lower self-reported sleep quality, and a shorter sleep duration both coincided with a worse QoL |

*Note*. F: females; PSQI: Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989); SF-36: Medical Outcome Survey (MOS) - Short Form (SF)-36 (Stewart, Hays, & Ware, 1988).^: Sleep duration recommendations based on Hirshkowitz et al (2015).

***Associations between self-reported sleep duration and QoL***

The relationship between QoL and (optimal) sleep duration can be better described by a standardized difference, such as Cohen's *d*, in the QoL of individuals reporting an optimal (i.e., more than 6 but less than 9 hours of sleep) as opposed to a suboptimal (i.e., less than 6 or more than 9 hours of sleep) sleep duration. Out of four studies that included this comparison, three reported standardized differences or statistics from which they could be calculated (Faubel et al., 2009; Lo & Lee, 2012; Mesas et al., 2010), while one reported odds ratios (Magee et al., 2011). For consistency with the rest of the study, we converted all effects into Fisher's Z, and report them here as Pearson's correlations to facilitate their comparison with other estimates in our analysis. We also report the corresponding Cohen's d, however, for a better interpretation.

The overall meta-analytical estimate was Pearson's $r$=-.14 [95% CI: -.19, -.09], $p$<.001 (which corresponds to a standardized difference of Cohen's $d$=-.28). The test for heterogeneity was statistically significant, Q(11) = 154.16, p < .001, but the estimated standard deviation in random effects across studies was not very large, σ=.04. Figure 1S shows the forest plot, with all observed effects. Once again, there was no evident asymmetry towards a larger effect size in the funnel plot (see Figure 2S), and the "trim and fill" method did not suggest any need to deflate the meta-analytical estimate. The PET-PEESE method further confirmed that there was no risk of publication bias, as the effect size was not moderated by either standard error, B = .07 [-1.90, 2.05], p = .94, or variance of the effects, B = -1.17 [-28.30, 25.97], p = .93.

*Figure 1S*. Descriptive forest plot of the observed effects for (optimal vs suboptimal) sleep duration.

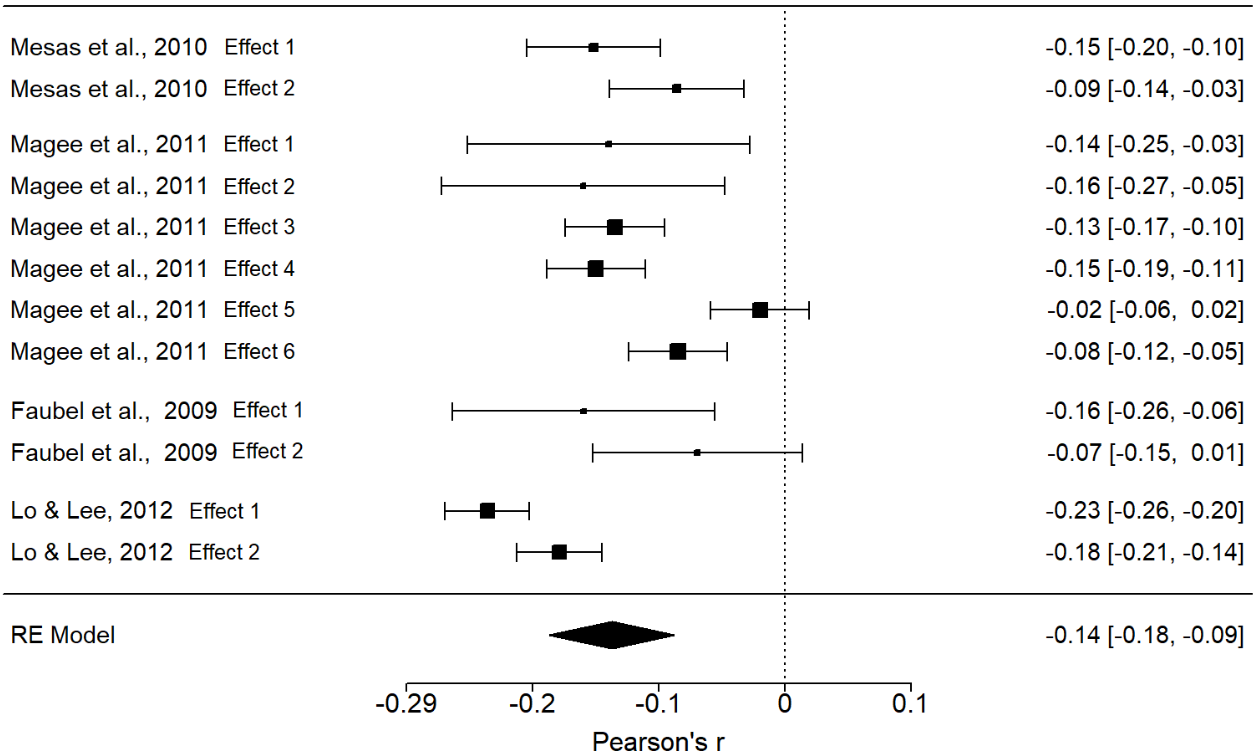
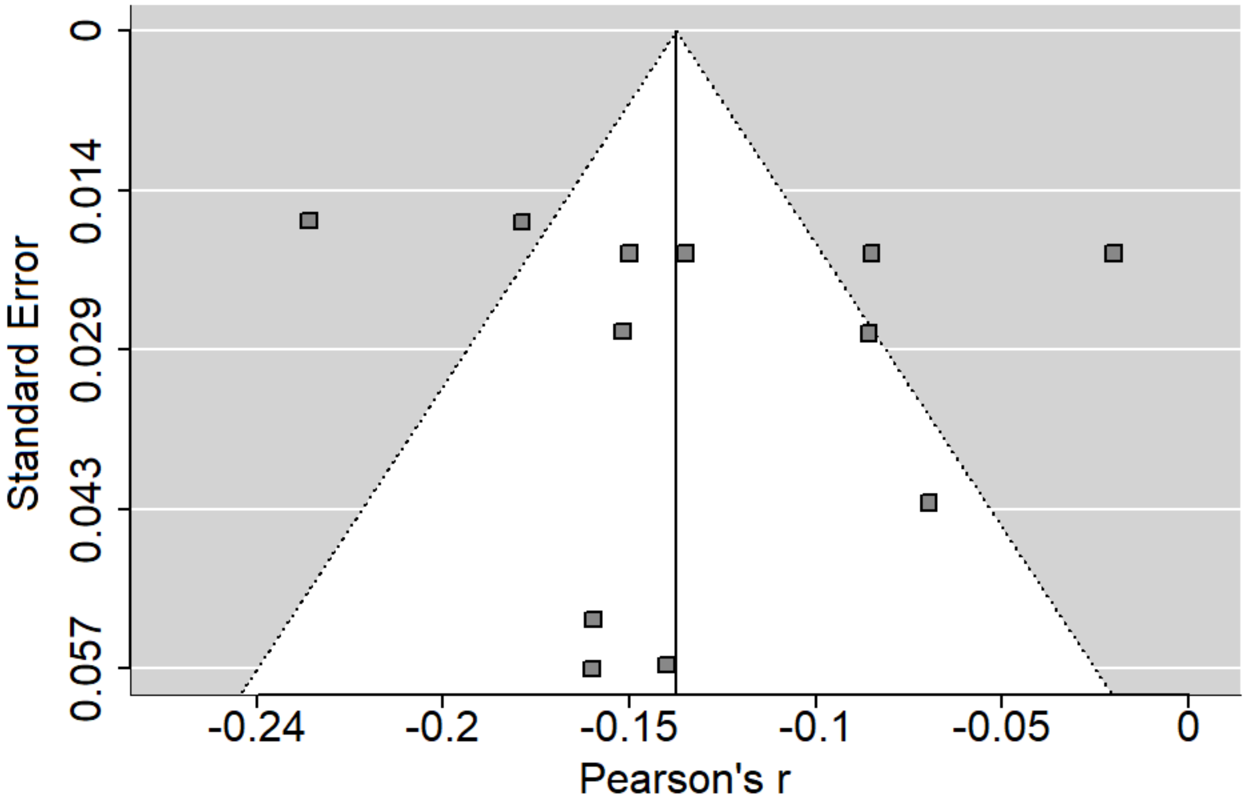



*Figure 2S*. Funnel plot of all effects of interest for (optimal vs suboptimal) sleep duration.



Analyzing the moderators, the type of QoL domain measured (physical or psychological health) did not emerge as a significant moderator, $\chi^2(1)=2.00$, $p=.16$. The estimates were: r = -.15 [-.21, -.10] for physical QoL; and r = -.17 [-.22, -.11] for psychological QoL. Caution is warranted in interpreting this latter finding, however, as the estimates were based on only three studies.

***The effect of age on the associations between sleep duration and QoL***

The mean age of the sample was significantly associated with a smaller effect size, $\chi^2(1)=64.52$, $p<.001$. The meta-regression coefficient was $B=.008$, $p<.001$. To clarify, the estimated relationship was Pearson's $r=-.25$ at 65 years of age (corresponding to Cohen's $d=-.52$ between those with an optimal vs suboptimal sleep duration), and Pearson's $r=-.09$ at 85 years of age (equating to Cohen's $d=-.18$). In other words, age seemed to moderate the association between QoL and sleep duration: the link between an optimal sleep duration and a better QoL seemed to fade gradually with aging.

***Quality assessment of the studies on sleep duration***

*Self-reported sleep duration*. As discussed in the paper, we examined the methodological quality of each eligible study using an adaptation of the Joanna Briggs Institute Critical Appraisal Checklist for assessing the risk of bias (see Munn et al., 2014).

Among the four studies involved in the overall analysis, only one was classified as "low" risk, and three at "moderate" risk of bias (see Table 4S). As only one study was available for one condition of the moderator, the results cannot be meaningfully interpreted. A statistically significant difference nonetheless emerged between the estimates in the two cases, $\chi^2(1)=10.35$, $p=.001$. The estimated correlation for the only study at "low" risk of bias was $r$ = -.21 [-.24, -.18], $p< .001$, while it was r = -.10 [-.12, -.08], $p< .001$, for the other three studies at "moderate" risk.

***Table 4S.*** Risk of bias for each study included in the analysis

| ***Study*** | ***Q1*** | ***Q2*** | ***Q3*** | ***Q4*** | ***Q5*** | ***Risk of*** |
|---|---|---|---|---|---|---|

| | | | | | | ***bias*** |
|---|---|---|---|---|---|---|
| Mesas et al., 2010 | Y | Y | N | Y | Y | Moderate |
| Magee et al. 2011 | Y | Y | N | NC | Y | Moderate |
| Faubel at al., 2009 | NC | Y | N | Y | Y | Moderate |
| Lo & Lee, 2012 | Y | Y | Y | Y | Y | Low |

*Note.* Q1: Were the criteria for inclusion in the sample clearly defined? Q2: Were the study subjects and the setting described in detail? Q3: Was sleep duration measured with a valid and reliable instrument? Q4: Was quality of life measured with a valid and reliable instrument? Q5: Were appropriate statistics reported for the effect size of interest"?
Assessment= Y: yes (low risk of bias); N: no, or NC: not clear (high risk of bias); NA: not applicable.

**Discussion**

All four studies on self-reported sleep duration and QoL found that older adults who reported a suboptimal sleep duration (less than 6 or more than 9 hours a night on average) also reported a lower overall QoL. This is in line with previous quantitative reviews addressing the association between sleep duration and older people's health and QoL (Itani et al., 2017; Jike et al., 2018), and demonstrating that spending too many or not enough hours asleep can also affect "healthy" older people's QoL.

In intriguing contrast with the findings discussed in the paper, when we looked at self-reported sleep duration, age appeared to moderate the association between hours spent asleep and older adults' QoL: the link between a suboptimal sleep duration and a lower QoL seemed to fade with aging. This might be explained by changes in people's sleeping patterns as they grow older. Sleep duration changes considerably over the course of our lives (e.g., Ohayon et al., 2004), and especially in older age (e.g., Mander et al., 2017; Li et al., 2018). What our results newly suggest is that such age-related changes in sleep duration may be a sensitive aspect of the association between sleep quality and QoL in healthy aging with no sleep disorders.

Though these findings seem interesting, the association between older adults' QoL and their sleep duration emerged from just a handful of studies, and therefore need to be considered with caution. Future studies might confirm these results.

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