A scoping review of sleep discrepancy methodology: what are we measuring and what does it mean?

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1 Abstract

1.1 Study Objectives

To examine how past studies have conceptualised sleep discrepancy and identify and evaluate the methods used for its measurement and analysis.

1.2 Method

We searched MEDLINE, Embase, PsycINFO, CINAHL Plus, PubMed, Scopus, and Web of Science in April 2022 for studies comparing self-report and objective measures of sleep. Methodological information was extracted from relevant studies and included measures of self-report and objective sleep, sleep variables (e.g., total sleep time), derived discrepancy indices (e.g., difference scores), handling of repeated measurements, and methods of measure comparison (e.g., Bland-Altman analyses).

1.3 Results

Two hundred and forty-four relevant records were identified. Studies varied according to objective sleep measure; actigraphy algorithm, software, and rest interval; polysomnography setting and scoring criteria; sleep variables; self-report sleep measure; number of nights of objective recording; time frame of self-report measure; self-report sleep variable definition; sleep discrepancy derived index; presence and handling of repeated measurements; and statistical method for measure comparison.

1.4 Conclusions

Sleep discrepancy was predominantly conceived as discordance in sleep states or sleep time variables, and various forms of this discordance differed in their conceptual distance to sleep misperception. Furthermore, studies varied considerably in methodology with critical conceptual and practical implications that have received little attention to date. Substantive methodological issues were also identified relating to the use of derived indices for operationalising sleep discrepancy, defining objective sleep onset latency, calculating actigraphy rest intervals, measuring correlation and concordance, averaging sleep variables across nights, and defining sleep quality discrepancy. Solutions and recommendations for these issues are discussed.

1.5 Key words

Sleep discrepancy; sleep misperception; scoping review

1.6 Statement of Significance

Sleep discrepancy, the discordance between self-report and objective measures of sleep, is an important feature for theory in insomnia and a key issue in sleep measurement. Despite the considerable research in this area, the status of sleep discrepancy as a concept is unclear and varied methodologies are employed with unknown theoretical or conceptual implications. This scoping review integrates a comprehensive range of methodological details from sleep discrepancy studies, clarifying the concept of sleep discrepancy and critically evaluating approaches to its measurement. The broad view of the literature afforded by the systematic search allows us to identify and discuss conceptual and methodological issues that have received little attention and are critical for the advancement of research in sleep discrepancy.

2 Introduction

Sleep is measured in two principal ways: objectively through polysomnography or actigraphy, and by self-report through questionnaires or sleep diaries. The discordance that can exist between these two forms of measurement is known as subjective-objective sleep discrepancy, or more simply, sleep discrepancy. Sleep discrepancy is a common feature of insomnia disorder, where it is also referred to as sleep misperception or paradoxical insomnia. Individuals with insomnia tend to underestimate total sleep time (TST), and overestimate sleep onset latency (SOL) and wake after sleep onset (WASO) relative to objective measures (Baglioni et al., 2014; Edinger & Fins, 1995; Means, 2003) and are more likely to report prior wakefulness after being woken in laboratory studies (Mendelson et al., 1986; Mercer et al., 2002).

Sleep discrepancy has been investigated with diverse methods for its conceptualisation and measurement, such that it can be difficult integrate findings across studies. For example, sleep discrepancy may be considered as a spectrum (Trajanovic et al., 2007), ranging from positive (self-report exceeds objective) to negative (objective exceeds self-report), or as a measure of absolute sleep agreement (Baillet et al., 2016). Any number of sleep variables such as TST, SOL, or WASO can used to operationalise sleep discrepancy, each differing conceptually with a range of theoretical implications. Sleep discrepancy may even be considered beyond these sleep time-based metrics and represent discordance in self-report and objective sleep patterns (Al Lawati et al., 2021), or sleep quality. Sleep discrepancy can be characterised in a sample by directly comparing self-report and objective sleep with a range of statistical analyses. Other studies may calculated derived variables to define sleep discrepancy quantitatively to measure its relationship with other variables, for example using a difference score of self-report TST − objective TST.

To date, there have been limited systematic attempts to synthesise or evaluate the varied approaches to investigating sleep discrepancy. Three reviews have been conducted in this area. Castelnovo et al. (2019) conducted a systematic review of quantitative definitions of paradoxical insomnia, an insomnia subvariant defined, in part, by the presence of sleep discrepancy. This excluded studies where sleep discrepancy was not used to form diagnostic criteria. Two subsequent reviews were conducted by Rezaie et al. (2018) and Stephan et al. (2023) focussing on paradoxical insomnia and the correlates of sleep misperception, respectively. Whilst informative discussions of research findings, these studies excluded a focus on concepts or methodology.

Consequently, sleep discrepancy remains an ambiguous construct, with conceptual and methodological sources of variation that are yet to be formally delineated. This threatens the development of theory in research areas such as insomnia as it can be unclear whether sleep discrepancy studies are measuring or operationalising the same or different phenomena. The replicability of findings can also be affected where proliferation of varying analysis strategies introduces uncertainty into the data analysis process (Hoffmann et al., 2021). Research is needed to integrate and evaluate the varied approaches to sleep discrepancy, clarify its conceptual boundaries, and facilitate comparisons across studies.

A scoping review is a method of research synthesis that aims to map existing literature in a field of interest and identify types of evidence available in a given topic (Arksey & O'Malley, 2005). We used a scoping review strategy to examine how sleep discrepancy has been conceptualised in the literature and identify and evaluate the methods used to investigate it. A preliminary search of MEDLINE (Ovid), the Cochrane Library, Embase (Ovid), and PsycINFO (Ovid) was conducted to identify existing or in-progress systematic or scoping reviews on the topic. Except for the three reviews mentioned above, no records were identified.

3 Methods

3.1 Protocol and registration

The review was conducted according to guidelines provided by the JBI scoping review methodology group (Peters et al., 2020) and reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist (Tricco et al., 2018). A review protocol was registered with the Open Science Framework on April 4, 2022 (doi: 10.17605/OSF.IO/BCJNQ), prior to conducting searches. Deviations from the protocol are outlined in the appendices (11.2).

3.2 Eligibility criteria

Participants of all age groups and clinical populations were included in the review. To adequately map the boundaries of sleep discrepancy as a concept, we included any study that compared an objective measure of sleep (e.g., polysomnography, actigraphy) with an equivalent self-report measure of sleep (e.g., sleep diaries, questionnaires), through statistical analysis or derived indices. Any measure of self-report and objective sleep was considered including indices of sleep time such as TST, SOL, and WASO, in addition to measures of sleep quality, sleep patterns, or any other sleep-related experience or behaviour.

3.3 Exclusion criteria

Studies were excluded that (i) made no direct comparisons between equivalent self-report and objective sleep measures, (ii) included informant, rather than self-report measures, (iii) were case reports or review articles, (iv) were limited to self-report or objective measures not related to sleep, (v) contained no empirical data, (vi) omitted either a self-report or equivalent objective measure of sleep, (vii) were a grey literature source including theses, dissertations, and conference abstracts, or (viii) were not available in English. No records were excluded on the basis of geographic location, cultural factors, or any other contextual feature.

3.4 Search strategy

The search strategy aimed to identify articles published in peer-reviewed journals and, initially, grey literature including theses, dissertations, and conference abstracts. Due to the large number of records returned by initial searches, grey literature was excluded at the full text extraction stage. The following databases were searched: MEDLINE (Ovid), Embase (Ovid), PsycINFO (Ovid), CINAHL Plus, PubMed, Scopus, Web of Science, ProQuest Theses and Dissertations, and OSF Preprints. The search strategy included keywords, index terms, and search operators adapted for each database. Searches across all databases were conducted on the 24$^{\text{th}}$ April 2022. The full search strategy for Embase (Ovid) is provided as an example in Table 1 below. See Appendix A for full search strategies for other databases.

3.5 Sources of evidence selection

Records identified from searches were exported to EndNote 20 (The EndNote Team, 2013) for collation and then uploaded to Rayyan (Ouzzani et al., 2016) for deduplication and title and abstract screening. Two independent reviewers (TW and SF) screened titles and abstracts to identify studies for full-text retrieval using the inclusion criteria. Percentage of agreement between reviewers was 87.6% and conflicts were resolved via discussion. The full-texts of articles passing title and abstract screening were screened by TW with reasons for exclusion reported. Due to the unanticipated size of the literature, articles from sources other than peer-reviewed journals were added to exclusion criteria after protocol registration.

3.6 Charting the data

Data extraction was performed by TW. Methodological features of included articles were selected on their potential influence on the measurement or operational definition of sleep discrepancy and included the following: objective sleep measure type/hardware, actigraphy algorithm, software, and rest interval, polysomnography setting and scoring criteria, self-report sleep measure, sleep variables (e.g., TST, WASO etc…) and definitions

Table 1: Search strategy for Embase (Ovid)

Step	Terms and Operators	Records
1	sleep discrepancy or paradoxical insomnia or subjective insomnia or (sleep adj2 misperception).mp	488
2	((self report* or diary or subjective*) and (objective* or actigraph* or polysomnograph* or polygraph*)).mp.	193243
3	(exp polysomnography/ or exp actimetry/) and exp self report/	1676
4	(sleep* and (”over estimat*” or ”over report*” or ”under estimat*” or ”under report*” or overestimat* or overreport* or underestimat* or underreport* or discrepan* or concordan* or agreement or disagreement or discordan* or congruen* or incongruen*)).mp.	9362
5	2 or 3	193302
6	4 and 5	1234
7	1 or 6	1569

thereof, methods of handling repeated measurements, methods of comparing self-report and objective sleep within groups, and methods for operationalising sleep discrepancy to investigate its relationship with other variables.

3.7 Data items

Extracted data items numbered in the hundreds and are described comprehensively in the codebook available at: https://github.com/tfwalton/sleep-discrepancy-review/raw/main/data/codebook.xlsx.

3.8 Synthesis of results

This manuscript, including all tables and figures summarising data were generated using computationally reproducible methods (Lindsay, 2023; Piccolo & Frampton, 2016) in R version 4.4.0 (2024-04-24 ucrt) (R Core Team, 2023), with R Studio (Posit team, 2024) and R Markdown (Allaire et al., 2023). Packages used in the code for this manuscript include tidyverse (Wickham et al., 2019), bookdown (Xie, 2023a), knitr (Xie, 2023b), kableExtra (H. Zhu, 2023), english (Fox et al., 2021), and DiagrammeR (Iannone, 2023). All code and data are available through the Github repository: https://github.com/tfwalton/sleep-discrepancy-review.

4 Results

The initial search of databases returned 6,190 from which 3,903 duplicate articles were removed. Details of the review process from article identification, screening, and selection are available in the PRISMA flowchart depicted in Figure 1.

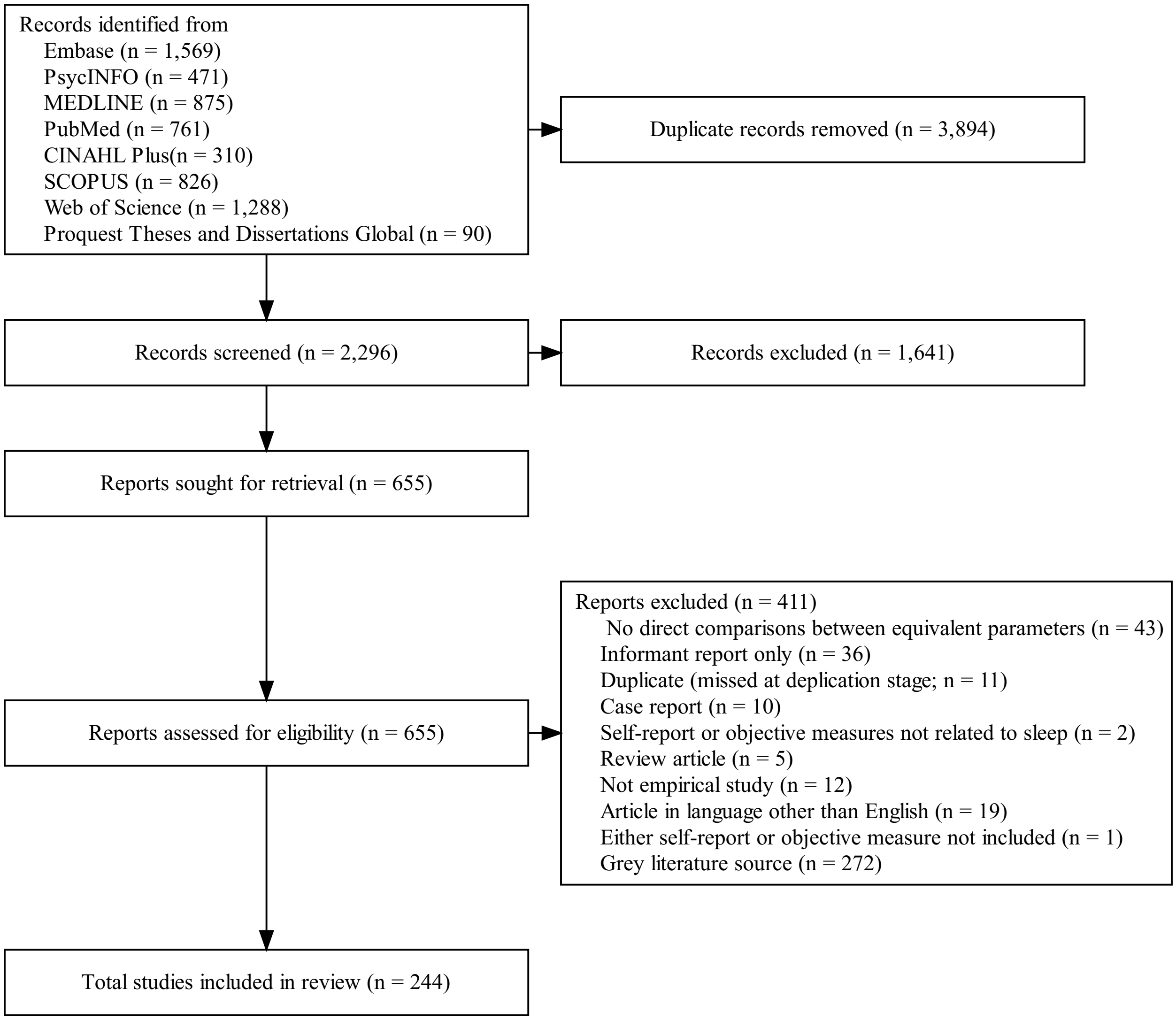

Figure 1: PRISMA flowchart

4.1 Article characteristics

A total of 248 studies was identified from 244 records, with 4 records reporting two studies or experiments within a single text. Records spanned 32 countries, with the majority originating from the USA (n = 96).

Sample sizes for studies ranged from 8 to 8,438 (median = 66, IQR = 119.5). Most studies included both sexes in their samples (n = 229), whereas 8 and 11 comprised only males or females, respectively. Most studies contained samples of adults of all ages (n = 197). Others reported specific age groups: older adults (n = 23), younger adults (n = 14), adolescents (n = 8), and children (n = 6). Sample characteristics for studies are included in Figure 2. For a full list of article characteristics, see the appendices (5)

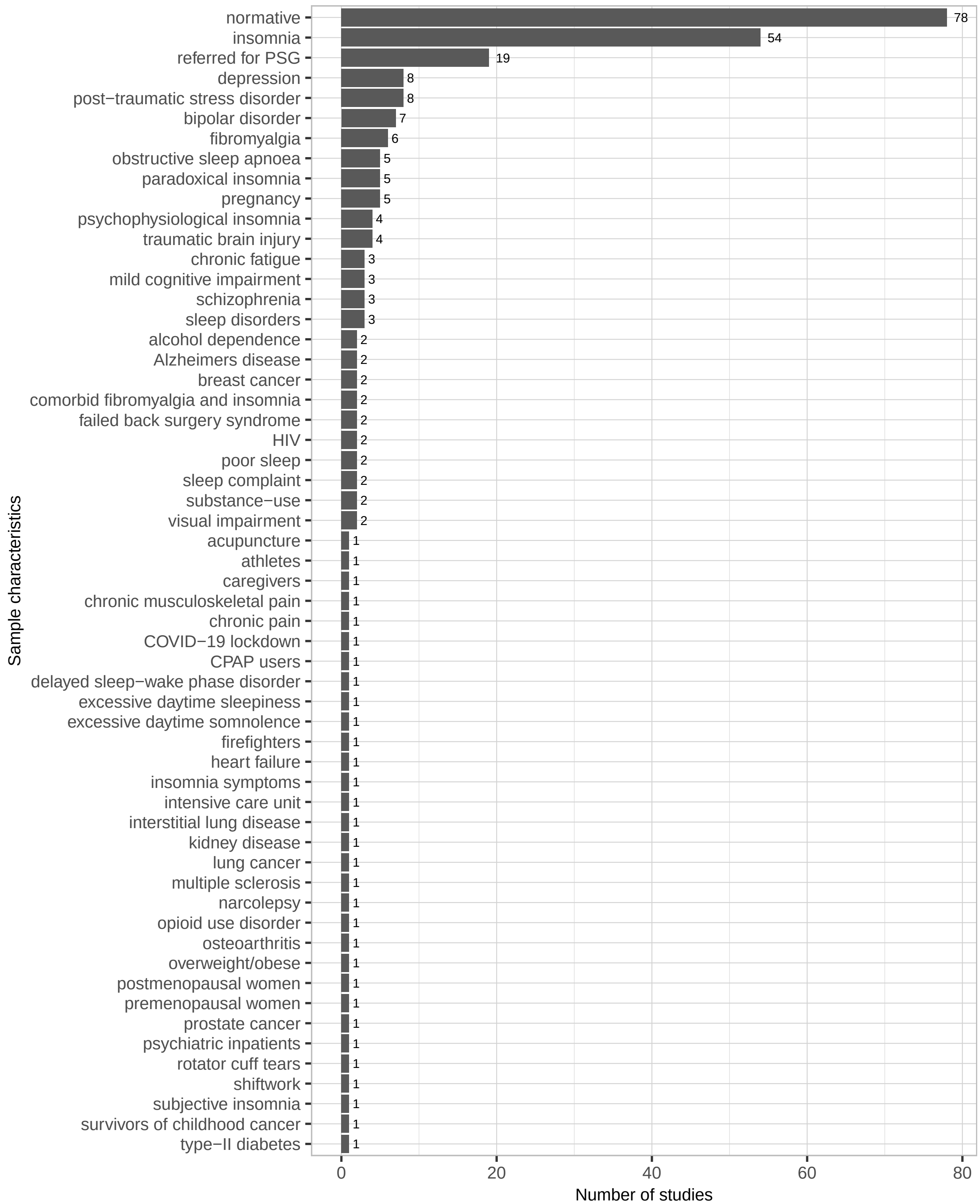

Figure 2: Sample characteristics

4.2 Methodological features

4.2.1 Measures of objective sleep

Objective methods of recording sleep formed two major groups: EEG-based methods and movement-based methods. See Figure 3 for number of studies using each method. All movement-based methods involved tri-axial accelerometry through actigraphs or similar devices. PSG was the predominant EEG-based method (n = 106), however a handful of studies used EEG alone, in either single channel (n = 2), standard (n = 4), or high-definition formats (n = 3). A single study used a method of sleep recording that involved recording verbal responses from participants elicited by soft tones played at intervals throughout the night (Espie et al., 1989).

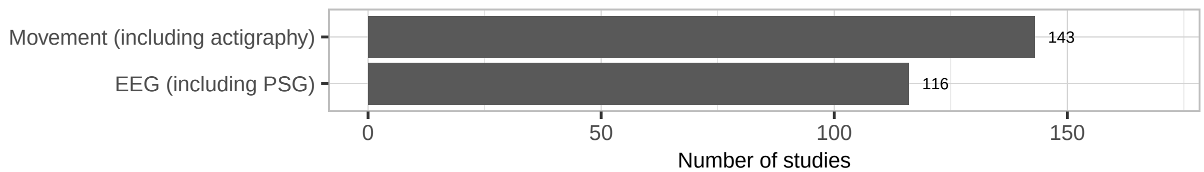

Figure 3: Measures of objective sleep

4.2.1.1 Polysomnography Methodological features charted for PSG included scoring criteria, setting, and recording period. See Figure 4 for scoring criteria of included studies.

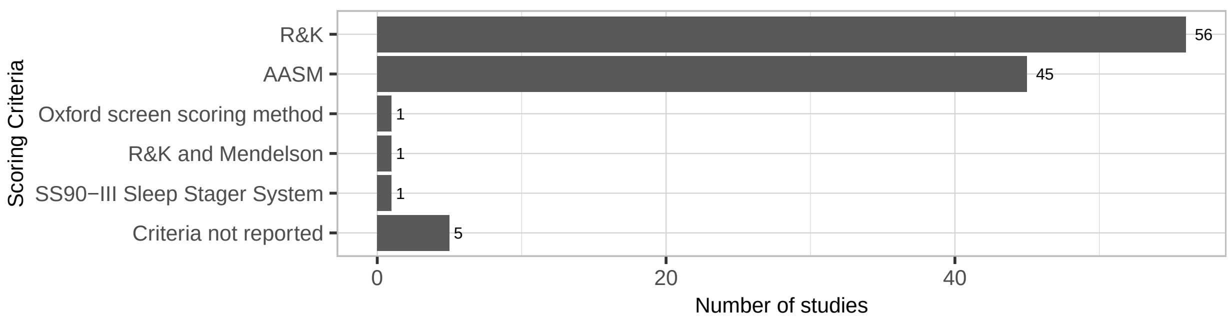

Figure 4: PSG scoring methods

Methods for scoring PSG were mostly divided between American Academy of Sleep Medicine (AASM) and Rechtschaffen & Kales (R&K) guidelines. Rogers et al. (1993) used an automated system for sleep staging, the SS90-III Sleep Stager System (Oxford Medicals, Oxford). Vanable et al. (2000) used Mendelson's (2012) guidelines in addition to R&K. Edinger (1995) used combined audio and visual criteria for sleep staging (1989). Settings for PSG varied and are depicted in Figure 5.

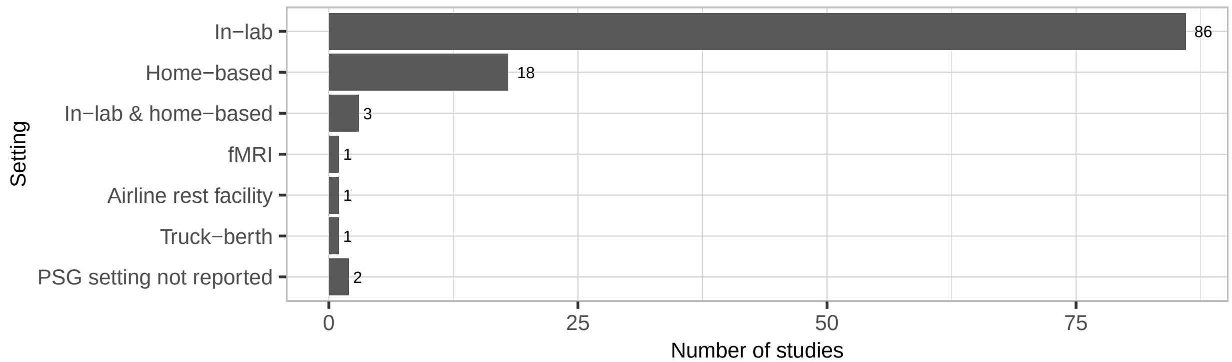

Figure 5: PSG setting

In-lab and home-based tests comprised the substantial majority of PSG settings with a handful of more unusual settings noted. As for recording periods, PSG most often occurred during the night although a number of alternative periods were noted. See Figure 6 for a depiction of PSG recording periods.

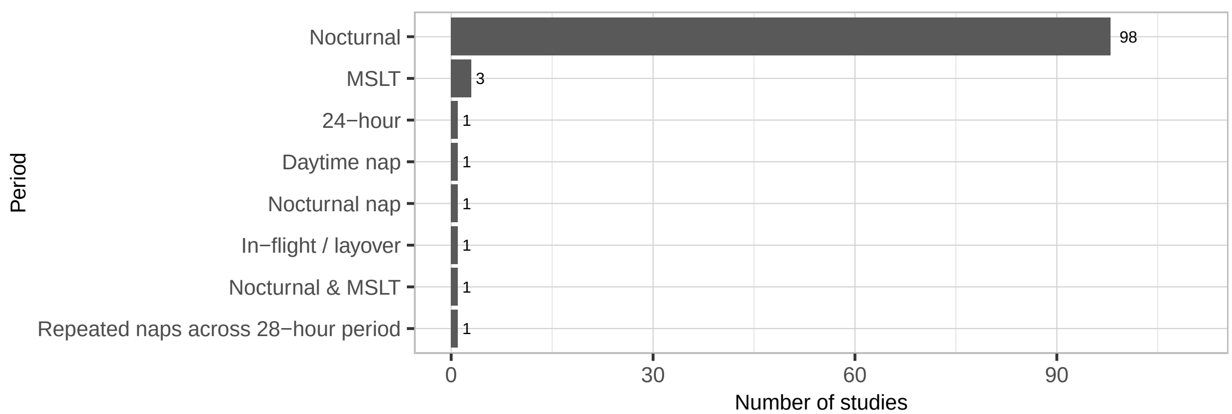

Figure 6: PSG recording period

Note. MSLT refers to the multiple sleep latency test.

4.2.1.2 Actigraphy We recorded features of actigraphy including device name, scoring algorithm, software, and rest interval definition. See Table 6 in the appendices for full tabulations of actigraphy characteristics. Actigraphy scoring algorithms are responsible for determining wakefulness and sleep from accelerometer-derived motor activity. Scoring algorithms varied across studies and included Actiware (Boyne et al., 2013), MotionWare (CamNTech, UK), SenseWear (Lopez et al., 2018), Domino Light (Gorny et al., 1996), Cole-Kripke (Cole et al., 1992), Kripke (Kripke et al., 1978), Sadeh (Sadeh et al., 1994), Actiheart (Barreira et al., 2009), Fitbit (Jean-Louis et al., 2001), UCSD (Jean-Louis et al., 2001), ActiLife (Peach et al., 2014), Actillume (Jean-Louis et al., 2001), Micro-Electro-Mechanical-Systems (Dunne et al., 2013), Sleep Sign Act (Kissei Comtec Co, Japan), IM Systems (Individual Monitoring Systems, Inc., UWA), Machine Learning Alogrithms (John et al., 2019), Fatigue Science (Russell et al., 2000), Barouni (Barouni et al., 2020), Choi (L. Choi et al., 2011), Tudor-Locke (Tudor-Locke et al., 2014), and Troiano (Troiano et al., 2008). The frequencies of these algorithms are depicted in Figure 7.

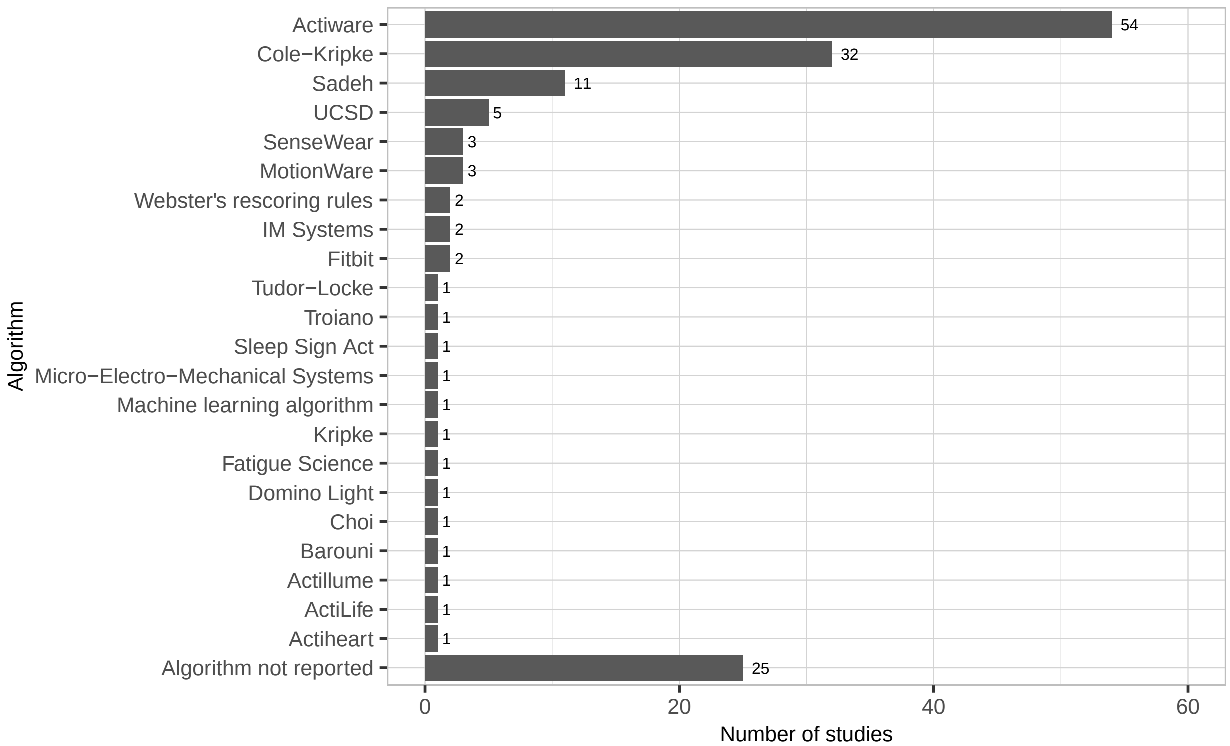

Figure 7: Actigraphy algorithms

Studies using Actiware algorithms varied in their selection of thresholds for scoring wakefulness. These are depicted in Figure 8 below.

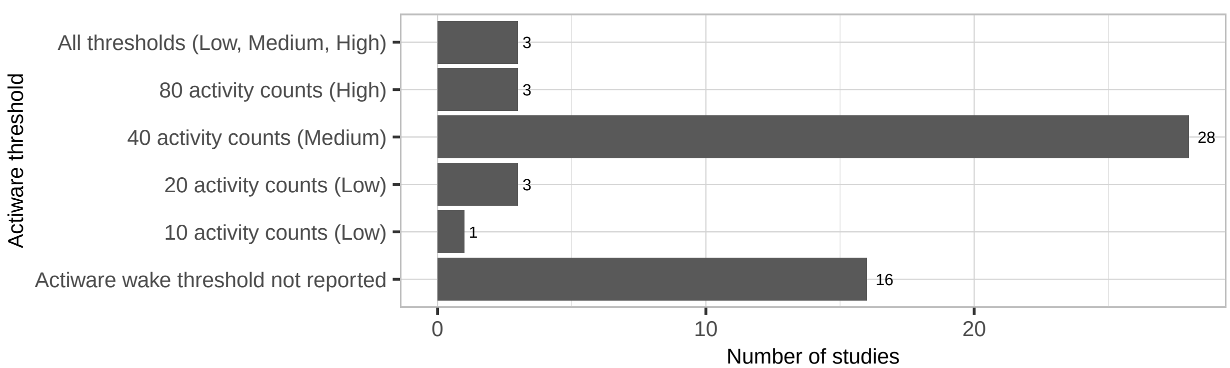

Figure 8: Actiware algorithm threshold settings

The rest interval in actigraphy is the period of time where activity is assessed for sleep and is usually intended to coincide with the time the wearer is in bed, attempting to sleep. Information used to define rest intervals varied across reviewed studies and included, singly or in combination, are depicted below in Figure 9.

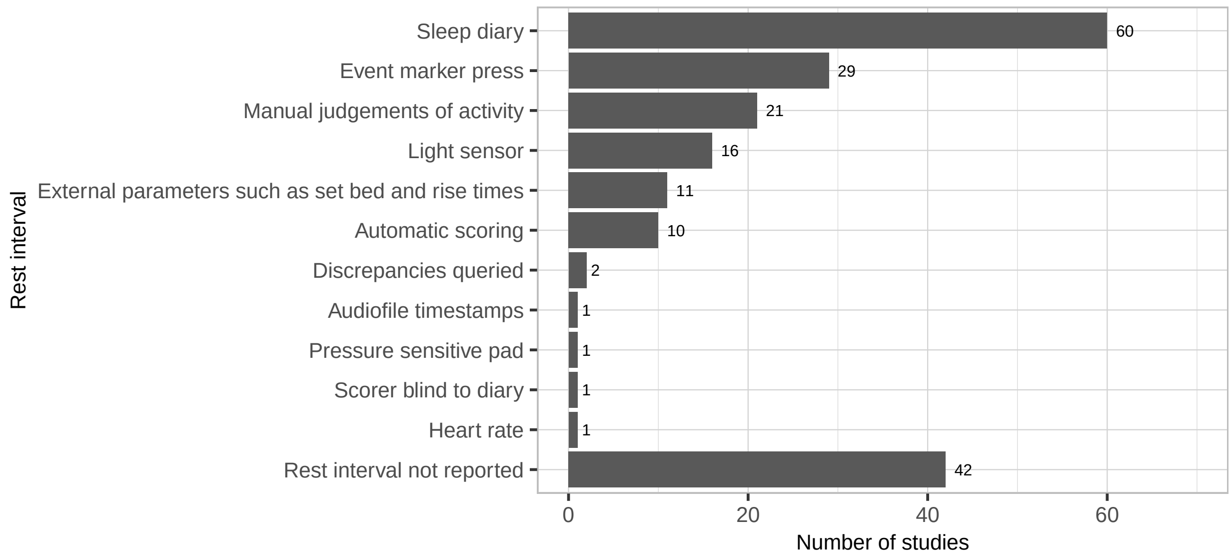

Figure 9: Methods for defining rest intervals in actigraphy

The precise combination and order of priority of methods in each study varied markedly. See Table 6 in the appendices for qualitative descriptions of rest interval approaches across reviewed studies. “Discrepancies queried” indicates that discrepant sleep diary and actigraphy bed and wake times were queried directly with participants and adjusted following discussion.

4.2.2 Measures of self-report sleep

Self-report sleep measures comprised seven major types. See Figure 10 for the number of studies including each of these.

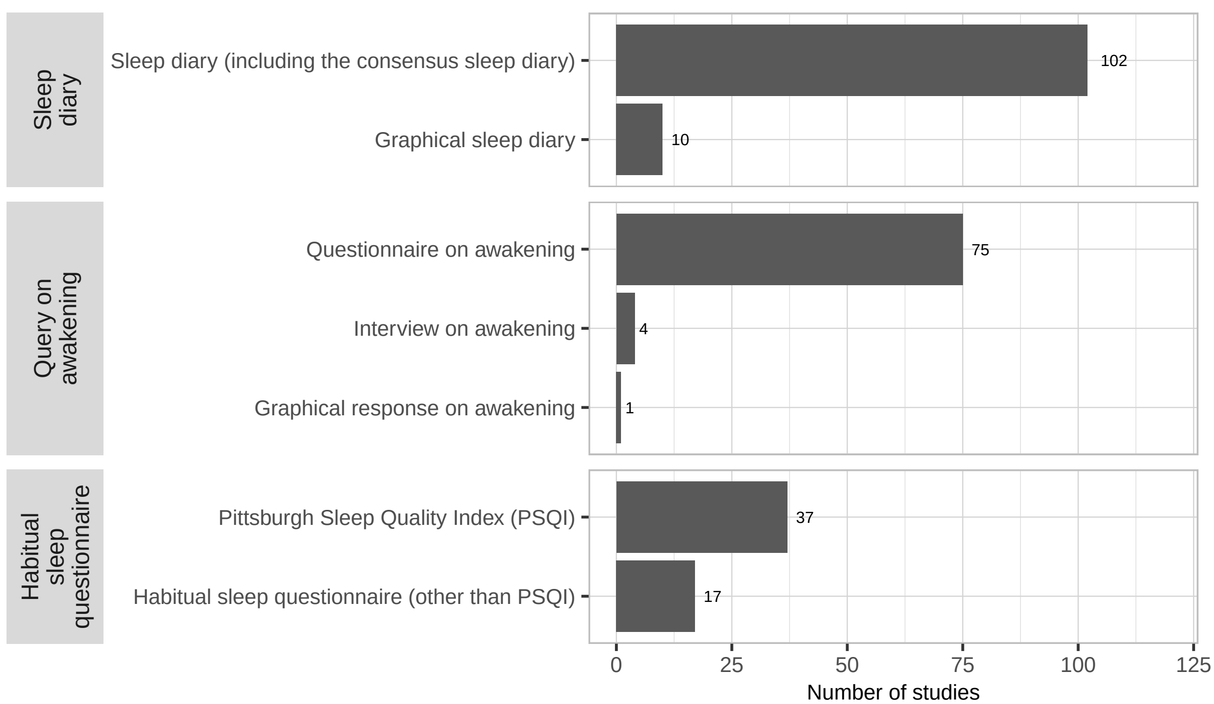

Figure 10: Measures of self-report sleep

Sleep diaries and questionnaires on awakening were the most common measure of self-report sleep, followed by habitual sleep questionnaires including the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989). Note, habitual sleep refers to questionnaires that require participants to provide global judgements about their sleep that correspond to a period of time longer than a single night such as a week or a month. Graphical response formats for sleep diaries and questionnaires on awakening required participants to draw their sleep on scales comprising discrete blocks of time. We also recorded whether self-report measures overall attempted to capture habitual sleep or rather *episodic* sleep that occurred night-by-night/episode-by-sleep episode at the same time as objective measures. Results are depicted in Figure 11 below.

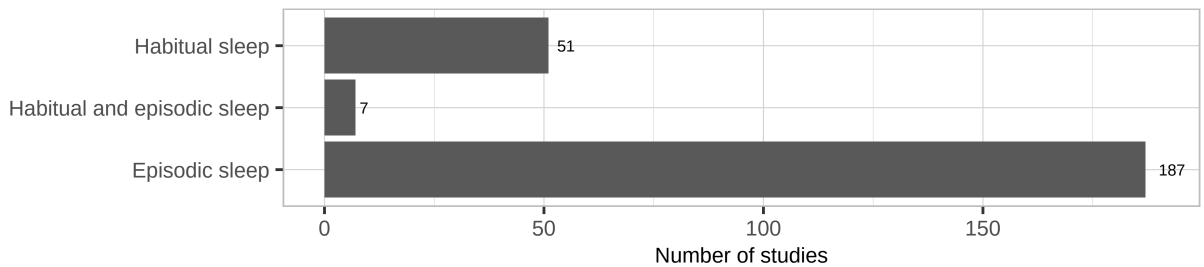

Figure 11: Habitual or episodic sleep

4.3 Sleep variables

A range of variables were used to operationalise sleep discrepancy. These are listed below in Figure 12.

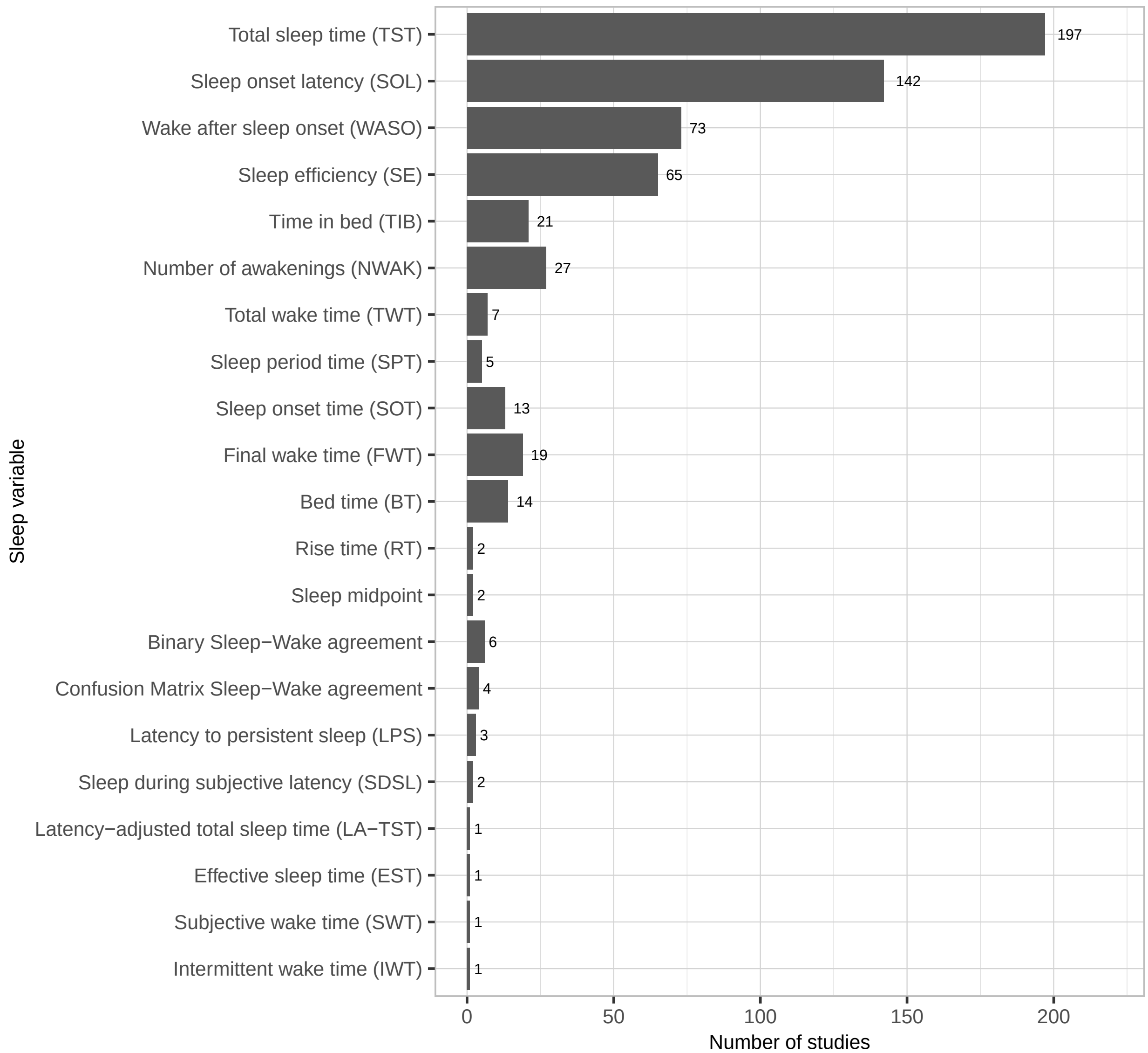

Figure 12: Sleep variables

Note. TST was considered equivalent to sleep duration in this review. Calculation of TST and SE varied across studies in both objective and self-report form. SOL (also referred to as sleep latency; SL) varied only in its objective form whilst WASO varied only in its self-report form. TIB was calculated as the time between bedtime (BT) and rise time (RT). BT and polysomnographic lights off time for PSG studies were considered equivalent in this review. RT was considered equivalent to actigraphic sleep offset and polsomnographic lights on. Sleep mid-point was calculated as (FWT–BT)/2. LPS was defined as latency to 10 minutes of uninterrupted sleep. SDSL was defined objective total sleep time following the point of subjective sleep onset. EST was defined as TST–WASO–SOL. SWT was defined as WASO + SOL. TWAK was defined as the length of time between RT and FWT. No definition was reported for IWT. Binary sleep-wake involved measuring at one or multiple instances whether a participant's reported sleep state matched the objective sleep state upon which the query was conditional (e.g., participants were only queried during objectively-confirmed sleep). On the other hand, confusion matrix sleep-wake involved measuring at one or multiple instances whether a participant's reported sleep state matched an objective sleep state that was allowed to vary independent of the query (e.g., participants were queried at a certain time point irrespective of sleep state). The states were called so as the former approach produces a binary outcome whereas the latter produces a confusion matrix.

The sleep variables TST, SOL, WASO, and SE were most common and formed the majority of identified parameters. Direct sleep-wake agreement was measured by a small subset of studies. Almost all identified sleep variables were measures related to sleep time or awakenings, although we did note some more unconventional parameters listed below separately from the figure above. Allawati et al. (2021) compared self-report and actigraphic measures of sleep patterns including monophasic, biphasic dawn, biphasic siesta, and polyphasic. Lockley et el (1999), Dautovich et al. (Dautovich et al., 2008), Hanisch et al. (Hanisch et al., 2011), and Nguyen-Michel et al. (Nguyen-Michel et al., 2015) reported discrepancy for naps specifically, including variables such as number of naps, number of days napped, mean duration of naps, and total nap time. Baek et al. (2020) and Chan et al. (2018) compared self-report and actigraphic assessments of variability in TST and other sleep parameters. Thun et al. (2012) compared self-report and actigraphic measures of morningness-eveningness. Finally, McIntyre et al. (2016) investigated self-report-objective discrepancy across a range of sleep behaviours including position at sleep onset, position at wake, number of positional changes, and the presence of leg twitches or jerks.

4.3.1 Self-report sleep variable definitions

Calculation of self-report TST, WASO, SE, and TIB varied across studies. Variations across three major types of self-report TST were observed: TST queried directly (e.g., "how many minutes did you sleep last night", TST calculated from other parameters such as TIB, SOL, and WASO, and TST calculated from graphical responses. The results for TST definitions are depicted in Figure 13 below.

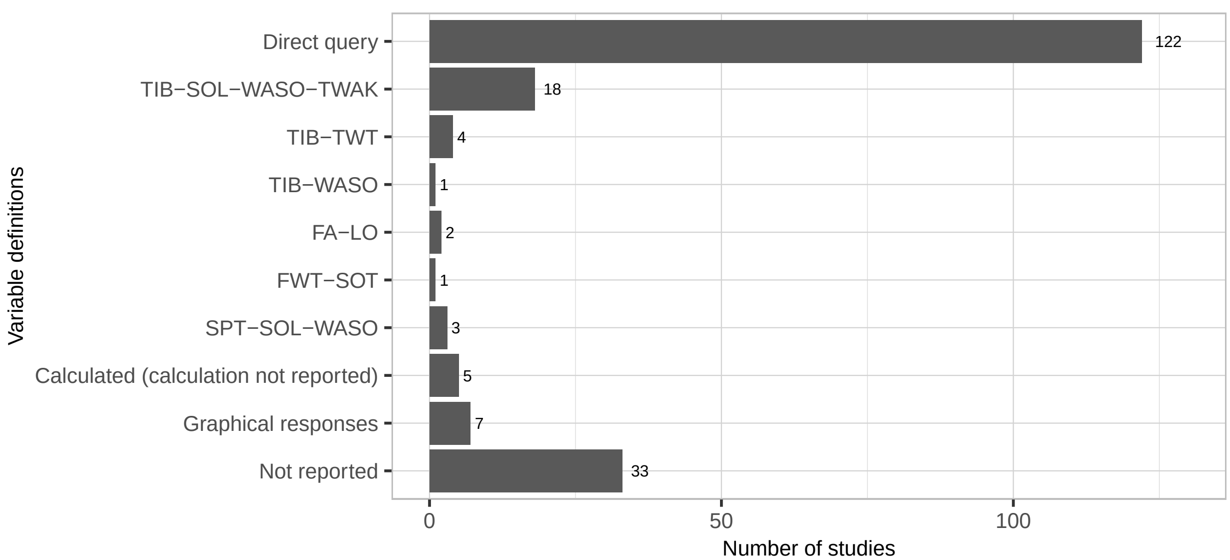

Figure 13: Self-report TST definitions

Note. FA–LO indicates lights off to final awakening. By conventional definitions of SPT, SPT–SOL–WASO is equal to TIB–SOL–WASO–TWAK, but is listed separately above to reflect differences in terminology. Definitions for WASO also varied and these are depicted in 14 below.

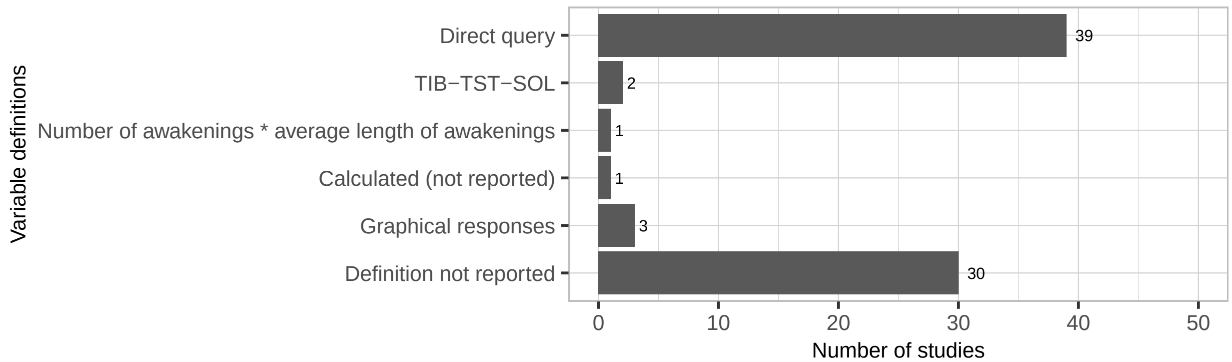

Figure 14: Self-report WASO definitions

Definitions for self-report TIB used in operationalising sleep discrepancy are depicted Figure 15.

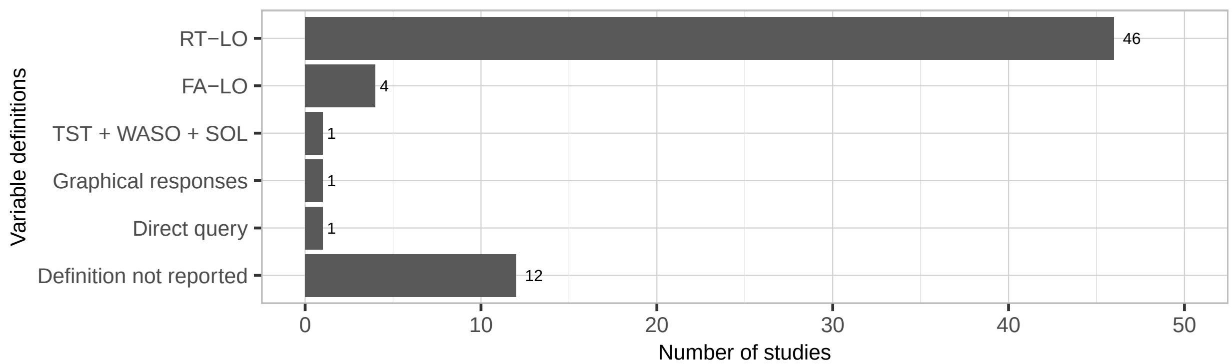

Figure 15: Self-report TIB definitions

Note. RT–LO refers to the time between lights off and rise time. SE was almost unanimously calculated as TST/TIB*100 , although varying definitions for the TST and TIB components affect this outcome. One study (Neu et al., 2007) used two definitions of SE, one comprising TST/TIB and the other TST/sleep period time (SPT).

4.3.2 Objective sleep variable definitions

Objective TST was defined very consistently with the exception of Sinclair et al. (2014) who, in addition to providing a standard definition for TST, measured TST across a 24-hour period, such that time spent asleep outside the usual nocturnal period (i.e., naps) contributed to this measurement. Objective definitions for SOL varied considerably and these are depicted in Figure 16 below.

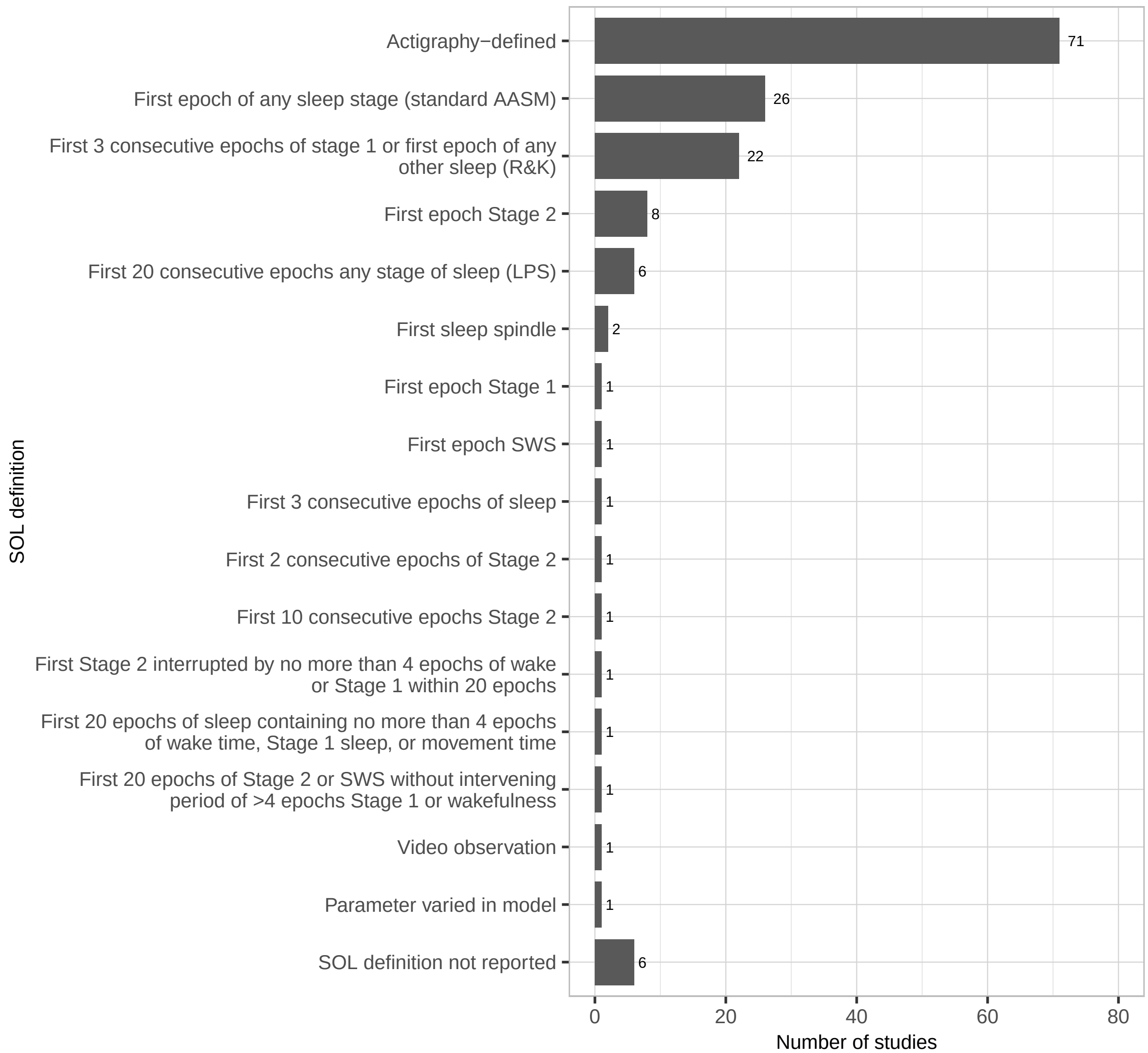

Figure 16: SOL definitions

Note. SWS = slow wave sleep, LPS = latency to persistent sleep, AASM = American Academy of Sleep Medicine guidelines, R&K = Rechstaffen & Kales guidelines. Parameter varied in model indicates that the definition of sleep onset was varied within the context of a predictive model. Among PSG studies, the two most common approaches were dependent on standard definitions provided by the R&K (Rechtschaffen & Kales, 1968) and AASM (Berry et al., 2012) scoring guidelines.

Most studies used standard PSG or actigraphy criteria for defining objective number of awakenings (i.e., a single epoch of wakefulness). A single exception was Lewis et al. (1969), who stipulated that a period last over a minute to count as an awakening. Neu et al. (2007) used the same definitions for objective SE as they did for self-report SE.

4.3.3 Sleep quality

Sleep quality discrepancy was measured by 14 studies using (on the self-report side) sleep quality ratings (n = 8), PSQI total scores (n = 3), sleep quality factor scores (n = 1), sleep depth ratings (n = 1), or sleep quality composite scores (n = 1). On the objective side, sleep quality measures included SE (n = 7), factor scores from sleep variables (n = 2), sleep architectural variables (n = 7), N3 sleep quantity (n = 1), TWT (n = 1), and a composite variable formed from SOL, WASO, and SE (n = 1). Although approaches varied substantially, the most common combination of sleep quality measures was a sleep quality rating and SE.

4.4 Method of handling repeated measurements

Sleep data often involves repeated measurements of the same individual. Actigraphy and sleep diaries usually involve data collection across 7 to 14 days and multiple consecutive nights of PSG are sometimes recorded. Methods for handling repeated measurements are depicted below in Figure 17

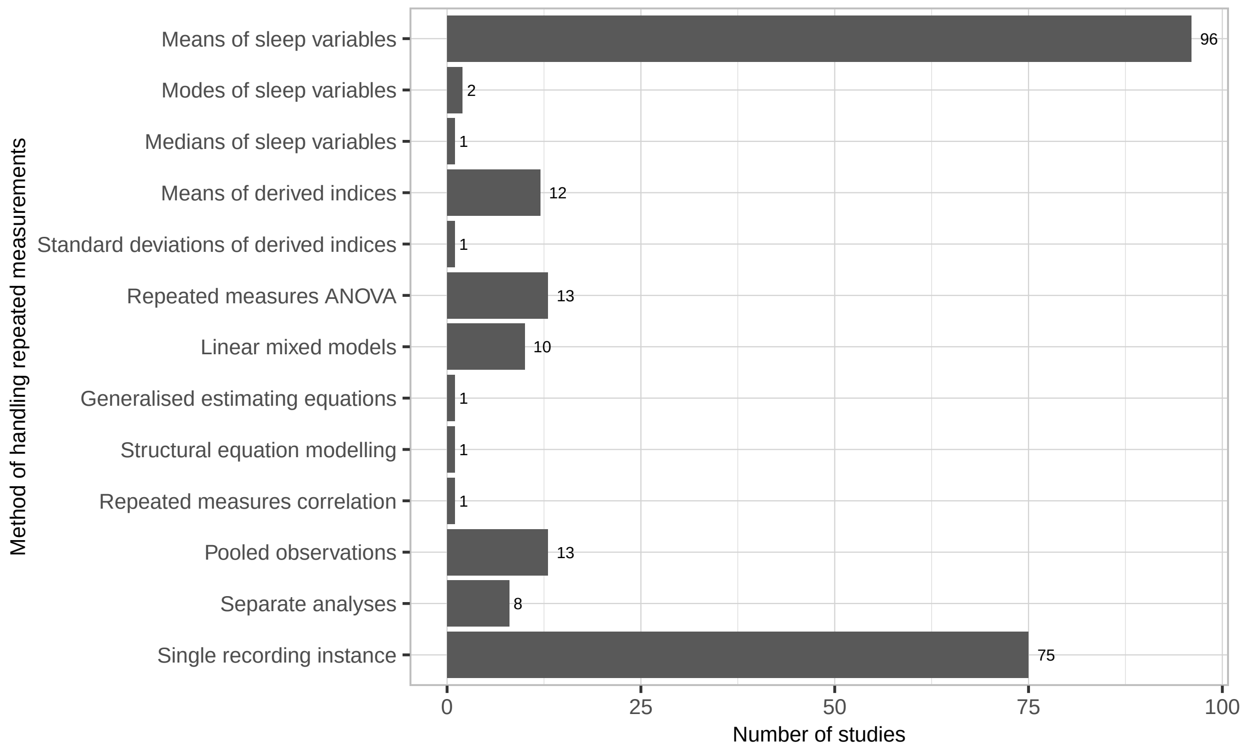

Figure 17: Methods for handling repeated measurements

Note. pooled observations involved collapsing data across multiple instances of recording. Separate analyses indicate that analyses were conducting separately for each instance of recording. In addition to the above, some studies measuring naturalistic sleep in the home environment took day of week into consideration for analyses. Three studies calculated a weighted average for sleep variables equal to 5/7* (mean weekday sleep) + 2/7* (mean weekend sleep), and 9 performed analyses for weeknights and weekends separately.

4.5 Direct comparisons of self-report and objective sleep

A total of 172 studies measured sleep discrepancy at the group level by directly comparing self-report and objective sleep. Methods for achieving this varied and are depicted below in Figure 18

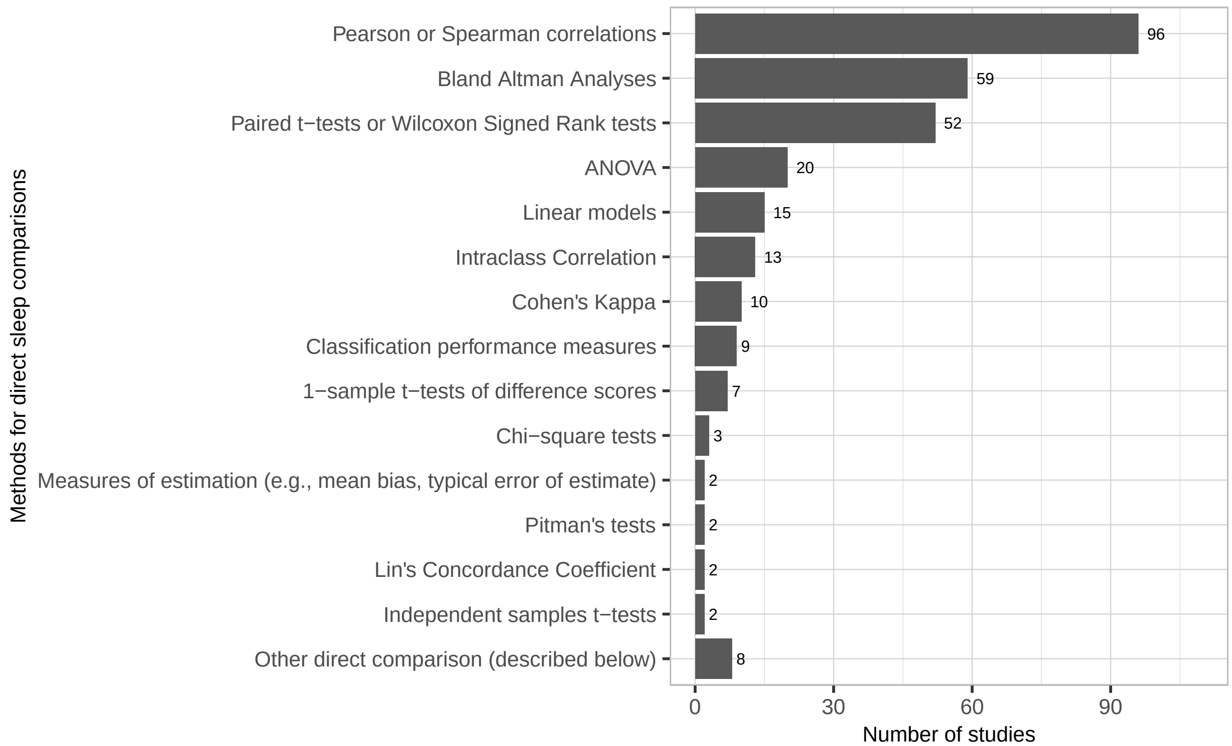

Figure 18: Statistical methods for comparing self-report and objective sleep

Note. Bland Altman analyses include Bland Altman plots and the reporting of 95% limits of agreement (Bland & Altman, 1999). Pitman's test (also known as the Pitman-Morgan test) is a test of differences of variances between dependent samples (Morgan, 1939; Pitman, 1939) and was used to compare the variability of self-report and objective sleep. One-sample *t*-tests of difference scores are equivalent to paired *t*-tests but are included separately in the figure to reflect differences in reporting. Classification performance measures include percentage agreement, accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Formulae used for the intra-class correlation coefficient varied across studies. Spearman correlations and Wilcoxon Signed Rank Tests were often used to handle the skew of variables such as SOL and WASO. Other methods included the delta coefficient (Girschik et al., 2012), partial correlation and factor analysis (Regestein et al., 2004), errors-in-variables regression (Lauderdale et al., 2008), repeated measures correlation (Gibson et al., 2023), non-parametric limits of agreement (Thurman et al., 2018), survival agreement (Guedes et al., 2016), latent correlations for testing associations at within-subjects and between-subjects level (Feng & Svetnik, 2018), and structural equation modelling (Friedmann et al., 2022).

4.6 Methods for investigating the relationship of sleep discrepancy with other variables

A total of 133 studies aimed to investigate the relationship of sleep discrepancy with other variables of interest. Most studies achieved this by operationalising sleep discrepancy at the individual level through the calculation of a derived index.

4.6.1 Derived indices

Approximately half (n = 128) of included studies calculated a derived index (e.g., self-report TST–objective TST) to operationalise sleep discrepancy. Some studies used indices directly in statistical analyses (n = 107) whilst others used indices to divide samples into groups (n =18) either dichotomising (n = 12) or trichotomising (n = 6) derived score values. Methods for deriving indices varied across studies and can be broadly categorised into four groups: arithmetic difference scores, where one measure is simply subtracted from the other (e.g., sTST–oTST); absolute difference scores, composed of the absolute value of algebraic difference scores (e.g., |sTST–oTST|); ratio scores, when one measure is divided by the other (e.g., sTST/oTST); and combination scores that incorporate both subtraction and division of component measures (e.g., oTST–sTST/oTST). A list of indices including the number of studies that used them are provided in Figure 19 below.

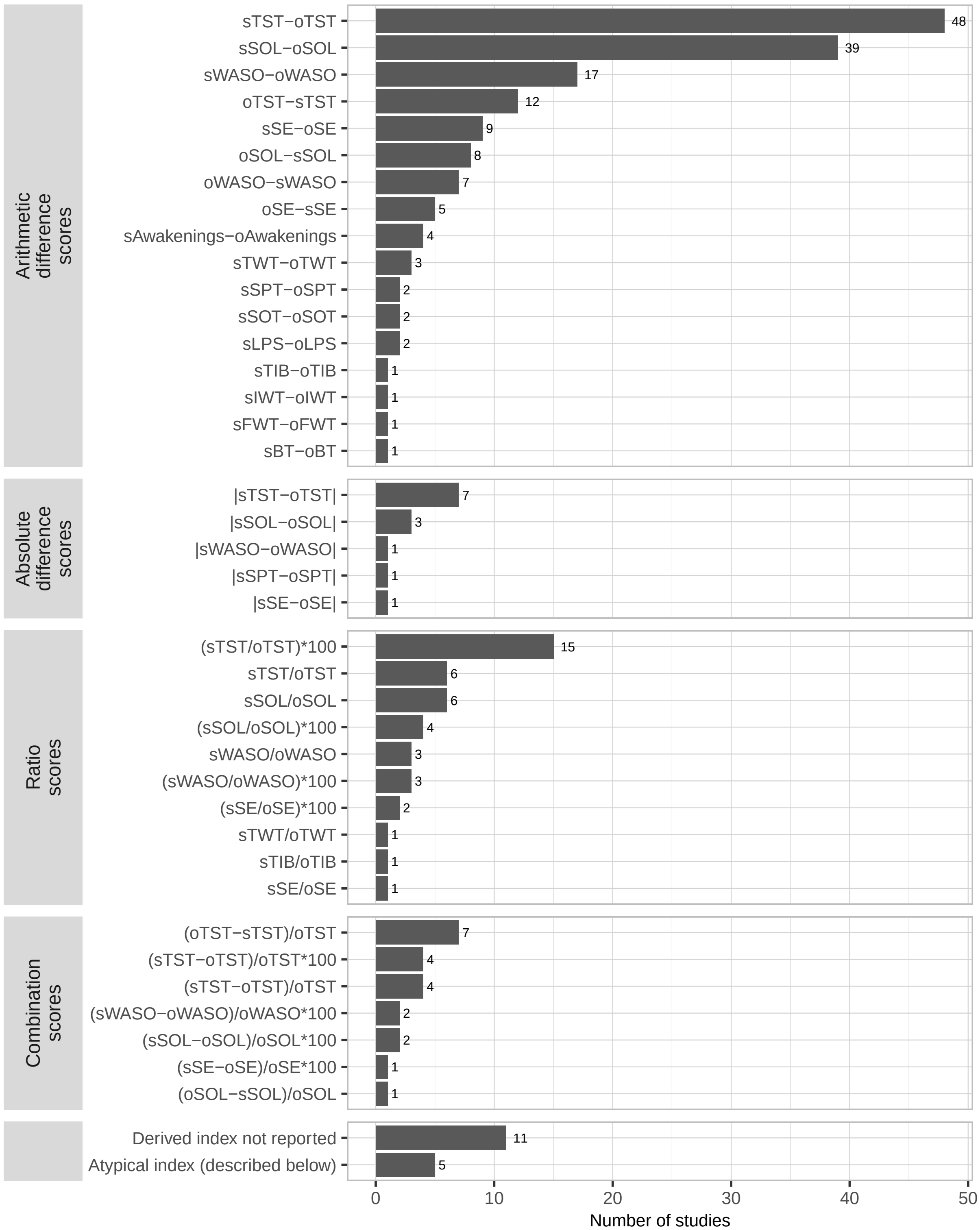

Figure 19: Derived indices used for operationalising sleep discrepancy

Overall, the sleep variables TST, SOL, and WASO represented the substantial majority of derived indices. Arithmetic difference scores were the most common derived index and with these objective sleep was subtracted from self-report sleep considerably more often than vice-versa. By contrast, ratio scores did not differ in directionality, and all that were recorded featured self-report sleep as the numerator and objective sleep as the denominator. Absolute differences are unique amongst derived indices for operationalising negative sleep discrepancy as equal to positive sleep discrepancy. With the relatively few absolute difference scores noted here it appears that the literature has mostly conceived of sleep discrepancy as a directional concept. All the combination scores identified followed the general format of an arithmetic difference score divided by a component of the difference.

A handful of more atypical derived scores were identified. Jackowska et al. (2011) created a sleep quality discrepancy index by subtracting a z-transformed self-report sleep quality rating from z-transformed objective SE. Kay et al. (2013) derived a nightly variability index for sSOL–oSOL and sWASO–oWASO by dividing intra-individual standard deviations by the sample-wise standard deviation for each variable. Mendelson et al. (1986) divided self-report sleep following experimental awakenings by objective sleep following experimental awakenings. Winer et al. (2021) derived a difference score from subtracting composite scores composed of the average of z scores of TST, SE, and sleep fragmentation (number of awakenings/SPT*100) from z-transformed PSQI total scores.

4.6.2 Other methods for operationalising sleep discrepancy

A number of other ways to characterise the relationship of sleep discrepancy with other variables of interest were identified and are depicted in Figure 20 below. Some studies operationalised sleep discrepancy using an interaction term within an ANOVA or other linear model such that the other variable(s) of interest was/were instantiated as the moderator of the relationship between self-report and objective sleep. Others used percentage agreement for sleep or other classification performance metrics in subsequent statistical analyses with other variables. Differences between correlations amongst self-report and objective sleep between groups were also tested with bootstrapped confidence intervals Jackson et al. (2020), or the Fisher transformation (De Francesco et al., 2021). Some operationalised sleep discrepancy with the Sleep Fragment Perception Index (SFPI), an index that exploits the fact that longer sleep fragments are more likely to be identified as sleep by individuals than shorter fragments (Hermans, Van Gilst, et al., 2020). The SPFI is a parameter modelled to assume the shortest length of objective sleep that is perceived as subjective sleep. For the SFPI, a higher value corresponds to a longer sleep fragment necessary for subjective awareness of sleep and hence greater sleep discrepancy.

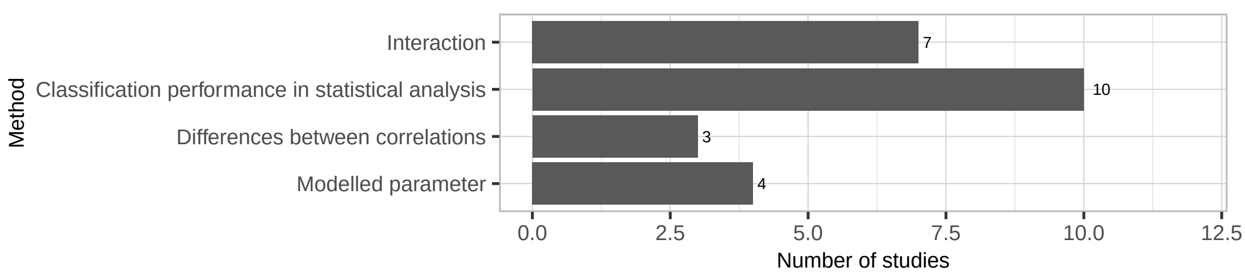

Figure 20: Other methods for operationalising sleep discrepancy

4.7 Miscellaneous methodological features

Lastly, we recorded some other methodological features of studies that appeared pertinent to the study of sleep discrepancy. Eleven studies investigated sleep discrepancy during, as a predictor of response to, or as an outcome of, cognitive behaviour therapy for insomnia (CBT-I). Fifteen studies used an experimental awakening paradigm where participants were monitored in-lab and woken by sound probes or technician interventions. A total of 15 studies were conducted with the aim of validating or assessing a particular sleep instrument.

5 Discussion

This study reviewed ways of measuring, conceptualising, and analysing sleep discrepancy. Studies varied considerably across the broad range of recorded methodological characteristics and the number of records identified indicated a diverse literature. At the level of measurement, objective sleep mostly consisted of polysomnography and actigraphy, whilst self-report sleep spanned a range of questionnaires and diaries of varying response formats. Within objective sleep measures, approaches varied according to setting, equipment, and processing of data. Sleep time-related metrics (e.g., TST, SOL, WASO) preponderated in the identified studies, with a small minority measuring direct sleep-wake agreement and a handful of studies measuring other sleep-related features or behaviours. Sleep quality was also investigated by a small number of studies. Definitions for sleep variables themselves did vary across studies although mainly on the self-report side and principally for the variables TST, WASO, and TIB, although objective SOL varied considerably. At the level of data processing and analysis, a range of strategies were employed to accommodate repeated measurements but for many studies, too, there was a single instance of recording. Direct comparisons were commonly made between self-report and objective sleep and these spanned a number of statistical approaches. Many studies went further than comparing self-report and objective sleep directly and attempted to investigate the relationship between sleep discrepancy and other variables. This was achieved most often with derived indices (e.g., self-report TST–objective TST), although other strategies were also used. Our findings are discussed below with recommendations for further research where relevant.

5.1 Methodological heterogeneity poses a problem for sleep discrepancy research

In measuring the discrepancy between two concepts, the discrepancy—or variability—within each concept itself is an important consideration. This is because in any single instance, the discrepancy being measured can be accounted for partially or completely by the variation within each concept. Our results indicate that self-report sleep or objective sleep are not monolithic entities but variegated in ways that may be important. Take, for example, the simplest methodological distinction in objective sleep measurement: polysomnography versus actigraphy. In comparison with PSG, actigraphy generally overestimates sleep and underestimates wake time, and can have trouble distinguishing sleep from quiescent periods of wakefulness (Marino et al., 2013). These trends have been observed to be greater for samples experiencing chronic medical or psychiatric conditions (Conley et al., 2019). Tryon (2004) has emphasised that these differences between polysomnography and actigraphy are systematic, rather than random, and that each validly measure different aspects of sleep.

This issue continues through finer methodological distinctions. For example, within actigraphy, estimation of sleep can vary substantially across the various scoring algorithms identified in this review. There is ample evidence indicating that the concordance of actigraphy to PSG by algorithm can vary according to the sample in question (Gao et al., 2022; Haghayegh et al., 2019; Quante et al., 2018; Souza et al., 2003) and algorithm performance can even vary based on the actigraph device used (Kripke et al., 2010). A further example can be represented by the sheer range of sleep variables available to operationalise sleep discrepancy. Discrepancy within each variable is likely to have a distinct theoretical meaning. For example, Castelnovo et al. (2019) noted that little overlap was found between individuals who misperceive TST and misperceive SOL. Important distinctions continue even within sleep variables themselves. We identified a range of self-report TST definitions, with the most common being direct queries (e.g., "how many hours did you sleep last night?") and calculated parameters (e.g., TST = TIB–SOL–WASO–TWAK). Alameddine et al. (2015) compared these two definitions and found that calculated estimates tended to exceed those from direct queries. TST discrepancy was overall negative across their sample for those with and without insomnia and so it is possible that indirect queries produce self-report TST that is closer to objective estimates.

For each of these examples, there are differences in sleep discrepancy across methodological approaches that evidence indicates is likely to be systematic. To the extent to which these systematic differences map on to known conceptual differences, distinct kinds of sleep discrepancy must be assumed. If methodological differences do not correspond to distinct concepts, methodological choices are arbitrary and introduce undue uncertainty into inferences (see, Hoffmann et al., 2021). This can be a significant problem. For studies investigating the relationship between sleep discrepancy and another construct, the variance accounted for by the span of possible approaches may well exceed that of the effect for which the researchers are looking. For studies describing sleep discrepancy within a population, findings may not generalise beyond the particular combination of methodological choices that were made in the study.

Addressing this issue may take a number of approaches. A stronger research focus on methods would be helpful overall, with studies such as Alameddine et al. (2015) having the potential to further demonstrate the effect of deceptively small changes in methodology. A more formal large-scale approach could involve the *multiverse analysis* of Steegen et al. (2016), systematically analysing across a variety of data sets resulting from different but justifiable methodological decisions. Specific tools such as structural equation modelling could be used to account for the variance represented by various methodological choices alone or in relation to other constructs (Bagozzi & Yi, 2012). Theoretical justification or another such rational account should also be provided for selection of sleep variables where possible, as many are likely to be conceptually distinct. A standardised approach to conducting and scoring actigraphy would also be tremendously beneficial, and serve to reduce the considerable methodological variance identified in this particular area.

5.2 Methodological heterogeneity may influence the rate of false-positive findings

Methodological diversity may also have consequences for the rate of false-positives in the sleep discrepancy literature. The term *researcher degrees of freedom* has been used to refer to the range of possible decisions throughout the data collection and analysis process that can be exploited to yield tests that reach statistical significance (Simmons et al., 2011). As evidenced by this review, the amount of researcher degrees of freedom in sleep discrepancy research is considerable, particularly at the data analysis stage, and especially for sleep variable definition and selection. Any combination of the large number of sleep variables identified in this review may be chosen as an alternative analytic decisions during analysis. When the different possible definitions of each of these variables are also enumerated, the number of possible decisions seems endless. Note, this issue is not confined to the case of a researcher deliberately exploring analytical alternatives following a null result. In a problem referred to as the *garden of forking paths* (Gelman & Loken, 2013), any methodological decision made in response to an observed feature of the data increases the likelihood that findings will be misleading. An example of this would be selecting SE over TST for a subsequent analysis after observing that SE discrepancy best discriminated individuals with and without insomnia. Even though the eventual result is at this point unknown, the decision of sleep variable is contingent on the data, and ultimately, p-values will not reflect what would have happened had TST been chosen instead. For any study investigating the relationship of sleep discrepancy with other constructs, pre-registration of hypotheses and plans for data collection and analysis (Nosek et al., 2018) is likely to be helpful in minimising inflated Type I error through post-hoc methodological decisions.

5.3 Definitions of objective sleep onset latency are multifarious and mostly arbitrary

Definitions of objective SOL vary considerably in the sleep discrepancy literature. Self-report sleep onset is more likely to coincide with the occurrence of the first sleep spindle, an EEG waveform associated with stage 2 sleep, than with the first incidence of stage 1 sleep (Bonnet & Moore, 1982). As such, R&K SOL is likely to have greater correspondence to self-report SOL than AASM SOL. This disparity would be expected to increase with greater sleep fragmentation in the early sleep period and substantial differences in AASM and R&K sleep discrepancy should be expected in samples with disrupted initial sleep. Stricter/longer SOL definitions including the Latency to Persistent Sleep (LPS) (Bianchi et al., 2012) and complex definitions from Means et al. (2003) and Lehrer et al. (2022) are expected to have the closest correspondence to self-report SOL, as research indicates 22-minutes of uninterrupted sleep is needed for healthy adults to perceive a bout of sleep during the beginning of the night (Hermans, Nano, et al., 2020).

Sleep onset is a continuous process for which it is difficult to identify a clear start-point (Tryon, 2004). For example, with PSG scored by AASM criteria, 50% of a 30-second epoch is needed to exhibit sleep for the scoring of a first sleep stage. This means sleep latency is defined as the number of epochs preceding the first uninterrupted ~16 seconds of an EEG depicting activity consistent with sleep. An individual could conceivably achieve this 16-second threshold within two minutes, wake up, and not return for another two hours (SOL = 2 minutes). Equally, an individual could spend a two hour period getting 14-second blocks of sleep before achieving a consolidated bout of sleep (SOL = 120 minutes). These are extreme examples, but they highlight the difficulty with defining a single point of sleep onset. Of course, a line needs to be drawn somewhere, but the position of this line appears to be an arbitrary decision.

Saline et al. (2016) noted another problem although only for studies that investigate both TST and SOL concurrently. In the estimation of TST, individuals may attempt to judge the length of time between their subjective sleep onset and final wake time—anchoring their TST estimate to their SOL estimate. In measuring TST and SOL discrepancy, SOL discrepancy is thus being tested for twice: once in SOL and again implicitly in TST. Their solution to this problem was to obtain independent measurements by estimating the amount of objective sleep measured during the subjective sleep latency period (sleep during subjective latency; SDSL) and the amount of objective sleep measured following the subjective sleep latency period (latency adjusted total sleep time; LA-TST).

In view of these issues, three options are recommended in the context of sleep discrepancy research:

1. Proceed with defining objective SOL using latency to persistent sleep (LPS)—the first 20 consecutive epochs of sleep. Due to the considerable time it takes to perceive a bout of sleep and the rarity and limited magnitude of SOL underestimation (Hermans, Nano, et al., 2020; Saline et al., 2016) it makes sense to use a longer criterion than a shorter one. LPS also has the advantage of being simpler than many of the alternatives we identified.
2. Use SDSL for the reasons described in the previous paragraph. It should be noted, however, positive discrepancy (i.e., SOL underestimation) is not measurable with this method.
3. Avoid SOL as a sleep variable and to model sleep perception parameters during the sleep onset period according to Hermans et al. (2020).

Options 2 and 3 have the added advantage of operationalising sleep discrepancy without the use of derived scores—the problems with which are discussed briefly in a following paragraph.

5.4 Sleep discrepancy is mostly restricted to sleep states or sleep time and varies in its conceptual distance to sleep misperception

To map the boundaries of the concept of sleep discrepancy, we included any studies comparing objective sleep with an equivalent measure of self-report sleep. From the very few studies identified investigating sleep patterns or other sleep-related behaviours it appears that sleep discrepancy is mostly restricted to discordance in sleep states (e.g., wakefulness versus sleep) or discordance in sleep time parameters (e.g., total sleep time). It may be helpful to consider sleep discrepancy, as so defined, in relationship to sleep misperception. These two terms have been used interchangeably in the past and the problems with doing this have been noted by a number of authors (Moul et al., 2004; Tryon, 2004). Stated simply, sleep is a complex process for which there no one perfectly valid measure, and using the term *sleep misperception* brings a status to objective measures of sleep that may not be warranted. For example, sleep-like EEG activity can occur during waking consciousness in a phenomenon known as local sleep (Krueger et al., 2019), and other dissociations between the EEG and sleep-related physiological processes have been observed under some conditions (Krueger et al., 2013). Moreover, conventional sleep scoring is but one way of classifying EEG data and subtler systems exist, including the cyclic alternating pattern (Parrino et al., 2012).

Whilst it may not be possible to directly measure sleep misperception for these reasons, sleep discrepancy can be closer or further from sleep misperception conceptually depending on its operational definition. Closest are studies measuring sleep-wake agreement or classification using EEG under laboratory conditions. In a case where a participant who, being asleep for five minutes, is woken by a technician and reports complete wakefulness for the preceding period, only the fallibility of objective recording can account for a conceptual distinction between sleep discrepancy and true sleep-state misperception. This fundamental sleep discrepancy represented by direct sleep-wake agreement can be contrasted with sleep discrepancy represented by sleep time variables (e.g., TST, SOL). Moving from sleep-wake agreement to sleep time variables introduces additional factors that may account for the incongruence between self-report and objective sleep and hence provides a broader definition of sleep discrepancy. On the objective side, PSG potentially introduces artefact from transient (e.g., <15 second) awakenings (Smith & Trinder, 2000) and the arbitrary nature of SOL definitions (see section 5.3). Actigraphy introduces the potential for immobile wake to be scored as sleep (Paquet et al., 2007; Souza et al., 2003) and variance contributed by methodological factors such as choices in scoring algorithms. On the self-report side, sleep diaries and questionnaires introduce memory or reporting biases (Clegg-Kraynok et al., 2023) as potential factors contributing to sleep discrepancy. See Harvey et al. (2012) for a discussion of these factors in the context of insomnia.

In the present review, we reported a key distinction between *habitual* and *episodic* measures of self-report sleep. Moving from episodic to habitual measures broadens the concept of sleep discrepancy yet further. A more global sleep discrepancy may be represented by comparisons of habitual self-report sleep with aggregated objective sleep (e.g., mean sleep variables values across 14 nights of actigraphy), the underlying processes for which are likely different to those of individual nights. Where habitual self-report sleep is compared to objective estimates spanning one to a few nights, intra-individual variation in sleep patterns is introduced to sleep discrepancy. In other words, some component of the difference between objective and self-report sleep can be accounted for by the difference between habitual sleep and the circumstances of testing—which may be substantial. If the objective measure is PSG, effects of the laboratory/testing environment (i.e., the first night effect Agnew et al., 1966; Newell et al., 2012) are additionally introduced. These forms of sleep discrepancy are illustrated in the matrix provided in Figure 21.

Self-report sleep

Objective sleep	Self-report sleep state e.g., laboratory query	Episodic self-report e.g., morning questionnaire TST	Habitual self-report e.g., PSQI TST	Aggregate self-report e.g., weekly mean diary TST
Objective sleep state e.g., laboratory PSG	~ Sleep misperception	N/A	N/A	N/A
Episodic objective e.g., single night PSG	N/A	Sleep time discrepancy	Discrepancy between habitual and episodic sleep	Not typically observed
Aggregate objective e.g., weekly mean actigraphy TST	N/A	Not typically observed	Global sleep discrepancy	Problematic (see 5.6)

Figure 21: Sleep discrepancy matrix

Note. Conceptual proximity of sleep discrepancy to true sleep sate misperception decreases moving down and across the figure. Problems using aggregate measures of both self-report and objective sleep are described in more detail in section 5.6

5.5 Derived indices are common and the use of these as an operational measure of sleep discrepancy is problematic

Derived variables, including difference scores and ratio scores, are overwhelmingly the most common way of operationalising sleep discrepancy to investigate its relationship with other variables. The use of derived variables for such a purpose is associated with a range of conceptual and methodological problems (Cronbach & Furby, 1970; Edwards, 2002; Kronmal, 1993) that are severe enough to warrant discontinuing their use in sleep discrepancy research. Stated briefly, in a relationship with another variable, the effect of each component of a derived index (e.g., a difference score representing the subtraction of self-report from objective TST) is confounded such that it is not possible to determine whether self-report sleep, objective sleep, or some combination of the two is driving the relationship (Edwards, 2002). Moreover, derived scores impose inappropriate constraints on relationships between other variables that are often not entailed by, or else contradictory to, stated hypotheses (Edwards, 2002). A large range of derived variables were identified by this review, none of which escape the problems described by the aforementioned authors. Fortunately, a number of alternative strategies for characterising relationships between sleep discrepancy and other constructs are available. Such methods identified in this review included using classification performance metrics within conventional statistical analyses, representing sleep discrepancy with moderation/interaction effects, and modelling sleep discrepancy parameters mathematically.

5.6 Averaging sleep variables across multiple nights is a common practice and can cause problems

In the studies identified in this review, the most common way of handling repeated measurements of sleep variables was by averaging across multiple instances of recording. This technique is problematic when applied to concurrent episodic (i.e., nightly) measurements of self-report and objective sleep as it relies on the assumption that patterns of sleep over/underestimation are consistent across nights. Extreme positive and negative sleep discrepancy occurring alternately on successive nights could result in averages denoting negligible discrepancy. This may be a realistic concern for research in sleep discrepancy and insomnia, for example. Although most individuals with insomnia tend to underestimate sleep, high inter-night variability is observed (Herbert et al., 2017) and some individuals will overestimate sleep (Lindert et al., 2020; Trajanovic et al., 2007). An exception to this problem exists in the case of comparing aggregated objective sleep against a habitual measure of self-report sleep, such as the PSQI. Here, using means or medians to determine habitual measures of objective sleep is necessary to define sleep discrepancy at the habitual, rather than the episodic level. In other cases, linear mixed models, generalised estimating equations, and structural equation models were methods identified in this review that can avoid problems with averaging across repeated measures.

5.7 Correlations have sometimes been used inappropriately as a measure of concordance

Despite being the most common approach to comparing self-report and objective sleep measures, Pearson or Spearman correlations are broadly inappropriate for the characterisation of agreement or discrepancy. Correlation is strictly a measure of association between two variables and is insensitive to systematic error between measures (Liu et al., 2016). For example, the same correlation coefficient may equally describe a sample where self-report and objective estimates of sleep tend to be equal as one where (i), objective estimates tend to exceed self-report estimates by a given constant (e.g., two hours) or (ii), the value of objective sleep varies proportional to the level of self-report sleep. Measures of agreement including Bland-Altman analyses, intra-class correlation, and Lin's concordance coefficient were also used by a large number of studies and are preferable for the measurement of discrepancy in equivalent parameters.

5.8 Sleep quality discrepancy is conceptually unclear

Sleep quality discrepancy was measured by a small number of studies in this review, according to varying strategies. Sleep quality discrepancy is a difficult topic for two reasons. First, there is no consensus approach to operationalising sleep quality. A recent review of methods for measuring sleep quality identified an immense range in strategies, especially for objective measures (Mendonça et al., 2019). Second, there are no clear self-report analogues for objective measures of sleep quality, or vice-versa. An individual is unable to directly estimate their number of EEG arousals, quantity or proportion of N3 sleep, or other features of sleep macro or microstructure unavailable to consciousness. Equally, it is not clear how to compare a sleep quality rating judgement (e.g., on a Likert scale) with objective measures (see Krystal & Edinger, 2008). Overall, investigating the relationships of sleep quality discrepancy to other variables is unlikely to be profitable until the conceptual status of self-report and objective sleep quality is clearer.

5.9 Sleep diaries should not be used to define rest intervals in sleep discrepancy research

Sleep diaries were the most commonly identified method of rest interval definition in this review. Sleep diaries were classified by this review as a self-report measure of sleep. By using sleep diaries to define actigraphic rest intervals, self-report sleep is being used to partially define an objective sleep measure. In this case, the measured discrepancy between the two forms of sleep measurement will not be an accurate representation of their actual incongruence. The high frequency at which sleep diaries are back-filled or misreported (Clegg-Kraynok et al., 2023) highlights the significance of this issue. We noted that a single study in the present review addressed this problem directly. Krahn et al. (1997) ensured that manual scorers of the rest intervals for their actigraphy data were blinded to the sleep diary. It may be helpful for further research that alternatives such as these are sought for defining rest interval periods.

5.10 The scope of sleep discrepancy research is likely to have been underestimated

The scope of the literature on sleep discrepancy has been considerably underestimated to date. We intended to identify a broad range of studies in this review that may have captured the concept of sleep discrepancy without necessarily referring to this or related terms. A search across full texts of all studies included in this review returned 63 records making explicit mention of “sleep” and “discrepancy”, leaving 185 that would have otherwise been unidentifiable through simple keyword searching of this concept. It is likely that existing sleep discrepancy research across domains may be excessively siloed into respective research areas. Looking at the clinical populations encompassed in this review, there appear to be small but distinguishable sleep discrepancy research programmes in post-traumatic stress disorder, bipolar disorder, pregnancy, traumatic brain injury, and fibromyalgia, to name just a few. Whilst sleep discrepancy is best understood in the context of insomnia, it is possible similar processes underlie the presence of sleep discrepancy in these groups. For example, the role of sleep disturbance as a transdiagnostic factor across psychiatric disorders has been emphasised (Harvey et al., 2011) and a mechanistic role for sleep misperception has been suggested for disorders outside of insomnia (Richardson et al., 2016).

5.11 Strengths and limitations

This study represents the largest systematic approach to investigating methodology in the area of sleep discrepancy research. We reported a broad range of methodological features across a large number of studies and provided meaningful syntheses of research methods in a diverse field. Two major changes were made to our own methods during the screening process and following registration of the scoping review protocol that may be viewed as limitations. These changes were both made in response to the unanticipated number of records returned following title and abstract screening and in view of limited resources available for charting and synthesis. First, grey literature was removed from inclusion criteria. Although the issues and recommendations discussed in this paper were limited to published research, our findings remain broadly applicable and no syntheses of empirical findings have been made that could be influenced by publication bias. Second, reference lists were not screened for additional studies and the extent to which this review may be considered an exhaustive representation of the literature may be reduced as a result.

5.12 Practice points

1. Sleep discrepancy has been investigated throughout a broad range of clinical populations outside of insomnia
2. Many sleep discrepancy studies involve at least one significant methodological problem that may threaten the validity of findings
3. Available alternatives to operationalising SOL should be employed over traditional approaches
4. Rest intervals should be defined without the use of sleep diaries if actigraphy is to be used to measure sleep discrepancy

5.13 Research Agenda

1. Further research is necessary to determine where methodological differences in sleep discrepancy approaches indicate meaningful conceptual differences
2. The impact of varying justified approaches to measuring and operationalising sleep discrepancy should be assessed
3. Integrated and standardised approaches to conducting actigraphy would benefit sleep discrepancy research by reducing methodological heterogeneity
4. Open science practices including pre-registration and research transparency have the potential to improve sleep discrepancy research

5.14 Summary

Methods for investigating sleep discrepancy have varied considerably in the literature across the areas of study design, measurement, data processing, and data analysis. Many of these varied approaches have substantial effects on what sleep discrepancy means as a concept and sometimes are associated with methodological problems that may not be immediately clear. Sleep discrepancy research holds promise for advancing understanding of sleep, its disorders such as insomnia, and mechanisms at play in psychiatric and other disorders. Clear concepts and appropriate methodology is essential to ensure that work in this area remains a progressive science. Measuring discrepancy or congruence is often a deceptively complex undertaking and we hope that this scoping review will prove helpful and informative to those interested in designing or interpreting sleep discrepancy studies.

6 Data availability statement

All code and data underlying this article are available from github: https://github.com/tfwalton/sleep-discrepancy-review.

7 Acknowledgements

We would like to thank the librarians at the University of Western Australia library for their assistance with the development of the search strategy.

8 Financial disclosure statement

None.

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10 Declaration of competing interest

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

11 Appendices

11.1 Search strategies

Search strategies for databases searched using the Ovid system are available in Table 2.

Table 2: Search strategy for Ovid databases

Step	Terms and operators	Records
Embase		
1	sleep discrepancy or paradoxical insomnia or subjective insomnia or (sleep adj2 misperception).mp	488
2	((self report* or diary or subjective*) and (objective* or actigraph* or polysomnograph* or polygraph*)).mp.	193243
3	(exp polysomnography/ or exp actimetry/) and exp self report/	1676
4	(sleep* and ("over estimat*" or "over report*" or "under estimat*" or "under report*" or overestimat* or overreport* or underestimat* or underreport* or discrepan* or concordan* or agreement or disagreement or discordan* or congruen* or incongruen*)).mp.	9362
5	2 or 3	193302
6	4 and 5	1234
7	1 or 6	1569
PsycINFO		
1	sleep discrepancy or paradoxical insomnia or subjective insomnia or (sleep adj2 misperception).mp	175
2	((self report* or diary or subjective*) and (objective* or actigraph* or polysomnograph* or polygraph*)).mp.	57592
3	(exp polysomnography/ or exp actigraphy/) and exp self report/	59
4	(sleep* and ("over estimat*" or "over report*" or "under estimat*" or "under report*" or overestimat* or overreport* or underestimat* or underreport* or discrepan* or concordan* or agreement or disagreement or discordan* or congruen* or incongruen*)).mp.	2112
5	2 or 3	57592
6	4 and 5	346
7	1 or 6	471
Medline		
1	sleep discrepancy or paradoxical insomnia or subjective insomnia or (sleep adj2 misperception).mp	260
2	((self report* or diary or subjective*) and (objective* or actigraph* or polysomnograph* or polygraph*)).mp.	139088
3	(exp polysomnography/ or exp actigraphy/) and exp self report/	561
4	(sleep* and ("over estimat*" or "over report*" or "under estimat*" or "under report*" or overestimat* or overreport* or underestimat* or underreport* or discrepan* or concordan* or agreement or disagreement or discordan* or congruen* or incongruen*)).mp.	5280
5	2 or 3	139088
6	4 and 5	692
7	1 or 6	875

Search strategies for other databases are listed in Table 3.

Table 3: Search strategy for other databases

Database	Terms and operators	Records
Pubmed	(”sleep discrepancy” OR ”paradoxical insomnia” OR ”subjective insomnia”) OR (sleep AND misperception) OR ((”self report*” or diary or subjective*) AND (objective* or actigraph* or polysomnograph* or polygraph*)) OR ((”Polysomnography/methods”[MAJR] OR ”Actigraphy/methods”[MAJR]) AND ”Self Report”[MeSH]) AND (sleep* AND (”over estimat*” OR ”over report*” OR ”under estimat*” OR ”under report*” OR overestimat* OR overreport* OR underestimat* OR underreport* OR discrepan* OR concordan* OR agreement OR disagreement OR discordan* OR congruen* OR incongruen*))	761
CINAHL	(”sleep discrepancy” OR ”paradoxical insomnia” OR ”subjective insomnia”) OR (sleep AND misperception) OR ((”self report*” or diary or subjective*) AND (objective* or actigraph* or polysomnograph* or polygraph*)) AND (sleep* AND (”over estimat*” OR ”over report*” OR ”under estimat*” OR ”under report*” OR overestimat* OR overreport* OR underestimat* OR underreport* OR discrepan* OR concordan* OR agreement OR disagreement OR discordan* OR congruen* OR incongruen*))	310
Scopus	TITLE-ABS-KEY ((”sleep discrepancy” OR ”paradoxical insomnia” OR ”subjective insomnia”) OR (sleep AND misperception) OR ((”self report*” OR diary OR subjective*) AND (objective* OR actigraph* OR polysomnograph* OR polygraph*)) AND (sleep* AND (”over estimat*” OR ”over report*” OR ”under estimat*” OR ”under report*” OR overestimat* OR overreport* OR underestimat* OR underreport* OR discrepan* OR concordan* OR agreement OR disagreement OR discordan* OR congruen* OR incongruen*)))	826
Web of Science	(”sleep discrepancy” OR ”paradoxical insomnia” OR ”subjective insomnia”) OR (sleep AND misperception) OR ((”self report*” or diary or subjective*) AND (objective* or actigraph* or polysomnograph* or polygraph*)) AND (sleep* AND (”over estimat*” OR ”over report*” OR ”under estimat*” OR ”under report*” OR overestimat* OR overreport* OR underestimat* OR underreport* OR discrepan* OR concordan* OR agreement OR disagreement OR discordan* OR congruen* OR incongruen*))	1288
Proquest Theses and Dissertations Global	noft((”sleep discrepancy” OR ”paradoxical insomnia” OR ”subjective insomnia”) OR (sleep AND misperception) OR (((”self report*” or diary or subjective*) AND (objective* or actigraph* or polysomnograph* or polygraph*)) AND (sleep* AND (”over estimat*” OR ”over report*” OR ”under estimat*” OR ”under report*” OR overestimat* OR overreport* OR underestimat* OR underreport* OR discrepan* OR concordan* OR agreement OR disagreement OR discordan* OR congruen* OR incongruen*))))	90

11.2 List of deviations from protocol

The following are a list of deviations from the scoping review protocol registered on the Open Science Framework (doi: 10.17605/OSF.IO/BCJNQ).

1. The term actimetry in Medline and PSYCinfo searches was changed to actigraphy
2. The scoping review protocol listed an incorrect number of duplicates records following searches
3. All records that were not peer reviewed journal articles were excluded at the full-text screening stage in the final review
4. Other items were added to the exclusion criteria at the full-text screening stage including:

- study measured informant-report rather than strictly self-report sleep
- study did not include statistical comparison of self-report and objective sleep (e.g., numerical comparisons only, single-case design)

5. Reference lists were not searched for additional citations as planned in the protocol

11.3 PRISMA-ScR checklist

A PRISMA-ScR checklist is available below with section links to the corresponding checklist item.

Table 4: Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist.

Section	Item	PRISMA-ScR Checklist Item	Location reported
Title			
Title	1	Identify the report as a scoping review.	1
Abstract			
Structured summary	2	Provide a structure summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	1
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/ objectives lend themselves to a scoping review approach	2
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualise the review questions and/or objectives.	2
Methods			
Protocol and registrations	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	3.1
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	3.2
Information sources	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	3.4
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	3.1
Selection of sources of evidence	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	3.5
Data charting process	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	3.6
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made	3.7
Critical appraisal of individual sources of evidence	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	Formal quality assessment was not conducted
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted	3.8
Results			
Selection of sources of evidence	14	Give numbers of sources of evidence screen, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	4
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	11.4
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	Formal quality assessment was not conducted

Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	4.2
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	4.2
Discussion			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups	5
Limitations	20	Discuss the limitations of the scoping review process.	5.11
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	5.12
Funding			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	9

11.4 Additional tables

Full descriptions of study characteristics are available in Table 5.

Table 5: Characteristics of included studies

Study	Country of origin	Sample characteristics	Sample size
Ahn et al. (2021)	Korea	Patients >55 years with insomnia disorders	33
Al Lawati et al. (2021)	Oman	Healthy Omani nationals	321
Alameddine et al. (2015)	USA	Participants referred to a sleep centre for PSG	879
Ansok et al. (2020)	USA	Patients with rotator cuff tears	18
Argyropoulos et al. (2003)	United Kingdom	Outpatients with moderate to severe depression, without psychotic features, in an RCT of two antidepressants	40
Aritake-Okada et al. (2010)	Japan	Healthy males	22
Arora et al. (2013)	United Kingdom	Adolescents aged 11-13	255
Auger et al. (2013)	USA	Patients referred to an academic sleep centre	84
Baek et al. (2020)	Korea	Shiftwork nurses	94
Baillet et al. (2016)	France	Older adults with no sleep disorders, sleep medications, or depressive symptomatology	45
Baker et al. (1999)	South Africa	Healthy young subjects	20
Barbosa et al. (2017)	Brazil	Visually impaired individuals and participants without visual impairment	77
Bastien et al. (2013)	Canada	Individuals with chronic psychophysiological insomnia, paradoxical insomnia and good sleepers	88
Bean et al. (2021)	New Zealand	Chronic pain patients	47
Bensen-Boakes et al. (2022)	Australia	Participants with comborbid insomnia and OSA	145
Bian et al. (2016)	China	Inpatients with schizophrenia	148
Bianchi et al. (2012)	USA	Healthy subjects undergoing in-lab sleep experiment	44
Bianchi et al. (2013)	USA	Patients referred to a sleep centre	312
Billings (2020)	USA	Firefighters	24
Bonnet & Moore (1982)	USA	Young adults	12
Broomfield & Espie (2003)	United Kingdom	Individuals complaining of sleep-onset insomnia	34
Brychta et al. (2019)	Iceland	15-year, then 17-year old students of the same cohort	144
Caia et al. (2018)	Australia	Professional rugby league athletes	63
Campanini et al. (2017)	Brazil	School teachers	163
Carter et al. (2020)	USA	Collegiate athletes	121
Castelnovo et al. (2021)	Switzerland	Patients with insomnia	249
Castillo et al. (2014)	USA	Patients referred to a sleep centre for PSG	405
Cederberg et al. (2022)	USA	Patients with multiple sclerosis	49
Chan et al. (2018)	USA	Individuals with fibromyalgia and Insomnia	223
Chan et al. (2021)	USA	Community dwelling older adults with insomnia	62
Chen et al. (2015)	Taiwan	Individuals with osteoarthritis	30
Chervin & Guilleminault (1996)	USA	Patients referred to a sleep centre for an MSLT for suspected excessive daytime somnolence	147
Cho et al. (2022)	Korea	Participants from the sleep heart health study	2540
Choi et al. (2016)	Korea	Patients referred to a sleep centre for PSG in addition to healthy volunteers	420
Chou et al. (2020)	USA	Cognitively normal and mildly impaired older adults	293
Chung et al. (2020)	Korea	Outpatients with schizophrenia	66
Combertaldi & Rasch (2020)	Switzerland	Young healthy students	24
Conroy et al. (2006)	USA	Individuals experiencing insomnia in recovery from alcohol dependence	21
Creti et al. (2010)	Canada	Participants with chronic fatigue syndrome	49
Crönlein et al. (2019)	Germany	Patients receiving CBT-I for insomnia	92

Currie et al. (2004)	Canada	Individuals experiencing insomnia in recovery from alcohol dependence	56
Curtis et al. (2019)	USA	Participants with fibromyalgia and insomnia	199
D'Aoust et al. (2015)	USA	Informal caregivers of persons with dementia	53
Dautovich et al. (2008)	USA	Older adults who nap habitually	100
De Francesco et al. (2021)	United Kingdom	People with HIV and people without HIV matched on demographic variables	461
De Jaeger et al. (2019)	Belgium	Failed back surgery syndrome (FBSS) patients treated with spinal cord stimulation	19
Dean et al. (2019)	USA	Adults with inoperable non-small cell lung cancer	26
Devine et al. (2020)	USA	Army Reserve Officers' Training Corp Cadets	286
Dietch & Taylor (2021)	USA	Representative community-based normative sample	80
Dinapoli et al. (2017)	Italy	Older adults with mild cognitive impairment and subsyndromal depression	59
Dittoni et al. (2013)	Italy	Chronic primary insomnia patients	66
Dorrian et al. (2012)	Australia	Commercial passenger airline pilots	306
Dorsey & Bootzin (1997)	USA	Undergraduate students	31
Downey & Bonnet (1992)	USA	Subjective insomniacs	10
Duarte et al. (2020)	Brazil	Patients undergoing PSG for suspected sleep-disordered breathing	727
Duarte et al. (2022)	Brazil	Individuals with sleep disorders and contrls	2004
Dunican et al. (2017)	Australia	Judo athletes	23
Dzierzewski et al. (2019)	USA	Older adults with insomnia	159
Edinger & Fins (1995)	USA	Outpatients with insomnia presenting to a sleep disorders centre	173
Espie et al. (1989)	United Kingdom	Individuals with insomnia	20
Etain et al. (2021)	France	Adults with bipolar disorder and healthy controls	154
Facco et al. (2018)	USA	Nulliparous women enrolled in the first trimester of pregnancy	752
Feige et al. (2008)	Germany	Individuals with paradoxical insomnia and good sleeper controls	200
Feige et al. (2021)	Germany	Insomnia patients and good sleeper controls	100
Feng & Svetnik (2018)	United Kingdom	Primary insomnia patients	n/a
Fernandez-Mendoza et al. (2011)	USA	Insomniacs and controls	866
Finan et al. (2020)	USA	Participants with opioid use disorder	55
Franklin & Svanborg (2000)	Sweden	Individuals referred to sleep center for suspected OSA	100
Friedmann et al. (2022)	Germany	Women with PTSD after childhood abuse, mentally healthy women with a history of child abuse, and nontraumatised mentally healthy women	184
Gaina et al. (2004)	Japan	Healthy junior high school children	42
Ghadami et al. (2015)	Iran	War veterans diagnosed with chronic PTSD	32
Gibson et al. (2022)	Australia	Australian army recruits	59
Girschik et al. (2012)	Australia	Women recruited from the community	56
Gonzalez et al. (2013)	USA	Individuals with bipolar type I	39
Gooneratne et al. (2011)	USA	Older adults with and without insomnia complaint	200
Goudman et al. (2018)	Belgium	Patients with failed back surgery syndrome treated with spinal chord stimulation	39
Goulart et al. (2014)	Brazil	Healthy males with normal sleep randomised to three experimental groups	31
Guedes et al. (2016)	Brazil	Adolescents	37
Gökce et al. (2020)	Germany	Young adults in Munich	74
Hall et al. (2022)	USA	Women with PTSD secondary to interpersonal violence	45
Hanisch et al. (2011)	USA	Prostate cancer patients undergoing androgen therapy	60
He et al. (2021)	China	Adults participants subject to COVID-19 lockdown provisions in China	70
Heath et al. (2018)	Australia	Adolescents	385
Herbert et al. (2017)	United Kingdom	Individuals with insomnia symptoms	42
Hermans et al. (2019)	Netherlands	Older adults with and without insomnia	41

Hermans et al. (2020)	Netherlands	Insomnia patients and healthy controls	231
Hermans et al. (2020)	Netherlands	Participants with insomnia on a waitlist for CBT-I	31
Hermans et al. (2021)	Netherlands	Older adults involved in a double-blind crossover study with zopiclone and placebo	46
Herring et al. (2013)	USA	Urban low-income pregnant women	80
Hita-Yañez et al. (2013)	Spain	Patients with MCI and healthy elderly	50
Hodges et al. (2017)	USA	Cocaine-dependent persons admitted to an inpatient research facility	43
Hoogerhoud et al. (2015)	Netherlands	Patients receiving index or maintenance ECT for a depressive episode	12
Hsiao et al. (2018)	Taiwan	Healthy young adults	36
Huang et al. (2012)	China	Primary insomnia patients and healthy controls	170
Hughes et al. (2018)	USA	Vulnerable older adults participating in a Veterans Administration Adult Day Health Care (ADHC) program	59
Hur et al. (2020)	Canada	Patients with interstitial lung disease	111
Ihler et al. (2020)	France, Norway	Individuals with bipolar disorder and healthy controls	196
Jackowska et al. (2011)	United Kingdom	Women working at University College London and neighbouring institutions	179
Jackson et al. (2018)	USA	Adults enrolled in a large longitudinal study	1910
Jackson et al. (2019)	USA	African-American adults	821
Janků et al. (2020)	Czech Republic	Insomnia patients	36
Jungquist et al. (2016)	USA	Community-dwelling adults	300
Kang et al. (2018)	USA	Individuals with major depressive disorder, individuals with primary insomnia, and normal sleeping controls	82
Kaplan et al. (2012)	USA	Individuals with bipolar disorder and age and sex-matched controls	54
Kaufmann et al. (2019)	USA	Individuals with bopolar disorder and healthy controls	85
Kawada (2008)	Japan	Healthy university students	76
Kay et al. (2013)	USA	Older adults with and without sleep complaint	103
Kay et al. (2015)	USA	Older adults with and without insomnia	114
Kay et al. (2017)	USA	Individuals with paradoxical insomnia and good sleeper controls	62
Keklund & Akerstedt (1997)	Sweden	Individuals involved in a study of early morning work or a study of sleep in a truck-berth	37
Kennedy et al. (2020)	Ireland	Patients with advanced chronic kidney disease or end-stage kidney disease	54
Khou et al. (2018)	USA	Community dwelling older adults with and without mild Alzheimers disease	86
King et al. (2017)	USA	Female undergraduates enrolled in an interior design programme	28
Kishikawa et al. (2021)	Japan	Outpatients with primary insomnia undergoing CBT-I	52
Kobayashi et al. (2012)	USA	Urban-residing African Americans with and without trauma exposure and PTSD	103
Kolling et al. (2016)	Germany	German undergraduate and graduate physical education students	72
Kong et al. (2011)	China	Children recruited from primary and secondary schools in Hong King	133
Krahn et al. (1997)	USA	Psychiatric inpatients	30
Kreutz et al. (2021)	Germany	Breast cancer patients starting neoadjuvant chemotherapy	54
Krishnamurthy et al. (2018)	USA	Bipolar disorder patients and healthy controls similar in age, race, and sex	54
Kryger et al. (1991)	Canada	Patients with chronic insomnia	16
Krystal & Edinger (2010)	USA	Patients with primary insomnia with sleep maintenance difficulty evident in subjective sleep measures	30
Krystal et al. (2002)	USA	Individuals with subjective insomnia, objective insomnia and normal controls	50
Kundu et al.	India	Individuals with chronic insomnia and obstructive sleep apnoea	32
Kung et al. (2015)	Taiwan	Taiwanese adults with major depression	30
Lan Chun Yang et al. (2021)	Canada	Participants diagnosed with mTBI/concussion	37
Laranjeira et al. (2018)	Brazil	Individuals referred to a sleep centre	248

Lastella et al. (2018)	Australia	Well-trained male soccer players	12
Lauderdale et al. (2008)	USA	Young adults enrolled in the Coronary Artery Risk Development in Young Adults study	647
Lecci et al. (2020)	Switzerland	Population-based sample	2092
Lecci et al. (2020) (study 2)	Switzerland	Insomnia patients and healthy subjects	34
Lee (2021)	United Kingdom	Adults aged 20 or above	8438
Lee et al. (2021)	Korea	Adults with insomnia	105
Lee et al. (2022)	Korea	Patients with OSA	707
Lehrer et al. (2022)	USA	Middle-aged community-dwelling women	323
Lewis (1969)	United Kingdom	Healthy young men	8
Lipinska & Thomas (2017)	South Africa	Women with PTSD, trauma exposure with no PTSD, and healthy controls	60
Liu et al. (2019)	China	Healthy young adults	10
Liu et al. (2020)	China	Patients diagnosed with OSA	355
Locihova et al. (2020)	Czech Republic	Patients admitted to an intensive care unit of a hospital	20
Lockley et al. (1999)	United Kingdom	Blind individuals	49
Lubas et al. (2022)	USA	Participants enrolled in a longitudinal study of survivors of childhood cancer	477
Lund et al. (2013)	USA	Older adults with comorbid insomnia	60
Ma et al. (2021)	USA	Individuals with insomnia, insomnia & comorbid OSA, OSA only, and normal sleep controls	638
Maes et al. (2014)	Belgium	Female patients diagnosed with primary insomnia and healthy female controls	28
Maich et al. (2018)	Canada	Individuals with insomnia and good sleeper controls	74
Majer et al. (2007)	USA	Individuals with chronic fatigue and non-fatigued controls	75
Manconi et al. (2010)	Italy, USA	Normal subjects	288
Manconi et al. (2010) (study 2)	Italy	159 patients with primary insomnia	159
Maric et al. (2019)	Switzerland	Healthy right-hand males	14
Martinez et al. (2010)	Brazil	Patients referred to a university-affiliated sleep clinic for PSG	5764
Matousek et al. (2004)	Czech Republic	Patients with minor depression, complaining of insomnia	28
Mazza et al. (2020)	France	Children aged 8-9 years recruited from elementary schools	76
McCall & McCall (2012)	USA	Patients diagnosed with current major depressive episode and chronic insomnia	54
McCall et al. (1995)	USA	Individuals undergoing PSG for suspected sleep apnoea	84
McIntyre et al. (2016)	New Zealand	Healthy women late in third trimester	30
Means et al. (2003)	USA	Middle-aged and older individuals with insomnia and matched normal sleepers	101
Mendelson (1998)	USA	Participants who complained of poor sleep	8
Mendelson et al. (1986)	USA	Individuals with insomnia and age and sex matched controls	20
Mercer et al. (2002)	USA	Individuals with insomnia and good sleepers	22
Meyer et al. (2018)	United Kingdom	Outpatients with schizophrenia	14
Miner et al. (2022)	USA	Community-dwelling older adults	5835
Moore et al. (2015)	USA	43 women with insomnia who had completed treatment for breast cancer	43
Most et al. (2012)	Netherlands	Older adults with early and late stage alzheimers disease or healthy controls	81
Mundt et al. (2016)	USA	Adults with insomnia and fibromyalgia randomised to CBT-I, CBT for pain, or waitlist control	113
Nam et al. (2016)	Korea	Patients referred to a sleep clinic for evaluation of snoring/OSA	50
Narisawa et al. (2015)	Japan	Participants with subjective sleep difficulty	50
Nazem et al. (2016)	USA	Male veterans with traumatic brain injury	19
Neu et al. (2007)	Belgium	Individuals with chronic fatigue and female controls	40

Nguyen-Michel et al. (2015)	France	Older adults referred for insomnia complaints or suspected sleep apnoea	135
Normand et al. (2016)	Canada	Paradoxical insomnia, psychophysiological insomnia, good sleepers	70
O'Brien et al. (2016)	USA	Treatment-seeking overwieght/obese participants	63
Okifuji & Hare (2011)	USA	Patients with fibromyalgia	75
Okun et al. (2021)	USA	Pregnant women	104
Orta et al. (2016)	Chile	Female primary caregivers of children with disabilities	175
Ouellet & Morin (2006)	Canada	Patients with mild to severe traumatic brain injury and healthy good sleepers	28
Park et al. (2007)	USA	Postmenopausal women	384
Perlis et al. (1997)	USA	Female fibromyalgia patients	20
Perlis et al. (2001)	USA	Individuals with primary insomnia, insomnia secondary to depression, and good sleeper controls	27
Pinto Jr et al. (2009)	Brazil	Individuals selected from a university sleep laboratory	199
Provencher et al. (2020)	Canada	Individuals with psychophysiological insomnia, paradoxical insomnia, and good sleepers	67
Reess et al. (2010)	Germany	Patients with insomnia, sleep-related movement disorders (SMD), hypersomnia, and parasomnia	159
Regestein et al. (2004)	USA	Healthy, postmenopausal women having hot flash activity	88
Richardson et al. (2019)	Australia	Adolescents diagnosted with delayed sleep-wake phase disorder	103
Ritter et al. (2016)	Germany	Euthymic outpatients with bipolar disorder and healthy volunteers	50
Rogers et al. (1993)	USA	Patients with narcolepsy and matched controls	50
Saline et al. (2016)	USA	Adult patients referred to a clinical sleep laboratory	643
Santos et al. (2021)	Brazil	Participants in a longitudinal study	2036
Sato et al. (2010)	Japan	Patients experiencing psychophysiological insomnia	20
Scarlett et al. (2021)	Ireland	Community-dwelling older adults	1520
Schneider-Helmert & Kumar (1995)	Switzerland	Participants with primary insomnia	128
Schokman et al. (2018)	Sri Lanka	Sri Lankan adults	175
Schulz & Walther (2017)	Germany	Individuals referred to a sleep centre for investigation of sleep disorders	117
Segura-Jimenez et al. (2015)	Spain	Women with fibromyalgia and healthy controls	198
Sharkey et al. (2011)	USA	Patients in a methadone maintenance therapy for opioid dependence	62
Sharman et al. (2022)	United Kingdom	Healthy sleepers	16
Short et al. (2012)	Australia	Adolescents	385
Signal et al. (2005)	USA	Flight crew	21
Silva et al. (2007)	USA	Participants over 40	2113
Sinclair et al. (2014)	Australia	Patients with traumatic brain injury and non-injured controls	42
Slightam et al. (2018)	USA	Veterans with PTSD and demographically similar controls	120
Smagula et al. (2021)	USA	Males	2850
So et al. (2021)	USA	Prepubertal children	55
Somma et al. (2020)	Italy	Participants with insomnia and community dwelling adults matched on demographic variables	60
Spielmanns et al. (2019)	Germany	CPAP users	26
Spinweber et al. (1985)	USA	Laboratory-qualified poor sleepers laboratory-disqualified poor sleepers who were male students at a naval school	60
Sprajcer et al. (2020)	Australia	Healthy adult male on-call workers	72
St-Onge et al. (2019)	USA	Multi-racial, multi-ethnic sample of adults	113
Stout et al. (2017)	USA	Military veterans and active-duty service members, 17 with PTSD, 20 without PTSD	37
Sun-Suslow et al. (2022)	USA	People with and without HIV	94
Takano et al. (2016)	Belgium	Adults	54
Tang & Harvey (2004)	United Kingdom	Healthy good sleepers	54

Tang & Harvey (2004) (study 2)	United Kingdom	Healthy good sleepers	93
Tang & Harvey (2006)	Various	Individuals with primary insomnia	48
Tang et al. (2007)	United Kingdom	Poor and good sleepers	60
Tang et al. (2007) (study 2)	United Kingdom	Patients with primary insomnia split into a clock-monitoring group and display unit-monitoring group	38
Thun et al. (2012)	Norway	University students	166
Thurman et al. (2018)	USA	Healthy participants	30
Tomita et al. (2013)	Japan	patients complaining of excessive daytime sleepiness	28
Topalidis et al. (2021)	Various	Healthy participants	21
Trajanovic et al. (2007)	Serbia, USA	Patients referred to a sleep clinic	136
Tremaine et al. (2010)	Australia	Children and adolescents	66
Tremaine et al. (2010)	Australia	Children aged 11-16	65
Trimmel et al. (2021)	Austria	Patients with a range of sleep disorders who underwent laboratory or ambulatory PSG	303
Trimmel et al. (2021)	Austria	Patients referred to sleep clinic in a department of neurology	303
Tsuchiyama et al. (2003)	Japan	Patients with major depression admitted to a psychiatric hospital	23
Usui et al. (2003)	Japan	Older and younger adults	39
Valko et al. (2021)	Switzerland	Patients referred to a sleep clinic for PSG	3303
Vallieres & Morin (2003)	Canada	Participants with chronic primary insomnia	17
Van Den Berg et al. (2008)	Netherlands	Community-dwelling older adults	969
Vanable et al. (2000)	USA	Patients referred to sleep clinic with various sleep disorders	104
Wang et al. (2011)	Taiwan	Heart failure patients	43
Wang et al. (2022)	Canada	Naval sailors	66
Werner et al. (2016)	USA	Women with PTSD experiencing PTSD-related sleep disturbance	51
Williams et al. (2011)	USA	Community-dwelling older adults	142
Wilson et al. (1998)	Canada	Individuals experiencing insomnia associated with chronic musculoskeletal pain	40
Wilson et al. (2013)	Australia	Women in third trimester and first trimester of pregnancy and non-pregnant women	64
Winer et al. (2021)	USA	Cognitively normal older adults	89
Wolfson et al. (2003)	USA	High school students	302
Xu et al. (2022)	China	Young adults	47
Yamakita et al. (2014)	Japan	School-aged children	58
Yeung et al. (2015)	China	Individuals with insomnia undergoing placebo acupuncture	86
Yoon et al. (2022)	Korea	Patients with insomnia	150
Zak et al. (2022)	USA	Healthy premenopausal women	71
Zhu et al. (2018)	USA	Adults with type II diabetes	53
Zinkhan et al. (2014)	Germany	Participants recruited from the community	100
Zou et al. (2021)	China	Insomnia disorder patients and well-matched healthy controls	64
te Lindert et al. (2020)	Netherlands	Individuals with insomnia disorder and individuals without sleep complaints	236

Full qualitative methodological details for actigraphy studies are available in Table 6.

Table 6: Qualitative actigraphy characteristics

	Study	Actigraph device	Software	Algorithm	Algorithm reference	Rest interval definition
1	Chou et al. (2020)	Actiwatch 2	Actiware	Actiware Low (20)	Boyne et al. (2013)	Not reported
3	Janků et al. (2020)	MotionWatch 8	MotionWare	MotionWare	CamNTech, UK	Event marker –> sleep diary
4	King et al. (2017)	Actiwatch Spectrum Plus	not reported	Actiware Medium (40)	Boyne et al. (2013)	Not reported
5	Lehrer et al. (2022)	Actiwatch AW64	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Informed by sleep diaries, decided by study staff
7	Segura-Jimenez et al. (2015)	SenseWear Pro3 Armband	SenseWear Professional	SenseWear	Lopez et al. (2017)	Set intervals
8	Slightam et al. (2018)	Actiwatch AW64	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Event markers –> activity, sleep diary
10	Williams et al. (2011)	Actiwatch-L	Actiware-Sleep	Actiware (not reported)	Boyne et al. (2013)	Not reported
11	Al Lawati et al. (2021)	SOMNOwatch plus	Domino Light	Domino Light	Gorny et al. (1996)	Manual scoring
12	Ansok et al. (2020)	Actiwatch Spectrum Plus	not reported	Cole-Kripke	Cole et al. (1992)	Event markers –> sleep diary
14	Auger et al. (2013)	Actiwatch AW64	Actiware	Kripke	Kripke et al. (1978)	Automated –> sleep diary
15	Baillet et al. (2016)	MotionWatch 8	MotionWare	MotionWare	CamNTech, UK	Event markers –> sleep diary
18	Billings (2020)	ActiGraph wGT3X-BT	ActiLife	Cole-Kripke	Cole et al. (1992)	Sleep diary, inconsistenies reviewed with participant
19	Brychta et al. (2019)	ActiGraph GT3X+	ActiLife	Sadeh	Sadeh et al. (1994)	Visual inspection, sleep diaries
20	Cederberg et al. (2022)	ActiGraph GT3X+	ActiLife	Cole-Kripke	Cole et al. (1992)	Sleep diary
21	Chan et al. (2018)	Actiwatch 2	not reported	not reported		Complex criteria involving sleep diary, activity levels, light
25	Currie et al. (2004)	Mini Motion-logger	not reported	Cole-Kripke	Cole et al. (1992)	Event marker
26	Dietch & Taylor (2021)	Actiwatch Spectrum	Actiware	Actiware Low (10)	Boyne et al. (2013)	Event markers –> sleep diaries –> activity/light patterns
28	Dunican et al. (2017)	not reported	Readiband Sync	not reported		Not reported
29	Facco et al. (2018)	not reported	not reported	Actiware Medium (40)	Boyne et al. (2013)	Not reported
32	Ghadami et al. (2015)	not reported	not reported	not reported		Not reported
33	Girschik et al. (2012)	Actiwatch Spectrum	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Event marker –> sleep diary
36	Herring et al. (2013)	Actiwatch AW64	Actiware	Actiware (not reported)	Boyne et al. (2013)	Event markers –> sleep diary

37	Hoogerhoud et al. (2015)	not reported	not reported	Actiware (not reported)	Boyne et al. (2013)	Not reported
38	Ihler et al. (2020)	Actiwatch AW7	Actiwatch activity & sleep analysis	Actiware (not reported)	Boyne et al. (2013)	Event markers
39	Jackowska et al. (2011)	Actiheart monitor	Actiheart	Actiheart	Barreira et al. (2009)	Sleep logs; heart rate; activity
41	Kaplan et al. (2012)	Actiwatch AW64	Actiware	Actiware (Low, Medium, High)	Boyne et al. (2013)	Set to lights off and lights-on from PSG
42	Kawada (2008)	Actiwatch	not reported	Actiware Medium (40)	Boyne et al. (2013)	Not reported
43	Kay et al. (2015)	Actiwatch 2	Actiware	Actiware Medium (40), Cole-Kripke	Boyne et al. (2013); Cole et al. (1992)	Event marker; sleep diary; activity; light
44	Kay et al. (2013)	Actiwatch-L	not reported	Actiware High (80)	Boyne et al. (2013)	Not reported
47	Khou et al. (2018)	ActiGraph GT3X+	ActiLife	Cole-Kripke	Cole et al. (1992)	Self-report sleep logs compared against ActiLife defined bed and wake times, lux, movement data. If self-report within 30mins of actilife–interval set to self-report, if missing or invalid, ActiLife defined interval used
48	Kong et al. (2011)	not reported	not reported	not reported		Not reported
49	Krahn et al. (1997)	not reported	not reported	Cole-Kripke	Cole et al. (1992)	Scored manually (tech was blinded to sleep diary)
52	Liu et al. (2019)	Fitbit Alta	Fitbit software	Fitbit	Haghayegh et al. (2019)	Automatic (heart rate + activity)
53	Lockley et al. (1999)	Motionlogger, Mini Motion-logger	Action 3	not reported		Sleep diaries
58	Mazza et al. (2020)	Actiwatch 2	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Event marker, activity, light
61	Moore et al. (2015)	Actiwatch 2	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Not reported
62	Most et al. (2012)	Actiwatch	Actiware	Actiware (not reported)	Boyne et al. (2013)	Vinyl-covered pressure sensitive pad and light-dependent resistor
63	Mundt et al. (2016)	Actiwatch 2	Actiware	Actiware High (80)	Boyne et al. (2013)	Sleep diaries
65	Nazem et al. (2016)	Actiwatch 2	Actiware	Actiware (not reported)	Boyne et al. (2013)	Not reported
67	Okifuji & Hare (2011)	Micro Mini Motionlogger	Action	not reported		Not reported
68	Orta et al. (2016)	ActiSleep	ActiLife	Cole-Kripke	Cole et al. (1992)	Not reported

71	Regestein et al. (2004)	not reported	not reported	Actiware Medium (40)	Boyne et al. (2013)	Sleep diary
72	Ritter et al. (2016)	SOMNOWatch Plus	Domino Light	Cole-Kripke	Cole et al. (1992)	Event markers
74	Sato et al. (2010)	not reported	not reported	Cole-Kripke	Cole et al. (1992)	Not reported
76	Sharman et al. (2022)	Actiwatch AW4	Actiwatch Activity and Sleep Analysis	Actiware Medium (40)	Boyne et al. (2013)	Event markers –> sleep diary, verification from audio file timestamps
78	Spielmanns et al. (2019)	PAM Polar A300	not reported	not reported		N/a
82	Wang et al. (2022)	Micro Motionlogger	Action 4	not reported		Event markers
83	Werner et al. (2016)	not reported	Action W	UCSD	Jean-Louis et al. (2001)	Automatic
87	Barbosa et al. (2017)	ActiGraph GT3X+	ActiLife	Cole-Kripke	Cole et al. (1992)	Sleep diary, activity, light
90	Broomfield & Espie (2003)	Actiwatch 2	not reported	not reported		Event markers
91	Caia et al. (2018)	Actiwatch 2, ActiGraph GT3X+, Readiband	not reported	not reported		Not reported
92	Campanini et al. (2017)	Actiwatch 2	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Algorithms supplemented by event marker
93	Carter et al. (2020)	Actiwatch Spectrum Pro	not reported	Actiware Medium (40)	Boyne et al. (2013)	Light
97	Chung et al. (2020)	Actiwatch 2	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Event marker or sleep diary
98	Dautovich et al. (2008)	Actiwatch-L	Actiware-Sleep	Actiware High (80)	Boyne et al. (2013)	Naps identified in sleep diaries, Webster's rules (daily sleep logs, notes, illumination channel)
99	De Jaeger et al. (2019)	Actiwatch Spectrum Plus	Actiware	Actiware (not reported)	Boyne et al. (2013)	Not reported
100	Dean et al. (2019)	Octagonal Sleep Watch	Action 3	not reported		Sleep diary
104	Gonzalez et al. (2013)	Motionlogger	Action	UCSD	Jean-Louis et al. (2001)	Not reported
105	Goudman et al. (2018)	Actiwatch Spectrum Plus	Actiware	Actiware (not reported)	Boyne et al. (2013)	Not reported
107	Hanisch et al. (2011)	Actiwatch AW64	Actiware-Sleep	Actiware (not reported)	Boyne et al. (2013)	Sleep diary
111	Hughes et al. (2018)	Actiwatch Spectrum	not reported	Actiware Medium (40)	Boyne et al. (2013)	Not reported
112	Kaufmann et al. (2019)	Actisleep-BT	not reported	not reported		Not reported
113	Kreutz et al. (2021)	ActiGraph wGT3X-BT	ActiLife	Cole-Kripke, Tudor-Locke	Cole et al. (1992); Tudor-Locke et al. (2014)	Tudor-Locke algorithm
114	Krishnamurthy et al. (2018)	not reported	ActiLife	ActiLife	Peach et al. (2014)	Not reported

118	Lauderdale et al. (2008)	Actiwatch AW16	not reported	not reported		Event markers –> sleep log
119	Lubas et al. (2022)	Motionlogger	not reported	not reported		Event markers
120	Maich et al. (2018)	Actiwatch Score	Mini-Mitter Actiwatch Software	Actiware Low (20)	Boyne et al. (2013)	Not reported
126	Okun et al. (2021)	Actiwatch	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Autointerval option with event markers
127	Park et al. (2007)	Actillume I	Actillume Algorithm	Actillume	Jean-Louis et al. (2001)	Sleep diary, notes, light, Webster's rules
131	Scarlett et al. (2021)	GENEactiv	GENEactive	Micro-Electro-Mechanical Systems	Dunne et al. (2013)	N/a
132	Schokman et al. (2018)	Actiwatch Spectrum Pro	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Manual: visual inspection, sleep diary entry, Actiwatch timestamps (according to neurosleep manual)
133	Stout et al. (2017)	Micro Sleep Watch	not reported	not reported		Not reported
134	Tang & Harvey (2004)	Mini Motion-logger Basic	not reported	Cole-Kripke, Webster's rescoring rules	Cole et al. (1992)	Defined in-lab
135	Thun et al. (2012)	Actiwatch AW7	Actiwatch Activity and Sleep Analysis	Actiware Medium (40)	Boyne et al. (2013)	Not reported
136	Tomita et al. (2013)	MicroMini RC	Action W2	not reported		Manually corrected, using diaries where necessary
137	Tremaine et al. (2010)	not reported	Actiware-Sleep	Actiware Medium (40)	Boyne et al. (2013)	Not reported
139	Usui et al. (2003)	Motionlogger	not reported	Cole-Kripke	Cole et al. (1992)	N/a
142	Wilson et al. (1998)	Mini Motion-logger	not reported	Cole-Kripke, Webster's rescoring rules	Cole et al. (1992)	Not reported
143	Wolfson et al. (2003)	Mini Motion-logger	Action W2	Sadeh	Sadeh et al. (1994)	Sleep diary
144	Yamakita et al. (2014)	Lifecorder	Sleep Sign Act	Sleep Sign Act	Kissei Comtec Co, Japan	Set manually
145	Yeung et al. (2015)	Actiwatch 2	Actiware, Action W	Actiware (not reported)	Boyne et al. (2013)	Not reported
148	Baek et al. (2020)	Actiwatch Spectrum Pro	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Sleep diary
149	Chan et al. (2021)	Actiwatch-L	Actiware-Sleep	Actiware Medium (40)	Boyne et al. (2013)	Sleep diary
150	Chen et al. (2015)	not reported	not reported	not reported		Not reported
154	Heath et al. (2018)	Micro Mini Motionlogger	Action W2	Sadeh	Sadeh et al. (1994)	Not reported

156	Kobayashi et al. (2012)	Mini Motion-logger	Action W2	Sadeh	Sadeh et al. (1994)	Sleep diary, habitual sleep questionnaire
157	McCall & McCall (2012)	Actiwatch AW64	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Not reported
159	Vallieres & Morin (2003)	IM Systems Actigraph	Individual Monitoring Systems	IM Systems	Individual Monitoring Systems, Inc., USA	Not reported
160	Zhu et al. (2018)	ActiGraph wGT3X	ActiLife	Actiware Medium (40), Cole-Kripke	Boyne et al. (2013); Cole et al. (1992)	Not reported
161	Hall et al. (2022)	Motionlogger Basic	Action W	UCSD	Jean-Louis et al. (2001)	N/a
163	Kolling et al. (2016)	SenseWear MF Armband	SenseWear Professional	SenseWear	Lopez et al. (2017)	Event marker –> activity
164	Locihova et al. (2020)	ActiGraph wGT3X-BT	ActiLife	Cole-Kripke	Cole et al. (1992)	Externally defined
167	Winer et al. (2021)	Micro Motionlogger	Action W2	Sadeh	Sadeh et al. (1994)	Sleep diary and event markers
168	D'Aoust et al. (2015)	Actiwatch-L	Actiware	Actiware (not reported)	Boyne et al. (2013)	Sleep diary
169	Dinapoli et al. (2017)	SenseWear MF Armband	SenseWear	SenseWear	Lopez et al. (2017)	Not reported
170	Dorrian et al. (2012)	not reported	Actiware-Sleep	Actiware Medium (40)	Boyne et al. (2013)	Not reported
173	O'Brien et al. (2016)	Motionlogger Basic	Action W	Sadeh	Sadeh et al. (1994)	Sleep diary, discrepancies queried
174	St-Onge et al. (2019)	ActiGraph GT3X+	not reported	not reported		Not reported
176	Arora et al. (2013)	ActiGraph GT3X+	not reported	not reported		Sleep diary
180	Curtis et al. (2019)	Actiwatch 2	Actiware	Actiware (not reported)	Boyne et al. (2013)	Sleep diary
181	Devine et al. (2020)	Actiwatch 2	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Automatically defined, sleep diary/ other daily schedule info
183	Dzierzewski et al. (2019)	Actiwatch Spectrum	not reported	Actiware (not reported)	Boyne et al. (2013)	Not reported
184	Etain et al. (2021)	Actiwatch AW7	Actiwatch Activity and Sleep Analysis	Actiware (not reported)	Boyne et al. (2013)	Sleep diary and event markers
186	Gibson et al. (2022)	ActiGraph GT9X Link	ActiLife	Cole-Kripke	Cole et al. (1992)	Externally defined (platoon sleep record)
187	Gökce et al. (2020)	ActiGraph wGT3X-BT	Actiware	Cole-Kripke	Cole et al. (1992)	Software-defined
188	Herbert et al. (2017)	MotionWatch 8	MotionWare	Sadeh	Sadeh et al. (1994)	Sleep diary
191	Jackson et al. (2018)	Actiwatch Spectrum	Actiware-Sleep	Actiware (not reported)	Boyne et al. (2013)	Event marker, sleep diary, light sensor
193	Kung et al. (2015)	Mini Motion-logger	Action W2	not reported		Externally-defined (lights on/off times at psychiatric ward)

196	Lee (2021)	ActiGraph GT3X+	not reported	Machine learning algorithm	John et al. (2019)	Not reported
199	Meyer et al. (2018)	Fitbit Charge HR	Sleepsight	Fitbit	Haghayegh et al. (2019)	N/a
200	Kishikawa et al. (2021)	Actiwatch 2	Actiware	Actiware Medium (40), Cole-Kripke	Boyne et al. (2013); Cole et al. (1992)	Event markers
201	Santos et al. (2021)	Actiwatch 2	not reported	not reported		Event marker
203	Smagula et al. (2021)	SleepWatch-O	Action W2	Cole-Kripke, UCSD	Cole et al. (1992); Jean-Louis et al. (2001)	Sleep diary –> manual scoring
204	te Lindert et al. (2020)	GENEactiv	GENEactive	Actiware (Low, Medium, High)	Boyne et al. (2013)	Sleep diary
205	Thurman et al. (2018)	Readiband Actigraph SBV2	Fatigue Science Software	Fatigue Science	Russel et al. (2016)	Sleep offset/onset defined by sleep state (9pm-11am)
206	Topalidis et al. (2021)	Xiaomi Mi Band 3, GT3X ActiGraph	ActiLife	Cole-Kripke	Cole et al. (1992)	N/a
207	Van Den Berg et al. (2008)	Actiwatch AW4	Actiware	Actiware Low (20)	Boyne et al. (2013)	Event marker –> sleep diary
208	Zak et al. (2022)	Mini Motion-logger, Actigraph Model AAM-32	Action	Cole-Kripke	Cole et al. (1992)	Event marker
209	De Francesco et al. (2021)	ActiGraph wGT3X-BT	not reported	not reported		Not reported
210	Gaina et al. (2004)	Actiwatch	not reported	not reported		Sleep diary
211	Guedes et al. (2016)	Mini Motion-logger Basic	Action W2	Sadeh	Sadeh et al. (1994)	Sleep/activity log
213	Sinclair et al. (2014)	not reported	Actiware	Actiware Medium (40)	Boyne et al. (2013)	Sleep diary
214	Takano et al. (2016)	ActiGraph wGT3X-BT	Actiware	Cole-Kripke	Cole et al. (1992)	Unsure/ not reported
215	Tang et al. (2007)	Mini Motion-logger Basic	Action W	Cole-Kripke	Cole et al. (1992)	Webster's rules (daily sleep logs, notes, illumination channel)
216	Tang & Harvey (2006)	Mini Motion-logger Basic	Action W	Cole-Kripke	Cole et al. (1992)	Webster's rules (daily sleep logs, notes, illumination channel)
217	Wang et al. (2011)	Motionlogger	Action W2	not reported		Not reported
219	Creti et al. (2010)	Actitrac	IM Systems Software	IM Systems	Individual Monitoring Systems, Inc., USA	Externally set (PSG)
222	He et al. (2021)	ActiGraph wGT3X-BT	ActiLife	Cole-Kripke, Choi, Troiano	Cole et al. (1992); Choi et al. (2011); Troiano et al. (2007)	N/a or not reported

223	Hur et al. (2020)	ActiGraph wGT3X-BT	ActiLife	Cole-Kripke	Cole et al. (1992)	Sleep diaries
224	Jungquist et al. (2016)	Camntech Pro-Diary	MotionWare	MotionWare	CamNTech, UK	Not reported
230	Short et al. (2012)	Motionlogger	Action W2	Sadeh	Sadeh et al. (1994)	Sleep diary
231	So et al. (2021)	Micro Motionlogger	not reported	Sadeh	Sadeh et al. (1994)	Event marker
233	Sun-Suslow et al. (2022)	ActiGraph GT9X Link	not reported	Cole-Kripke	Cole et al. (1992)	Sleep diary –> manual
234	Tremaine et al. (2010)	not reported	Actiware-Sleep	Actiware Medium (40)	Boyne et al. (2013)	Sleep diary
235	Jackson et al. (2019)	ActiGraph GT3X+	ActiLife	Cole-Kripke	Cole et al. (1992)	Manual: sleep diary, activity, light
237	Bean et al. (2021)	Actiwatch AW64	Cambridge Neurotechnology Sleep Analysis 5.5	Actiware (not reported)	Boyne et al. (2013)	Sleep diary
238	Miner et al. (2022)	SleepWatch-O	Action W2	UCSD	Jean-Louis et al. (2001)	Software and sleep diaries
239	Richardson et al. (2019)	Micro Mini Motionlogger	not reported	Sadeh	Sadeh et al. (1994)	Manual and sleep diary
241	Friedmann et al. (2022)	Move II	not reported	Barouni	Barouni et al. (2020)	Sleep onset during fixed interval: 20:00-00:00
243	Signal et al. (2005)	Actiwatch	Actiware-Sleep	Actiware (Low, Medium, High)	Boyne et al. (2013)	Event marker, sleep diary
244	Narisawa et al. (2015)	Actiwatch	not reported	not reported		Activity levels
245	Tang & Harvey (2004) (study 2)	Mini Motionlogger Basic	not reported	Cole-Kripke	Cole et al. (1992)	Defined in-lab
248	Tang et al. (2007) (study 2)	Mini Motionlogger Basic	Action W	Cole-Kripke	Cole et al. (1992)	Webster's rules (daily sleep logs, notes, illumination channel)

Note: The –> arrow designates the priority given to methods of calculating the rest interval. For example, event markers –> activity, sleep diary, indicates that event marker presses were first used to calculate rest intervals, followed by sleep diary and activity when event marker presses were not available.

A full list of studies that recorded sleep-wake agreement is available in Table 7 below.

Table 7: Direct sleep-wake agreement studies

	Study	Sample characteristics	Sleep variables	Sleep-wake agreement type	PSG setting
60	Mendelson et al. (1986)	individuals with insomnia and age and sex matched controls	TST, sleep after experimental awakenings, awake/asleep upon awakening (binary)	Binary	in-lab
73	Rogers et al. (1993)	patients with narcolepsy and matched controls	Sleep/wake agreement (15-minute blocks), 3 time periods (spanning 24hr) transition (lights on/off), sleep period, daytime	Confusion matrix	home-based
101	Dorsey & Bootzin (1997)	undergraduate students	SOL (MSLT), sleep / wake agreement [Terminal sleep stage at each sleep latency test (objective), estimated conscious state by subject (subjective)]	Confusion matrix	in-lab
123	Mendelson (1998)	participants who complained of poor sleep	Participant report of having been awake/asleep following experimental awakenings	Binary	in-lab
124	Mercer et al. (2002)	individuals with insomnia and good sleepers	home PSG: TST, SOL, WASO, SE; lab: signal detection for PSG-wake as signal (exp awakenings), TST, sleep between probes	Binary	in-lab, home-based
139	Usui et al. (2003)	older and younger adults	sleep/ wake agreement, 10-minute epochs	Confusion matrix	n/a
152	Downey & Bonnet (1992)	subjective insomniacs	SOL, participant sleep/wake judgement following experimental awakenings	Binary	in-lab
165	Nguyen-Michel et al. (2015)	older adults referred for insomnia complaints or suspected sleep apnoea	Perception of sleep during nap (binary)	Binary	in-lab
170	Dorrian et al. (2012)	commercial passenger airline pilots	TST; sleep/wake	Confusion matrix	n/a
229	Schulz & Walther (2017)	individuals referred to a sleep centre for investigation of sleep disorders	sleep / wake judgement following induced awakenings	Binary	in-lab

Note: Binary sleep-wake involved measuring at one or multiple instances whether a participant's reported sleep state matched the objective sleep state upon which the query was conditional (e.g., participants were only queried during objectively-confirmed sleep). On the other hand, confusion matrix sleep-wake involved measuring at one or multiple instances whether a participant's reported sleep state matched an objective sleep state that was allowed to vary independent of the query (e.g., participants were queried at a certain time point irrespective of sleep state). The states were called so as the former approach produces a binary outcome whereas the latter produces a confusion matrix.

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