

Positive Affect and Sleep: A Systematic Review

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Conflict of interest

The authors declare no conflict of interest

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SUMMARY

A sizeable literature has implicated sleep in the phenomenological experience of various mood disorders, vulnerability to psychopathology, and overall poor psychological functioning. By contrast, positive affective states (e.g., joy, happiness, vigor, positive mood) that may contribute to sleep have been understudied. This systematic review integrates findings from cross-sectional, longitudinal, ambulatory, and experimental studies that investigate the association between positive affect and sleep. A comprehensive search for all available research on the topic was performed in three electronic bibliographic databases (PubMed, PsycINFO, CINAHL). Two independent reviewers extracted data on study characteristics and quality. From 10,853 retrieved articles, 44 fulfilled inclusion criteria and formed the base of the review. The majority of studies (68.2%, $n = 30$) were classified as weak or having high risk of bias. In general, the pattern of findings suggests that aggregate or trait measures provide the most consistent evidence of an association between positive affect and sleep in healthy populations. More limited empirical data exists on the association between positive affect and sleep in clinical populations. We conclude that more rigorous and theoretically informed research is needed before firm conclusions can be drawn about the possible beneficial impact of positive affect on sleep outcomes.

Keywords: anhedonia, bipolar disorder, positive affect, positive emotions, mania, sleep, sleep duration, sleep quality

Glossary of terms

AIS-5	Athens insomnia scale
BCPQ	Bedtime counterfactual processing questionnaire
BD	Bipolar disorder
BFW/J	Bern well-being questionnaire for adolescents
CES-D	Center for epidemiologic studies depression scale
CSBS	Children's sleep behavior scale
CSWS	Children's sleep-wake scale
DAS	Dyadic adjustment scale
DISS	Daytime insomnia symptom scale
EEG	Electroencephalogram
GQ-6	Gratitude questionnaire-six-item form
GSQS	Groningen sleep quality scale
HCL-32	Hypomania check list
ISI	Insomnia severity index
JES	Job emotions scale
JSPS	Jenkins sleep problem scale
MASQ-SF	Mood and anxiety symptoms questionnaire-short form
mDES	Modified differential emotions scale
MSHS	Multidimensional sense of humor scale
MSRS	Manic state rating scale (aka, Beigel scale)
NA	Negative affect
PA	Positive affect
PANAS	Positive and negative affect schedule
PANAS-C	Positive and negative affect schedule for Children
PANAS-X	Positive and negative affect schedule Extended
PghSD	Pittsburgh sleep diary
POMS	Profile of mood states
POMS-SF	Profile of mood states-short form
PSQI	Pittsburgh sleep quality index
SAW	Sleep disturbance ascribed to worry scale
SHS	Subjective happiness scale
SOL	Sleep onset latency
SPW	Subjective psychological well-being
STAI	State-trait anxiety inventory
STAXI	State-trait anger expression inventory
SWS	Slow-wave sleep
TST	Total sleep time
TWT	Total wake time
USI	Uppsala sleep inventory
WHIIRS	Women's health initiative insomnia rating scale
Y-BOCS	Yale-Brown obsessive compulsive scale
YMRS	Young mania rating scale

Introduction

Extensive research has documented the importance of sleep for promoting restorative processes and protecting against impairments in a range of neurobehavioral functions, including emotion regulation, immune control, and memory consolidation [1-4]. Moreover, deficits in fundamental aspects of sleep, including sleep efficiency (i.e., initiating and maintaining sleep) and sleep quality (i.e., feeling rested and restored upon waking), can have profound health effects that contribute to increased risks for adult morbidity and all-cause mortality [5-8]. Given the significant role of sleep in psychiatric and health morbidities, it is important to advance understanding of the key factors that contribute to individual differences in sleep quality.

There is growing interest in associations between positive affect (PA) and health outcomes [9-12]. Positive affect can be defined as a state of pleasurable engagement with the environment that elicits feelings, such as happiness, joy, excitement, enthusiasm, and contentment [13]. Encompassing both enduring moods (e.g., affective traits) as well as short-term emotions (e.g., dynamic states), PA has been found to be robustly associated with lower morbidity and reduced mortality in both healthy and clinical populations [13-16]. Moreover, growing evidence suggests that PA is an important factor affecting individuals' overall sleep. Adults who report high levels of PA exhibit improved sleep patterns [17, 18]. In contrast, those who experience difficulties regulating PA report greater sleep disturbances [19].

How might PA influence sleep? Pressman and Cohen [9] propose two general mechanisms—*main effects* and *stress-buffering*—by which PA can promote health. In the main-effect model, PA impacts behaviors relevant to health in general, irrespective of its effects on stress responses. For example, individuals with high trait PA may be more likely to engage in restorative health practices such getting sufficient and restful sleep [17]. By contrast, in the

stress-buffering model, PA may act to reduce negative appraisals of stress and facilitate adaptive coping. Individuals with high trait PA may cope more effectively with stressors and, therefore, may not experience the adverse health consequences of stressor exposure vis-à-vis poor sleep quality [20]. Studies also suggest that PA and sleep are associated through a bidirectional relationship [17, 19]. For example, reciprocal inverse relations between vigor and insomnia were reported in a longitudinal study of working adults [21]. Regardless of whether PA influences sleep through direct, stress-buffering, or bidirectional effects, no systematic review has yet investigated the association between PA and sleep. Moreover, while a number of reviews have focused on links between general emotion and sleep [3, 22], results to date have raised important methodological questions, such as the directionality of emotion effects, the equivalence of standard subjective and objective measures of sleep, the contribution of PA to both resilience-enhancing and vulnerability-inducing sleep outcomes, and the extent to which associations between PA and sleep are independent of negative affect (NA).

Scope and organization of the review

To gain greater insight into the role of PA in sleep, the review is narrative rather than quantitative. Our goal in this review was to summarize research that assessed the relationship between PA and sleep. We use systematic methods and standardized procedures [23, 24] for locating and evaluating the relevance and quality of included studies. Specifically, the review includes investigations of the association between PA and sleep in healthy populations. We consider the association between disturbances in PA (e.g., chronically low/elevated PA) and sleep in clinical populations [25, 26]; however, given the small number of studies, we place less emphasis on this literature. In addition to considering the direct contribution of PA to sleep, we review evidence regarding potential bidirectional and stress-buffering effects. We also discuss

the role of behavioral and biological pathways in the association between PA and sleep. Lastly, we highlight important methodological limitations of extant studies and suggest key directions for future research.

To provide greater detail than presented in the text, the review includes corresponding tables with lists of all cross-sectional, longitudinal, ambulatory, and experimental studies that were located in the literature review. Cross-sectional studies examine the extent to which PA is associated with sleep outcomes. Longitudinal studies explore whether previous levels of PA predict subsequent levels of sleep across more extended periods of time. Ambulatory studies, in comparison, use intensive repeated measures methodology (e.g., experience sampling) across several days or weeks to examine how within-person variation in PA relates to sleep quality and quantity. Finally, experimental studies determine the effects of induced transient PA on concurrent sleep outcomes.

Methods

Database sources and searches

The review was conducted using PRISMA (Preferred reporting Items for systematic reviews and meta-analyses) guidelines [23]. A comprehensive search for all available research on the topic was performed in three electronic bibliographic databases (MEDLINE in PubMed, PsycINFO, CINAHL) on 29th June 2015. No date limits were applied but search results were restricted to English. The search strategy included terms reflecting PA, PA disturbance, and sleep. PA search terms included variations of *happy, cheerful, joy, vigor, excited, elated, enthusiastic, energetic interest, content, amused, humor, calm, relaxed, grateful, satisfied, positive affect, positive emotions, and positive mood*. Search terms for PA disturbance included *bipolar disorder, anhedonia, and mania*. Sleep-related search terms included variations of

insomnia, narcolepsy, time in bed, early waking, night waking, sleep, sleep deprivation, and sleep disorders. The complete PubMed, PsycINFO, and CINAHL search strategies are provided in Appendix A. Additional studies were identified through cited reference searching of included articles and known reviews.

Study screening and selection

Study screening was carried out by two independent reviewers. Discrepancies were resolved by consensus. In a first step, screening was carried out to exclude articles that did not meet inclusion criteria based on the title and abstract. Full-text screening was performed on potentially relevant studies that were identified to meet inclusion criteria or for which criteria could not be established. To be included, a study had to 1) be a published empirical study (rather than a meta-analysis or theoretical review); 2) involve more than a single human subject; 3) include, as an independent variable, a measure of PA or disturbance in PA (e.g., anhedonia, mania) or a PA manipulation (e.g., humorous films); and 4) include, as a dependent variable, a subjective or objective measure of sleep quality. Studies were excluded if they 1) used a single-case research design (e.g., clinical case study); 2) assessed only the contemporaneous correlation between PA or PA disturbance and sleep; 3) examined only the effect of sleep on PA or PA disturbance or mean differences in PA or PA disturbance between sleep impaired and non-impaired samples; or 4) used a reversed indicator of NA as a measure of PA (e.g., hopelessness vs. hopefulness; pessimism vs. optimism; fatigue vs. vigor/vitality) or assessed only propensities for sleep quantity or type. Figure 1 shows details of the search and screening process.

Data extraction and quality assessment

In this review, we assessed the methodological quality of reported research using the Effective public health practice project (EPHPP) tool [24]. We developed a standardized data

extraction protocol (available upon request) that included information about the publication, study design, participants, measures, and outcomes. The EPHPP assessment tool has been judged suitable for systematic reviews [27] and has been reported to have content and construct validity [28, 29]. The tool assesses six domains: 1) selection bias; 2) study design; 3) confounders; 4) blinding; 5) data collection; and 6) withdrawals/dropouts. In this review, we used an adapted form that excluded questions related to withdrawal/dropouts for the assessment of cross-sectional studies. Additionally, we included quality scores that reflect how strongly each study's finding was rated as consistent or inconsistent with the hypothesized PA-sleep relation. Each domain was rated as strong, moderate, or weak, and domain scores were averaged to provide a global rating for each study.

Results

From a total of 10,853 retrieved articles (4,458 from PubMed, 4,969 from PsycINFO, and 1,426 from CINAHL), 161 titles and abstracts were identified as potentially relevant and full-texts were screened to determine eligibility (see Figure 1). Forty-four articles fulfilled the inclusion criteria and were included for review.

Characteristics of included studies

The 44 studies recruited a total of 14,844 respondents. The average age of participants in each study ranged from 8 to 97 years old. Of the 38 studies that reported gender composition, 34 (89.5%) reported a higher percentage of females relative to males. The greater part of included studies were cross-sectional (43.2%, $n = 19$), followed by ambulatory studies (36.4%, $n = 16$). In addition, we retrieved 5 (11.4%) longitudinal studies and 4 (9.1%) experimental studies. The bulk of studies used US samples (43.2%, $n = 19$), with the remainder largely coming from European countries. Table 1 summarizes the general characteristics of included studies.

Quality assessment and strength of evidence

The assessment of the quality of the study methodology for the six domains (data collection, selection bias, confounders, study design, blinding, findings) is shown in Figure 2. Following the EPHPP tool, we categorized the majority of included studies (68.2%, $n = 30$) as “weak,” 10 studies (22.7%) as “moderate,” and 4 studies (9.1%) as “strong.” Weakness ratings derived from the inadequate control of confounders and insufficient information regarding study design, as well as blinding. Among the 6 studies using objective sleep assessment tools (e.g., polysomnography [PSG], actigraphy), 3 (50.0%) showed weak quality, 2 (33.3%) were categorized as moderate quality, and 1 study (16.7%) was rated as strong. Finally, among the remaining 38 studies that used a subjective assessment of sleep, 28 studies (73.7%) were rated as weak, 7 studies (18.4%) were categorized as moderate, and 3 studies (7.9%) were rated as strong.

Effects of PA on sleep

Table 2 presents cross-sectional, longitudinal, ambulatory, and experimental studies that address the potential association between PA and sleep.

Cross-sectional studies. Cross-sectional evidence linking PA to sleep has been reported in 19 previous studies. Table 2 summarizes the identified cross-sectional studies. Following the EPHPP tool, almost all included studies (89.5%) were categorized as “weak.” Most studies conceptualized PA as a trait (i.e., stable, enduring disposition) and used single-administration, paper-and-pencil questionnaires; however, two studies [17, 30] assessed trait PA using ecological momentary assessment approaches (measured by aggregating momentary assessment ratings over the day). Among the cross-sectional studies reviewed, 10 (22.7%) controlled for potential confounding factors, such as NA or psychological distress symptoms [20, 31-39], whereas the remainder (77.3%) did not control for NA when examining the association between

PA and sleep [40-48]. Finally, nine studies [34, 39-42, 45-48] examined the effects of specific PA states (i.e., vigor, gratitude, and love) on sleep outcomes. Overall, findings indicate that higher levels of trait/state PA are independently associated with better sleep quality in non-clinical samples of adults. Moreover, these associations were independent of NA, suggesting that high PA may have a salutary health effect that is distinct from that associated with low NA. Of note, four studies [37, 38, 40, 41] found no association between PA and sleep quality.

Longitudinal studies. Despite a limited set of studies, longitudinal evidence suggests an association between PA and improved sleep in the overall population. Table 2 summarizes the identified 5 longitudinal studies that examined the association between PA and sleep in healthy samples. The presence of basic methodological weaknesses (e.g., confounding, withdrawals and dropouts) among studies was frequent, and only two longitudinal studies [21, 49] had strong quality (according to EPHPP criterion). Consequently, available data should be interpreted with caution. Nonetheless, longitudinal studies provisionally support the link between PA and sleep found in cross-sectional work, demonstrating that this association holds even when the two variables are measured many months (ranging from 3 to 39 months) apart. Among the studies reviewed, 2 were consistent with theoretical predictions [49, 50], 1 reported bidirectional relations [21], and 2 reported null findings [51, 52].

Ambulatory studies. Evidence linking transient (state level) PA and sleep has been reported in more short-term longitudinal or ambulatory studies involving children, adolescents, and adults from the general population. Of the 16 studies identified, the majority (56.3%) showed weak quality (see Table 2). Seven studies reported an independent association between state (daily) PA and sleep [17, 19, 53-57]; 2 reported bidirectional relations [58, 59]; and 7

reported null findings [60-66]. Among studies reporting null results, the majority focused on the absence rather than presence of good sleep (i.e., adequate or restorative sleep).

Experimental studies. Very limited work has been done to evaluate whether experimentally manipulated PA influences sleep outcomes. Among the four experimental studies identified, two were consistent with theoretical predictions [67, 68] and two reported null effects [69, 70]. For example, Schmidt and Linden [69] examined whether inducing regret in healthy individuals would impair sleep the following night, as compared with focusing on pride or on a neutral working day schedule. Analyses revealed that while focusing on regret prior to sleep significantly delayed sleep onset, focusing on pride prior to sleep did not significantly alter sleep, as compared with the neutral condition. Thus, although the bulk of studies showed moderate methodological quality, there are too few experimental studies of PA and sleep to conclude anything at this time.

Methodological challenges

This is the first systematic review to focus on the association between PA and sleep. Although findings from the studies reviewed support a link in healthy populations, as noted, a significant number of included studies showed weak methodological quality. Of primary concern is the limited number of longitudinal and experimental studies. Indeed, studies to date have largely been cross-sectional, making it difficult to infer the causal significance of associations. Overall, perhaps one of the most striking findings is just how few studies have addressed issues related to causality and the direction of association between PA and sleep. Several authors have suggested that there is a bidirectional relationship between sleep and emotions [3, 22] and between sleep and PA in particular [17, 19]. However, with a few exceptions [e.g., 21, 58], reciprocal or bidirectional links between PA and sleep have rarely been examined in previous

work. In addition to providing a more rigorous assessment of mechanistic pathways, prospective, multi-wave, longitudinal studies are critically important in advancing the science of PA and sleep because they 1) allow for tests of theoretical models that assume stability of relations over time; 2) help address questions regarding duration of PA and whether sustained PA over time is associated with sleep outcomes above and beyond a single report; and 3) provide evidence against reverse-causality arguments, which posit that individuals who are sleep impaired may also report less PA. In comparison, experimental studies, in which positive emotions are experimentally manipulated, have not always included manipulation checks, thus complicating comparisons across studies [9]. Moreover, the experimental evidence for a causal link between PA and sleep, to date, comes largely from short-term laboratory studies. Overall, longitudinal and experimental studies addressing the reciprocal and long-term relationship between PA and sleep are urgently needed.

Another methodological drawback concerns inadequate assessment of potential confounders. Specifically, the inclusion of confounding variables, such as NA or psychological distress symptoms, varied considerably across studies. Given that NA may covary with PA [71], attention to potential confounding by negative arousal states is critical. Similarly, it is possible that certain measures of PA contain adjective terms (i.e., vigor, energetic, alert) that may be confounded with physical health [9]. This might be addressed in future work by including controls for self-rated health to rule out the possibility that vigor and other “high-arousal” PA states are merely markers of physical health.

Other methodological challenges concern the measurement of PA. Specifically, a prevalent methodological drawback of studies investigating the relationship between PA and sleep is the use of self-report measures. Indeed, the vast majority of included studies relied upon

self-report measures of PA, with some using single-item indicators with unknown psychometric properties. Measuring PA beyond self-report, i.e., using implicit measures that assess automatic processes operating outside of conscious awareness [72, 73] could add to our understanding of individual differences in sleep processes. Moreover, studies using diverse modes of PA assessments (e.g., informant reports, behavioral assessments, coding of facial expressions) would be less subject to reporting biases [74]. As has been noted by others [9, 10, 15], the measurement of PA also raises fundamental (but understudied) questions. For example, is the association between PA and sleep moderated by affective arousal? We could identify only one study [i.e., 75] which found that deactivated PA (e.g., relaxed, even-tempered, content) throughout the day was associated with beneficial cardiac function (elevated heart rate variability [HRV] and diminished heart rate [HR]) during sleep, thus providing indirect support for the hypothesis that low arousal PA throughout the day may foster good nighttime sleep [see also 76]. There is also reason to believe social norms surrounding PA may vary across cultures, with activated feelings associated with high-arousal PA (e.g., excitement, fun) being more generally valued by European Americans compared to East Asians [77]. Overall, additional research in this area is needed to determine what type, level, and duration of PA is associated with favorable sleep outcomes in different populations (healthy and ill) and cultures (e.g., individualistic vs. collectivist).

Beyond the measurement of PA, the measurement of sleep is also an issue for the current review. Specifically, so few investigations of PA and sleep have been conducted using objective sleep assessment tools (e.g., PSG and actigraphy) that conclusions must be made cautiously. Similarly, it remains unclear whether standard subjective assessments (e.g., Pittsburgh sleep quality index [PSQI], sleep diaries) and objective methods (e.g., actigraph, polysomnographic monitoring) are equivalent or whether they assess different underlying processes with potentially

differing sleep etiologies [22, 78]. Considering the significant heterogeneity across studies in measures of PA and sleep, measurement error remains an issue that may contribute to biases associated with effect estimation [79]. This suggests that the greatest clarity in future work would result from the inclusion of psychometrically valid, multichannel PA instruments and diverse measures of sleep (subjective and objective).

Finally, we note that the risk of publication bias is inherent in any systematic qualitative review. Positive publication bias can cause studies that report null associations between PA and sleep to remain unpublished [80]. It should be noted that such a bias may also result in a failure to publish inconclusive or disconfirming evidence [9]. This might be addressed in future meta-analyses by including methods for detecting, quantifying and adjusting for publication bias associated with effect estimation (e.g., funnel plots). Additionally, future reviews may include findings from studies reported in the gray literature including conference proceedings, theses and dissertations. Overall, the limitations in the existing data provide an important impetus for future work. Below we highlight several critical but, as yet, unresolved issues.

Future directions

First, limited research to date has focused on the potential stress-buffering or protective effects of PA [81-83]. As has been demonstrated in prior work, PA can influence stress in at least two ways. First, PA may *indirectly* influence sleep by modifying the effects of stress. In an illustrative study, Steptoe et al. [17] found that trait PA, as measured by ecological momentary assessment, partly accounted for the association between psychosocial risk factors (e.g., financial strains, poor social relationships, and psychological distress) and poor sleep (i.e., restless sleep, trouble falling asleep) in a sample of middle-aged and older adults (age range 58-72). Second, PA may act as a *moderator*, either accentuating or attenuating the impact of risk

factors on sleep. For example, Fortunato and Harsh [31] demonstrated a mitigating effect of interpersonal conflicts on sleep quality (i.e., falling asleep and reinitiating sleep) among individuals high in trait PA. Similarly, a study by Fredman et al. [20] found that PA was associated with fewer sleep problems in caregivers (but not noncaregivers), thus suggesting a protective effect. Taken together, existing data provide preliminary evidence for a protective function of PA and suggest that this is an important direction for future research.

Second, as noted above, research regarding PA and sleep would benefit greatly from prospective and experimental studies that can more clearly establish causal relationships. For example, prospective studies examining whether trait levels of PA precede changes in sleep across time would further illuminate the complex association between PA and sleep, particularly among older adults in whom the accrual of physiological deficits may accentuate vulnerability to disease and premature mortality. In addition to addressing questions about the causal direction of effects, future research should also examine the mechanisms accounting for the presumptive beneficial effects of PA on sleep [22]. Prior reviews of the literature [9, 15, 22, 84] suggest a number of variables that could be on the pathway to restorative or good sleep. These include stress hormones and inflammatory markers (e.g., cortisol, interleukin-6), neurobiological processes (e.g., nocturnal heart rate variability, circadian and serotonergic function), emotional brain networks, health behaviors (e.g., physical activity), and social relationships. These hypothesized mechanisms have yet to be empirically investigated.

Third, research designs that go beyond mere correlations will also permit the assessment on nonlinear relationships. For example, there is some evidence to suggest a link between chronically low levels of PA and sleep [e.g., 85]. By contrast, little work to date has examined (within non-clinical samples) the effects of excessively high levels of PA on sleep. Recent

reviews [26, 86] suggest that at very high levels, PA may confer detrimental outcomes. For example, Friedman and colleagues found that extremely cheerful people were more likely to engage in risky health behaviors [87] that increased their risk of early mortality [88]. Such investigations, thus, could confirm and extend previous clinical observations and experimental data concerning the link between PA deficits and sleep quality [78, 89].

Finally, too few studies exist to adequately distinguish between effects of PA on sleep in healthy vs. clinical populations. Given that the inability to appropriately regulate or control one's positive emotions has been found to be associated with psychopathology [25, 26], studying PA disturbance may enable better understanding of how the normative function of PA can go awry [26], thus affording a view of the critical limiting conditions that may determine the adaptive consequences of PA for sleep. Minimal data are available on sleep and positive affective functioning in depression and/or bipolar disorder. Recent work suggests that amplifying positive emotional states (via self-focused rumination) increases PA across both major depressive and bipolar disorders, while attempts to dampen PA paradoxically intensifies these states in bipolar individuals [90]. It remains unclear, however, what implications these PA regulation strategies have for reducing sleep disturbances (i.e., insomnia and hypersomnia) in psychiatric populations.

By comparison, studies of healthy adults have demonstrated links between various dynamic aspects of PA regulation (e.g., reactivity and variability) and functional impairments in sleep and diminished well-being in the general population. For example, in a 8-day ambulatory study of 100 healthy middle-aged adults (ages 43-68 yrs), Ong et al. [19] reported that greater positive affective reactivity in response to daily events was associated with poorer sleep efficiency, as measured by sleep actigraph. Other studies have found associations between heightened variability in PA and increased depression and anxiety symptoms [91] and low self-

esteem [92]. Given that mood lability and reactivity represent central features across psychiatric and sleep disturbances [25, 93], there is a critical need for additional studies examining PA variability and reactivity as potential mechanisms that contribute to the development of sleep impairments in individuals with depression and bipolar disorder.

Conclusions

Although there is growing support for an association between PA and sleep, full understanding of the phenomenon is far from complete. The main issues limiting the validity and generalizability of the results include inadequate control of confounders, insufficient information regarding study design, small heterogeneous samples, and a paucity of longitudinal and experimental studies. More carefully conducted and theoretically informed research is needed before one can have confidence that PA affects sleep in a favorable way. Overall, the pattern of findings suggests that aggregate or trait-like measures provide the most consistent evidence of an association between PA and good sleep. At present, less evidence exists for protective effects of PA. A critical direction for future research is to elucidate the mechanisms by which PA contributes to adaptive sleep outcomes. Additionally, although there is ample empirical evidence linking sleep disturbances to psychiatric outcomes such as depression and bipolar disorder, it is noteworthy that the preponderance of longitudinal studies have focused specifically on unidirectional effects, with sleep problems predicting later psychiatric difficulties. Moreover, while there is some evidence linking sleep to PA disturbance, the specific direction and nature of the effects are not always clear and present an important avenue for future research. Similarly, limited research to date has focused on PA dysregulation as a potential mechanism that underpins the association between sleep disturbance and presence of psychiatric disorder. To the extent that progress can be made on these issues, research on sleep and affect may begin to create

theoretically informed links to other neighboring fields currently attempting to probe the adaptive significance of positive affect.

Practice Points

1. The majority of the studies are cross-sectional in design. Aggregate measures provide the most consistent evidence of an association between PA and sleep in healthy populations. More limited data exists on the relation between PA and sleep in patient populations.
2. Use of objective measures of sleep would reduce measurement error and likely lead to less bias in effect estimation.
3. Current studies have various methodological weaknesses. The main issues limiting the validity and generalizability of the results include inadequate control of confounders, insufficient information regarding study design, small heterogeneous samples, and a paucity of longitudinal and experimental studies.

Research Agenda

Future research considerations:

1. Address the causal pathways linking PA and PA disturbance and sleep.
2. Develop better theoretical models that promote an in-depth understanding of the mechanisms and limiting conditions by which PA influences sleep outcomes..
3. Assess the contribution of age and disease severity to the relationship between PA and sleep.
4. Clarify the role of variability and level of PA in conferring vulnerability to poor sleep.
5. Investigate whether sustained PA over time shows stronger associations with sleep than a single PA episode.

Appendix A. Search strategy

Medline (PubMed)

- #1 positive affect[tw] OR positive emotion*[tw] OR positive mood[tw] OR at ease[tw] OR calm[tw] OR cheerful*[tw] OR elated*[tw] OR energetic[tw] OR enjoy*[tw] OR enthusiastic[tw] OR excite*[tw] OR fondness[tw] OR happi*[tw] OR happy[tw] OR hopeful*[tw] OR jovial*[tw] OR joy[tw] OR lively[tw] OR love[tw] OR optimis*[tw] OR pep[tw] OR pleas*[tw] OR relaxed[tw] OR satisfied[tw] OR surgency[tw] OR vigor[tw] OR amused[tw] OR contentment[tw] OR humor[tw] OR gratitude[tw] OR psychological well-being[tw] OR psychological wellbeing[tw] OR subjective well-being[tw] OR subjective wellbeing[tw] OR hedonic well-being[tw] OR hedonic wellbeing[tw] OR mood manipul*[tw] OR experimental manipul*[tw] OR emotion elicitation[tw] OR emotional stimuli[tw] OR happiness[MeSH] OR hope[MeSH] OR love[MeSH] OR pleasure[MeSH]
- #2 bipolar disorder[MeSH] OR anhedonia[MeSH] OR bipolar[tw] OR mania[tw] OR anhedonia*[tw] OR manic depress*[tw]
- #3 #1 OR #2
- #4 sleep[MeSH] OR sleep disorders[MeSH] OR snoring[MeSH] OR snoring[tw] OR insomnia*[tw] OR narcolepsy[tw] OR sleep*[tw] OR time in bed[tw] OR early awakening*[tw] OR early waking*[tw] OR night waking*[tw]
- #5 #3 AND #4
- #6 (animals[MeSH] NOT human[MeSH])
- #7 #5 NOT #6
- #8 Limits: English

PsycINFO (Ebsco)

- #1 TX (“positive affect” OR “positive emotion*” OR “positive mood” OR at ease OR calm OR cheerful* OR elated* OR energetic OR enjoy* OR enthusiastic OR excite* OR fondness OR happi* OR happy OR hopeful* OR jovial* OR joy OR lively OR love OR optimis* OR “pep” OR pleas* OR relaxed OR satisfied OR surgency OR vigor OR “amused” OR contentment OR humor OR gratitude OR “psychological well-being” OR “psychological wellbeing” OR “subjective well-being” OR “subjective wellbeing” OR “hedonic well-being” OR “hedonic wellbeing” OR “mood manipul*” OR “experimental manipul*” OR “emotion elicitation” OR “emotional stimuli”) OR DE (happiness OR hope OR love OR pleasure)
- #2 DE (bipolar disorder OR cyclothymic personality OR mania OR hypomania OR anhedonia) OR TX (“bipolar” OR mania OR “manic depress*” OR anhedonia)
- #3 #1 OR #2
- #4 DE (sleep OR napping OR NREM sleep OR REM sleep OR sleep disorders OR hypersomnia OR insomnia OR Kleine Levin syndrome OR narcolepsy OR parasomnias OR sleepwalking OR sleep deprivation OR snoring) OR TX (snoring OR insomnia* OR narcolepsy OR sleep* OR “time in bed” OR “early awakening*” OR “early waking*” OR “night waking*”)
- #5 #3 AND #4

#6 Limits: English

CINAHL (Ebsco)

- #1 TX (“positive affect” OR “positive emotion*” OR “positive mood” OR at ease OR calm OR cheerful* OR elated* OR energetic OR enjoy* OR enthusiastic OR excite* OR fondness OR happi* OR happy OR hopeful* OR jovial* OR joy OR lively OR love OR optimis* OR “pep” OR pleas* OR relaxed OR satisfied OR surgency OR vigor OR “amused” OR contentment OR humor OR gratitude OR “psychological well-being” OR “psychological wellbeing” OR “subjective well-being” OR “subjective wellbeing” OR “hedonic well-being” OR “hedonic wellbeing” OR “mood manipulat*” OR “experimental manipulat*” OR “positive emotion induc*” OR “emotion elicitation” OR “emotional stimuli”) OR MH (happiness OR hope OR love OR pleasure)
- #2 MH (bipolar disorder+ OR anhedonia) OR TX (“bipolar” OR mania OR “manic depress*” OR anhedonia)
- #3 #1 OR #2
- #4 MH (sleep+ OR sleep disorders+ OR snoring) OR TX (snoring OR insomnia* OR narcolepsy OR sleep* OR “time in bed” OR “early awakening*” OR “early waking*” OR “night waking*”)
- #5 #3 AND #4
- #6 Limits: English

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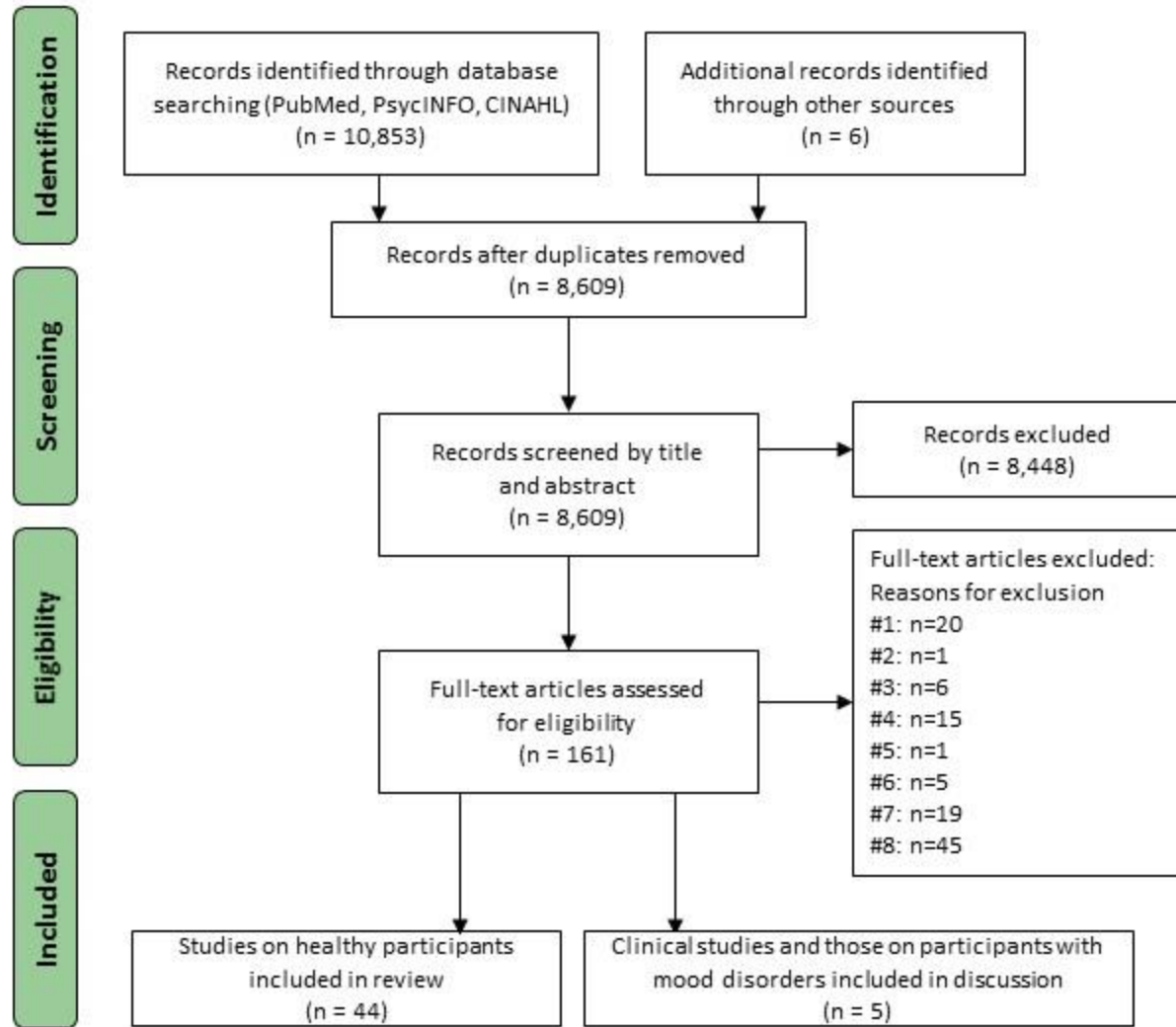
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* The most important references are denoted by an asterisk.

Figure Caption

Figure. 1. Study flow diagram. Full text articles were excluded if they met any one of the following eight exclusion criteria: 1) not an empirical study; 2) used a single-case research design (e.g., clinical case study); 3) no human subjects or human subjects with mood disorders other than bipolar disorder, mania, or anhedonia; 4) did not include, as an independent variable, a measure of positive affect (PA) or disturbance in PA (e.g., anhedonia, mania) or a positive mood manipulation (e.g., humorous films, pleasant images); 5) used a reversed indicator of negative affect as a measure of PA (e.g., hopelessness versus hopefulness; pessimism versus optimism; fatigue versus vigor/vitality); 6) did not include, as a dependent variable, a subjective or objective measure of sleep quality, or assessed only propensities for sleep quantity or type; 7) assessed only the contemporaneous correlation between PA or PA disturbance and sleep; 8) examined only the effect of sleep on PA or PA disturbance or mean differences in PA or PA disturbance between sleep impaired and non-impaired samples.

Figure. 2. Stacked bar graph shows summary of quality assessment results from the Effective health public practice project (EPHPP) tool.



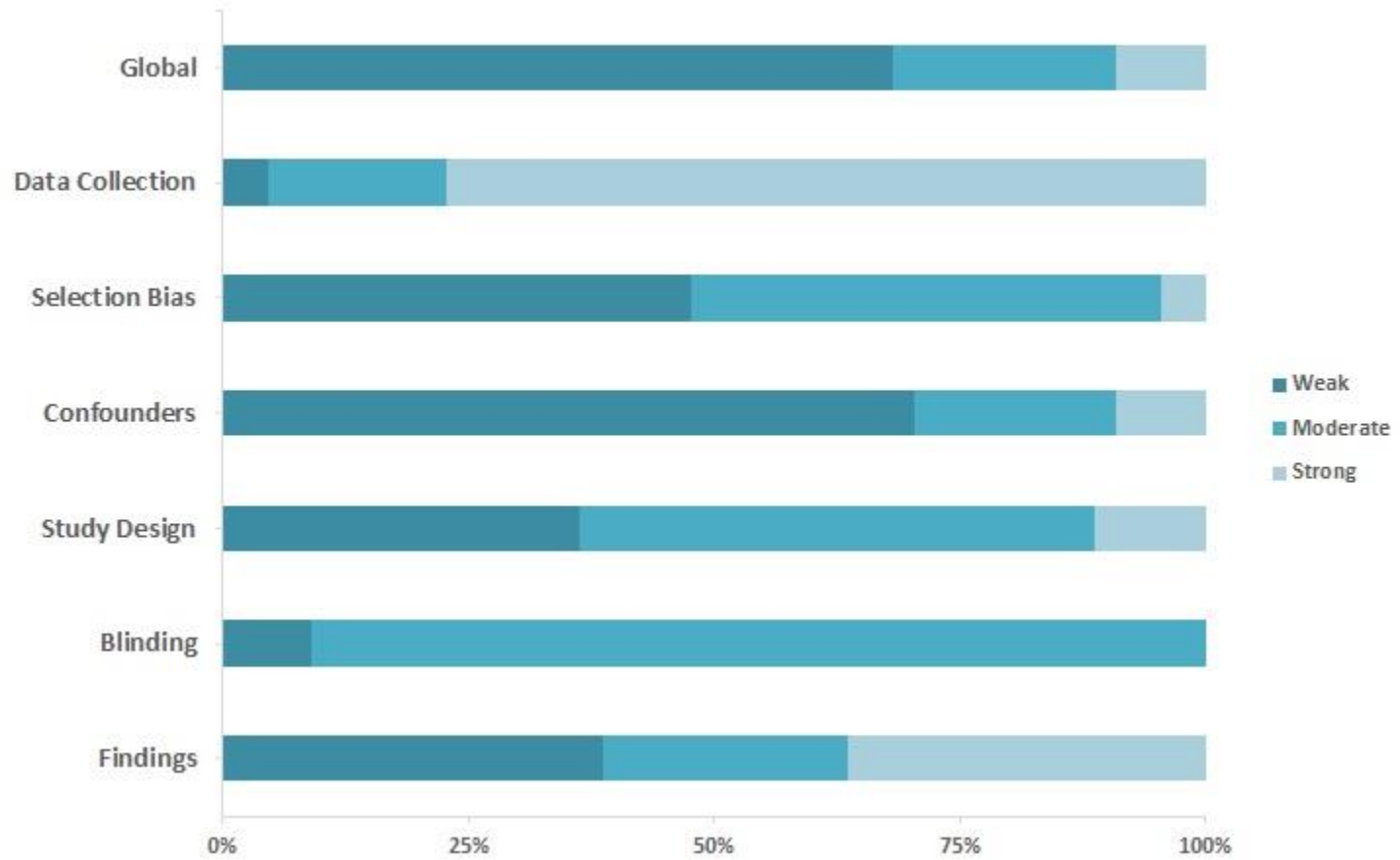


Table 1

Characteristics of Included Studies.

Authors, reference number	Region	Sample size	Age range (in years unless marked otherwise)	Study design
Armon G et al 2014 ²¹	Israel	1,414	21-71	Longitudinal
Bajoghli H et al 2013 ⁴⁰	Iran	201	Mean age 17.73	Cross-sectional
Bajoghli H et al 2011 ⁴¹	Iran	86	Mean age 17.97	Cross-sectional
Brand S et al 2015 ⁴²	Switzerland, Germany	844	Mean age 24.7	Cross-sectional
Brand S et al 2011 ⁴³	Switzerland	862	Mean age 24.67	Cross-sectional
Brand S et al 2007 ⁴⁸	Switzerland	107	Mean age 17.95	Cross-sectional
Brisette I Cohen S 2002 ⁵⁹	USA	47	18-54	Ambulatory
de Wild-Hartmann JA et al 2013 ⁶⁰	Belgium	362	18-61	Ambulatory
Doane LD Thurston EC 2014 ⁶¹	USA	78	17-18	Ambulatory
Emmons RA McCullough ME 2003 ⁶⁸	USA	157	Age not reported	Experimental
Emmons RA McCullough ME 2003 ⁷⁰	USA	65	22-79	Experimental
Fisher BE et al 1994 ⁵⁰	Canada	parents: 60, children: 29	8-10	Longitudinal
Fortunato VJ Harsh J 2006 ³¹	USA	467	Mean age 21.3	Cross-sectional
Fredman L et al 2014 ²⁰	USA	229	60-97	Cross-sectional
Fredrickson BL et al 2008 ⁸³	USA	139	Mean age 41	Longitudinal
Fuligni AJ Hardway C 2006 ⁵³	USA	761	14-15	Ambulatory
Galambos NL et al 2009 ⁵⁴	Canada	194	17.3-19.9	Ambulatory
Garcia C et al 2014 ⁶²	USA	19	14-17	Ambulatory
Garcia D et al 2012 ³²	Sweden	304	16-19	Cross-sectional
Gray EK Watson D 2002 ³³	USA	334	18-21	Cross-sectional
Jackowska M et al 2015 ⁶⁷	UK	119	Mean age 26.0	Experimental
Jackowska M et al 2012 ⁴⁴	UK	199	18-65	Cross-sectional
Jackowska M et al 2011 ³⁴	UK	199	18-65	Cross-sectional
Kalak N et al 2014 ⁵²	Switzerland, Norway	1,601	10-15	Longitudinal
Kalmbach DA et al 2014 ⁵⁷	USA	171	Mean age 20.07	Ambulatory

Kelly WE 2002 ⁴⁵	USA	135	18-57	Cross-sectional
Lawson KM et al 2014 ⁵⁵	USA	174	17-19	Ambulatory
Loft M Cameron L 2014 ⁵⁶	New Zealand	73	21-65	Ambulatory
MacDonald S Kormi-Nouri R 2013 ³⁵	Sweden	313	19-46	Cross-sectional
Ng MY Wong WS 2013 ⁴⁶	Hong Kong	224	19-61	Cross-sectional
Norlander T et al 2005 ³⁶	Sweden	91	Age not reported	Cross-sectional
Ong AD et al 2013 ¹⁹	USA	100	43-68	Ambulatory
Ryff CD et al 2004 ³⁷	USA	135	61-91	Cross-sectional
Schmidt RE Van der Linden M 2013 ⁶⁹	Switzerland	176	17-45	Experimental
Simor P et al 2015 ⁶³	Hungary	75	Mean age 22.15	Ambulatory
Song S et al 2015 ⁶⁵	USA	143	Mean age 65.5	Ambulatory
Stephoe A et al 2008 ¹⁷	UK	736	58-72	Ambulatory
Stewart JC et al 2011 ³⁸	USA	224	Mean age 23.4	Cross-sectional
Takano K et al 2014 ⁶⁶	Japan	49	Mean age 19.4	Ambulatory
Troxel WM et al 2009 ⁴⁷	USA	1938	Mean age 45.8	Cross-sectional
van Zundert RMP et al 2015 ⁵⁸	Netherlands	286	13-16	Ambulatory
von Kanel R et al 2014 ⁴⁹	USA	126	Mean age 74.20	Longitudinal
Wood AM et al 2009 ³⁹	UK	401	18-68	Cross-sectional
Wrzus C et al 2014 ⁶⁴	Germany	397	12-88	Ambulatory

Table 2

Summary of Positive Affect (PA) and Sleep.

Authors, reference number	PA measure	Sleep outcome	NA adjustment	Findings
<i>Cross-sectional studies</i>				
Bajoghli H et al 2013 ⁴⁰	Romantic love (self-report items), hypomania (HCL-32)	Sleep quality (daily sleep log questionnaire)	None	Neither romantic love nor hypomania were associated with sleep quality
Bajoghli H et al 2011 ⁴¹	Romantic love (self-report items), hypomania (HCL-32)	Sleep quality (daily sleep log questionnaire)	None	Neither romantic love nor hypomania were associated with sleep quality
Brand S et al 2015 ⁴²	Romantic love (Y-BOCS), hypomania (HCL-32)	Sleep quality & quantity (retrospective sleep log), insomnia (ISI)	None	Romantic love was associated with sleep disturbance (i.e., lower ISI scores) and sleep quality but not sleep quantity
Brand S et al 2011 ⁴³	Hypomania (HCL-32)	Insomnia (ISI)	None	Risk-taking/irritable hypomania, but not active/elated hypomania, was associated with sleep problems (i.e., higher ISI scores)
Brand S et al 2007 ⁴⁸	Romantic love (Y-BOCS), hypomania (HCL-32)	Sleep quality & quantity (daily sleep log questionnaire)	None	Early stage intense romantic love in adolescents was associated with better sleep quality and shorter TST, but not SOL
Fortunato VJ Harsh J 2006 ³¹	Positive affectivity (Sociability-free positive affectivity scale)	Sleep quality (CSWS)	NA	PA was independently associated with sleep quality and moderated the effect of interpersonal conflict on sleep quality
Fredman L et al 2014 ²⁰	Positive affect (CES-D)	Sleep quality & quantity (PSQI)	NA	PA was independently associated with sleep quality (i.e., lower PSQI scores for subjective sleep quality and daytime dysfunction) in caregivers
Garcia D et al 2012 ³²	Positive affect (PANAS)	Sleep problems (USI)	PANAS	PA was independently associated with sleep quality (i.e., fewer sleep problems)
Gray EK Watson D 2002 ³³	Positive affect (PANAS-X)	Sleep quality & quantity (PSQI, sleep questionnaire,	PANAS-X	PA was independently associated with sleep quality (i.e., lower PSQI scores) but not sleep quantity

		retrospective sleep log, sleep log)		
Jackowska M et al 2012 ⁴⁴	Positive affect (self-report items)	Sleep problems (JSPS)	None	PA was associated with fewer sleep problems (i.e. lower JSPS scores)
Jackowska M et al 2011 ³⁴	Happiness (SHS)	Sleep efficiency (actigraphy, JSPS)	PANAS (NA scale)	Happiness was independently associated with higher sleep efficiency but not objective sleep quality
Kelly WE 2002 ⁴⁵	Humor (MSHS)	Sleep disturbance (SAW)	None	Humor production, but not other measures of humor, was negatively associated with sleep disturbance
MacDonald S Kormi-Nouri R 2013 ³⁵	Positive affect (PANAS)	Insomnia (ISI)	PANAS	PA was independently associated with fewer sleep disturbances (i.e., lower ISI scores)
Ng MY Wong WS 2013 ⁴⁶	Gratitude (GQ-6)	Sleep quality & quantity (PSQI)	None	Gratitude was independently associated with better sleep (i.e., lower PSQI scores) in chronic pain patients
Norlander T et al 2005 ³⁶	Positive affect (PANAS)	Sleep quality (self-report)	PANAS	Affective personality (i.e., high PA and low NA) was independently associated with sleep quality
Ryff CD et al 2004 ³⁷	Positive affect (PANAS, MASQ-SF)	REM sleep, sleep quantity (Nightcap eye sensor)	PANAS	PA was not associated with sleep
Stewart JC et al 2011 ³⁸	Positive affect (PANAS)	Sleep quality & quantity (PSQI)	Trait Anxiety scale of the STAI, Trait Anger scale of the STAXI	PA was not independently associated with sleep disturbance
Troxel WM et al 2009 ⁴⁷	Marital happiness (DAS)	Sleep disturbance (WHIIRS)	None	Marital happiness was associated with fewer and less severe sleep disturbances (i.e., lower WHIIRS scores)
Wood AM et al 2009 ³⁹	Gratitude (self-report items)	Sleep quality & quantity (PSQI)	Neuroticism	Gratitude was independently associated with better sleep (i.e., lower PSQI scores)
<i>Longitudinal studies</i>				
Armon G et al 2014 ²¹	Vigor (SMVM)	Insomnia (AIS-5)	Neuroticism	Bidirectional relations between vigor and insomnia symptoms. Vigor and insomnia were negatively associated over time.
Fisher BE et al 1994 ⁵⁰	Excitement (self-report items)	Sleep behavior (parent CSBS), sleep quality (child self-report)	None	Children's and parent's excitement ratings were positively associated with children's ratings of their own sleep behavior and parent's ratings of sleep behavior
Fredrickson BL et al 2008 ⁸³	Positive affect (mDES)	Sleep quantity (PSQI)	NA (mDES)	PA was not independently associated with sleep quantity

Kalak N et al 2014 ⁵²	Subjective psychological well-being (BFW/J)	Sleep quantity (self-report)	None	Sleep quantity was a longitudinal predictor of SPW, but SPW was not a longitudinal predictor of sleep quantity
von Kanel R et al 2014 ⁴⁹	Positive affect (PANAS)	Sleep quality & quantity (PSQI, actigraphy)	PANAS	PA was independently associated with better subjective (i.e., lower PSQI scores) but not objective (i.e., actigraphy) sleep
<i>Ambulatory studies</i>				
Brisette I Cohen S 2002 ⁵⁹	Positive affect (PANAS)	Sleep quality & quantity (PSQI, self-report)	NA	PA was not independently associated with sleep disturbance the following day.
de Wild-Hartmann JA et al 2013 ⁶⁰	Positive affect (self-report items)	Sleep quality & quantity (sleep diary)	NA	Sleep quality was negatively associated with prior daytime PA, whereas sleep latency, sleep period, and number of awakenings showed no significant association with prior day's PA.
Doane LD Thurston EC 2014 ⁶¹	Positive affect (PANAS)	Sleep quality & quantity (actigraphy)	PANAS	Prior day PA was not independently associated with sleep duration, efficiency, or latency
Fuligni AJ Hardway C 2006 ⁵³	Happiness (POMS)	Sleep quantity (self-report)	POMS (anxious feelings, depressive feelings, fatigue)	Prior day happiness was positively associated with sleep quantity and negatively associated with variability in sleep quantity
Galambos NL et al 2009 ⁵⁴	Positive affect (PANAS)	Sleep quality & quantity (self-report)	PANAS	PA was independently associated with same-day sleep quality but not sleep quantity
Garcia C et al 2014 ⁶²	Positive affect (PANAS)	Sleep quality & quantity (self-report)	NA (adapted from the PANAS)	PA was not independently associated with following night sleep quality
Kalmbach DA et al 2014 ⁵⁷	Positive affect (PANAS-X)	Sleep quality & quantity (PSQI)	PANAS-X (three subscales)	Bidirectional relations between PA and sleep quality. Sleep quality at night predicted and was predicted by PA during the day, and daily PA was independently associated with following night SOL and TST.
Lawson KM et al 2014 ⁵⁵	Positive mood (PANAS)	Sleep quality (PSQI) & quantity (self-report)	NA (adapted from the PANAS)	Youths' reports of mothers' PA after work (proxy measure of PA) were independently associated with youths' sleep quality that night (i.e., lower PSQI scores) and sleep quantity
Loft M Cameron L 2014 ⁵⁶	Work-related positive emotions (JES)	Sleep quality & quantity (PSQI)	NA	PA during the workday was independently associated with sleep quality but not quantity that night
Ong AD et al 2013 ¹⁹	Positive affect (self-report items)	Sleep quality (self-report, actigraphy)	NA	PA was independently associated with morning rest and overall sleep quality across individuals

Simor P et al 2015 ⁶³	Positive affect (PANAS)	Sleep quality (GSQS)	PANAS	Average PA (but not day-to-day PA) was associated with better sleep quality
Song S et al 2015 ⁶⁵	Positive mood (self-report items)	Sleep quality (PSQI, self-report)	NA	Daily PA was associated with feeling more refreshed after sleep.
Steptoe A et al 2008 ¹⁷	Positive affect (self-report items)	Sleep problems (JSPS)	None	Frequency of PA was independently associated with fewer sleep problems (i.e., lower JSPS scores) and attenuated the effects of psychological risk factors across individuals
Takano K et al 2014 ⁶⁶	Positive mood (PANAS)	Sleep quality & quantity (actigraphy)	NA	Evening PA was not associated with sleep onset latency, efficiency, or total sleep time
van Zundert RMP et al 2015 ⁵⁸	Positive affect (self-report items)	Sleep quality (self-report)	NA	Bidirectional relations between PA and sleep. Sleep quality at night predicted and was predicted by PA during the day.
Wrzus C et al 2014 ⁶⁴	Affect balance (self-report items)	Sleep duration (self-report)	NA (in affect balance measure)	Affect balance during the previous night was not independently associated with the amount of sleep during the following night
<i>Experimental studies</i>				
Emmons RA McCullough ME 2003 ⁷⁰	Gratitude (self-report items)	Sleep quality & quantity (self-report)	NA	Gratitude was associated with increased PA but was not associated with sleep quality or quantity
Emmons RA McCullough ME 2003 ⁶⁸	Gratitude (self-report items)	Sleep quality & quantity (self-report)	NA	Gratitude was associated with increased PA and reduced NA, and was associated with sleep quantity
Jackowska M et al 2015 ⁶⁷	Hedonic well-being (Positive emotional style scale)	Sleep quality & quantity (PSQI, self-report)	None	Gratitude was associated with increased sleep quality (i.e., lower PSQI scores) and reduced sleep disturbance
Schmidt RE Van der Linden M 2013 ⁶⁹	Pride (BCPQ-extended)	Sleep disturbance (ISI)	NA (regret, shame, guilt)	Pride was not associated with sleep quality or quantity (i.e., SOL, TWT, TST)

Note: **AIS-5** = Athens insomnia scale; **BCPQ** = Bedtime counterfactual processing questionnaire; **BD** = Bipolar disorder; **BFW/J** = Bern well-being questionnaire for adolescents; **CES-D** = Center for epidemiologic studies depression scale; **CSBS** = Children's sleep behavior scale; **CSWS** = Children's sleep-wake scale; **DAS** = Dyadic adjustment scale; **EEG** = Electroencephalogram; **GQ-6** = Gratitude questionnaire-six-item form; **GSQS** = Groningen sleep quality scale; **HCL-32** = Hypomania check list; **ISI** = Insomnia severity index; **JES** = Job emotions scale; **JSPS** = Jenkins sleep problem scale; **MASQ-SF** = Mood and anxiety symptoms questionnaire-short form; **mDES** = Modified differential emotions scale; **MSHS** = Multidimensional sense of humor scale; **MSRS** = Manic state rating scale (aka, Beigel scale); **NA** = Negative affect; **PA** = Positive affect; **PANAS** = Positive and negative affect schedule; **PANAS-C** = Positive and negative affect schedule for children; **PANAS-X** = Positive and negative affect schedule extended; **POMS** = Profile of mood states; **POMS-SF** = Profile of mood states-short form; **PSQI** = Pittsburgh sleep quality index; **REM** = Rapid eye movement sleep; **SAW** = Sleep disturbance ascribed to worry scale; **SHS** = Subjective happiness scale; **SMVM** = Shirom-Melamed vigor measure; **SOL** = Sleep onset latency; **SPW** = Subjective psychological well-being; **STAI** = State-trait anxiety inventory; **STAXI** = State-trait anger expression inventory; **SWS** = Slow wave sleep; **TST** = Total sleep time; **TWT** = Total wake time; **USI** = Uppsala sleep inventory; **WHIRS** = Women's health initiative insomnia rating scale; **Y-BOCS** = Yale-Brown obsessive compulsive scale; **YMRS** = Young mania rating scale