Approaches to Measuring and Conceptualising Sleep Discrepancy: A Scoping Review

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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.

1.2 Method

We searched MEDLINE (Ovid), Embase (Ovid), PsycInfo (Ovid), CINAHL Plus, PubMed, Scopus, and Web of Science in April 2022 for relevant studies. Titles and abstracts, and then full text records of searched studies were screened. Methodological information was extracted including measures of self-report and objective sleep, sleep variables, 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

Conceptually, sleep discrepancy was mostly restricted to discordance in sleep states and sleep time variables, and some forms of sleep discrepancy differ in their similarity to sleep misperception. Methodologically, approaches to sleep discrepancy varied considerably across areas of study design, measurement, data processing, and data analysis. This variability may exceed the size of effects looked for in relationships with other constructs and may pose difficulties in the pragmatics of research in this area. Additional issues are discussed relating to the use of derived indices for operationalising sleep discrepancy, objective sleep onset latency definitions, calculation of actigraphy rest intervals, differences between correlation and concordance, averaging of sleep variables across nights, the conceptual status of sleep quality discrepancy, and the scope of the sleep discrepancy literature.

1.5 Key words

Sleep discrepancy; sleep misperception; scoping review

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).

There are diverse ways to conceptualise and measure sleep discrepancy. It may be considered as a spectrum (e.g, 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 (e.g., Baillet et al., 2016). Any number of sleep variables such as TST, SOL, or WASO may used to operationalise sleep discrepancy, each differing conceptually and carrying varying theoretical implications. Sleep discrepancy may even be considered beyond these sleep time-based metrics and represent discordance in self-report and objective sleep patterns (e.g., Al Lawati et al., 2021), or sleep quality. Sleep discrepancy may be characterised in a sample by directly comparing self-report and objective sleep with a range of statistical techniques. Other studies may derive 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. There appear to be a variety of ways to derive these variables each of which, again, are likely to hold varying conceptual implications.

To date, there have been few 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 & Siclari (2023) focussing on paradoxical insomnia and the correlates of sleep misperception, respectively. Whilst informative discussions of research findings, these study excluded a focus on concepts or methodology and did not incorporate a systematic search–potentially under representing the breadth of the literature.

Presently, it isn’t clear how sleep discrepancy should best be defined and the diversity in its measurement and conceptualisation may present a challenge to theory-building for research in insomnia and other areas. 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 two 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 ([10.2](http://127.0.0.1:32157/rmd_output/1/#deviations)).

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 composite index scores. For measures of self-report and objective sleep, we included traditional 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) included self-report or objective measures that were 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. 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 24th April 2022. The full search strategy for Embase (Ovid) is provided as an example in Table [3.1](http://127.0.0.1:32157/rmd_output/1/#tab:egsearch) below. See Appendix A for full search strategies for other databases.

| Table 3.1: 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 |

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 independently by the first author 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 post-hoc.

3.6 Charting the data

Data extraction was performed by a single author (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 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

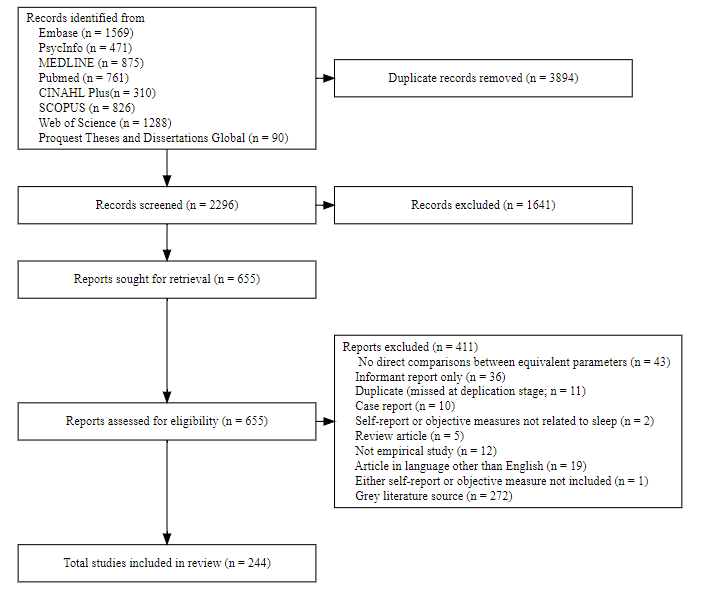
Extracted data items numbered in the hundreds and are described comprehensively in the codebook available at: <https://github.com/tfwalton/sleep-discrepancy-review/raw/main/codebook.xlsx>.

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 4.3.2 (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 6190 from which 3903 duplicate articles were removed. Details of the review process from article identification, screening, and selection are available in the PRISMA flowchart depicted in [4.1](http://127.0.0.1:32157/rmd_output/1/#fig:PRISMA) below.

Figure 4.1: PRISMA flowchart

4.1 Article characteristics

A total of 248 studies were identified from (n = 244) records, with (n = 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 8438 (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 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 [4.2](http://127.0.0.1:32157/rmd_output/1/#fig:samplechar). For a full list of article characteristics, see the appendices ([10.4](http://127.0.0.1:32157/rmd_output/1/#tab:studychar))

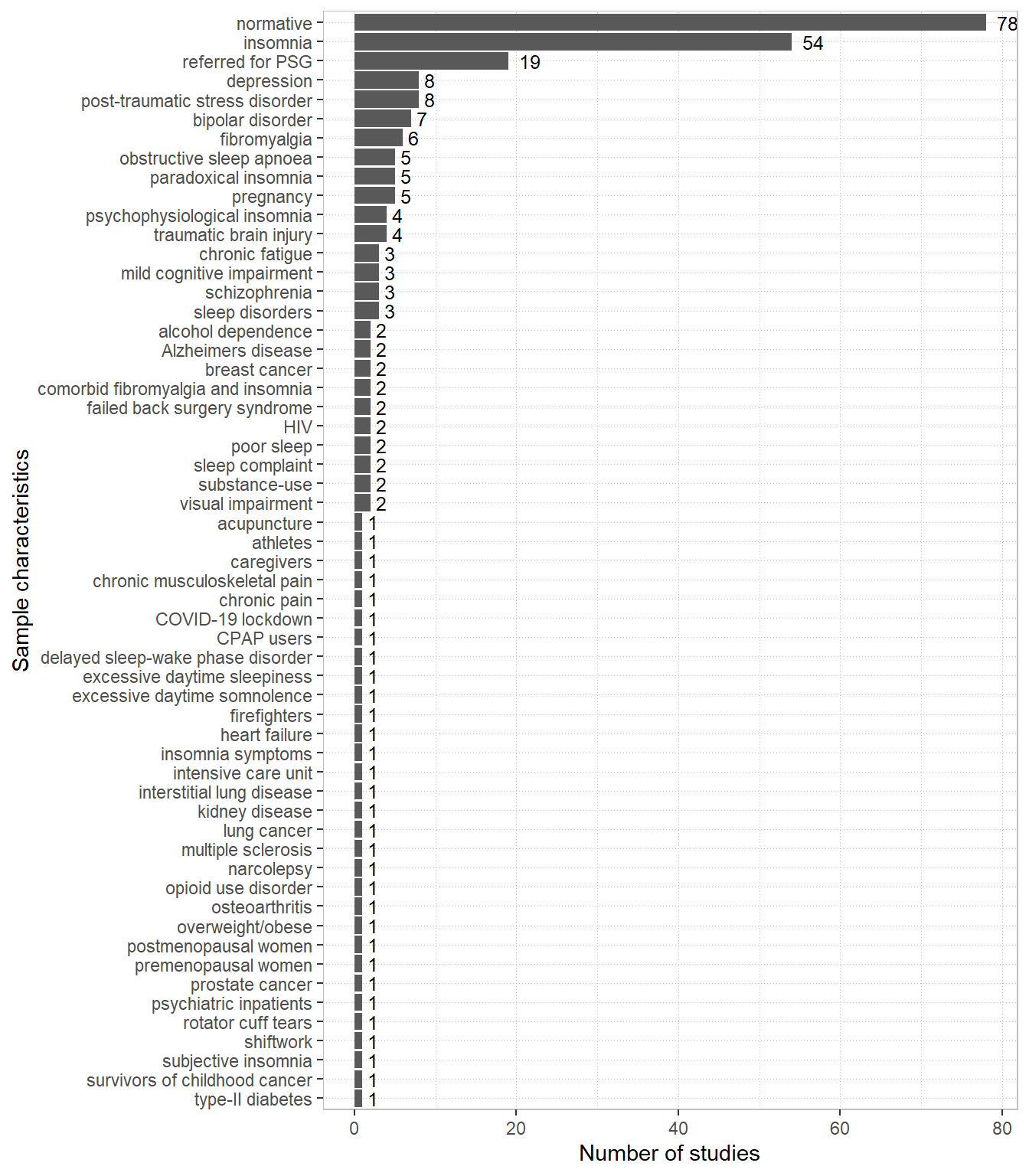


Figure 4.2: Sample characteristics

4.2 Methodological features

4.2.1 Measures of objective sleep

Objective methods of recording sleep formed two major groups: EEG-based methods (n = 116) and movement-based methods (n = 143). 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).

4.2.1.1 Polysomnography

Methodological features charted for PSG included scoring criteria, setting, and recording period. Scoring criteria for PSG were split between American Academy of Sleep Medicine (AASM; n = 45) and Rechtschaffen & Kales (R&K; n = 56) 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 (2012)’s guidelines in addition to R&K. Edinger & Fins (1995) used combined audio and visual criteria for sleep staging (Erwin & Ebersole, 1989). A total of 5 studies did not report scoring criteria. In terms of setting, PSG was more frequently conducted in a laboratory (n = 89) than at home (n = 21). Other environments included a truck-berth (n = 1), fMRI (n = 1) and an airline rest facility (n = 1). A total of 2 studies did not report scoring criteria. Recording periods were predominantly nocturnal (n = 99), but also included daytime naps (n = 5), and other sleep periods (n = 4).

4.2.1.2 Actigraphy

We recorded features of actigraphy that included device name, scoring algorithm, software, and rest interval definition. See Table [10.5](http://127.0.0.1:32157/rmd_output/1/#tab:bigacti) in the appendices for full tabulations of actigraphy characateristics. Actigraphy scoring algorithms are responsible for determining wakefulness and sleep from accelerometer-derived motor activity. Use of scoring algorithms varied across studies and are listed below in Figure [4.3](http://127.0.0.1:32157/rmd_output/1/#fig:algorithms).

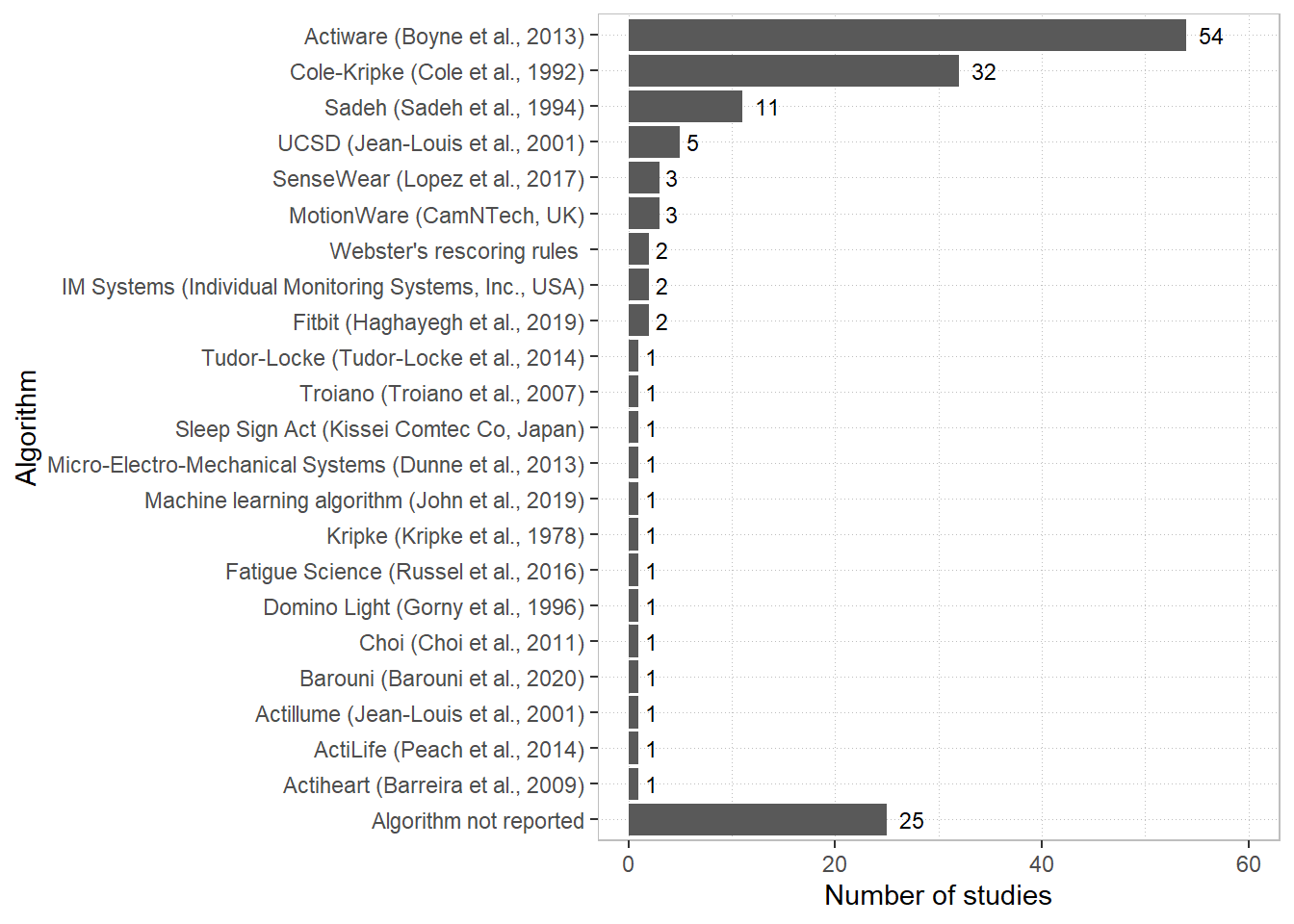


Figure 4.3: Actigraphy and accelerometer algorithms

Studies using Actiware algorithms varied in their selection of thresholds for scoring wakefulness. These are depicted in Figure [4.4](http://127.0.0.1:32157/rmd_output/1/#fig:actiware) below.

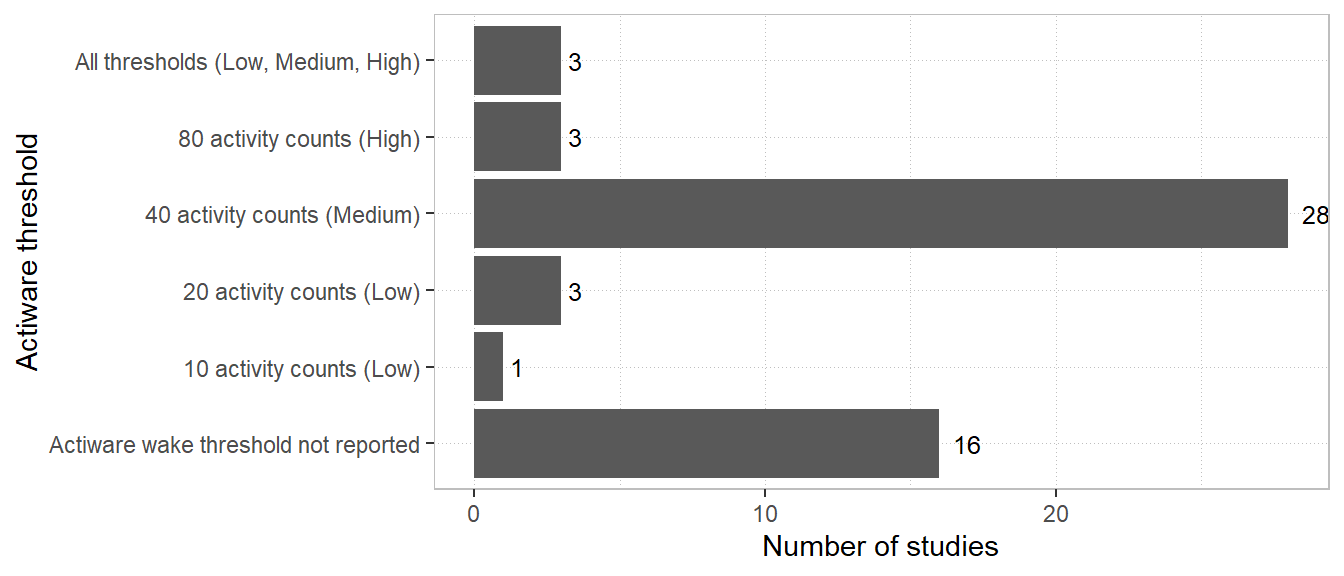


Figure 4.4: Actiware algorithm threshold settings

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 [4.5](http://127.0.0.1:32157/rmd_output/1/#fig:intervals).

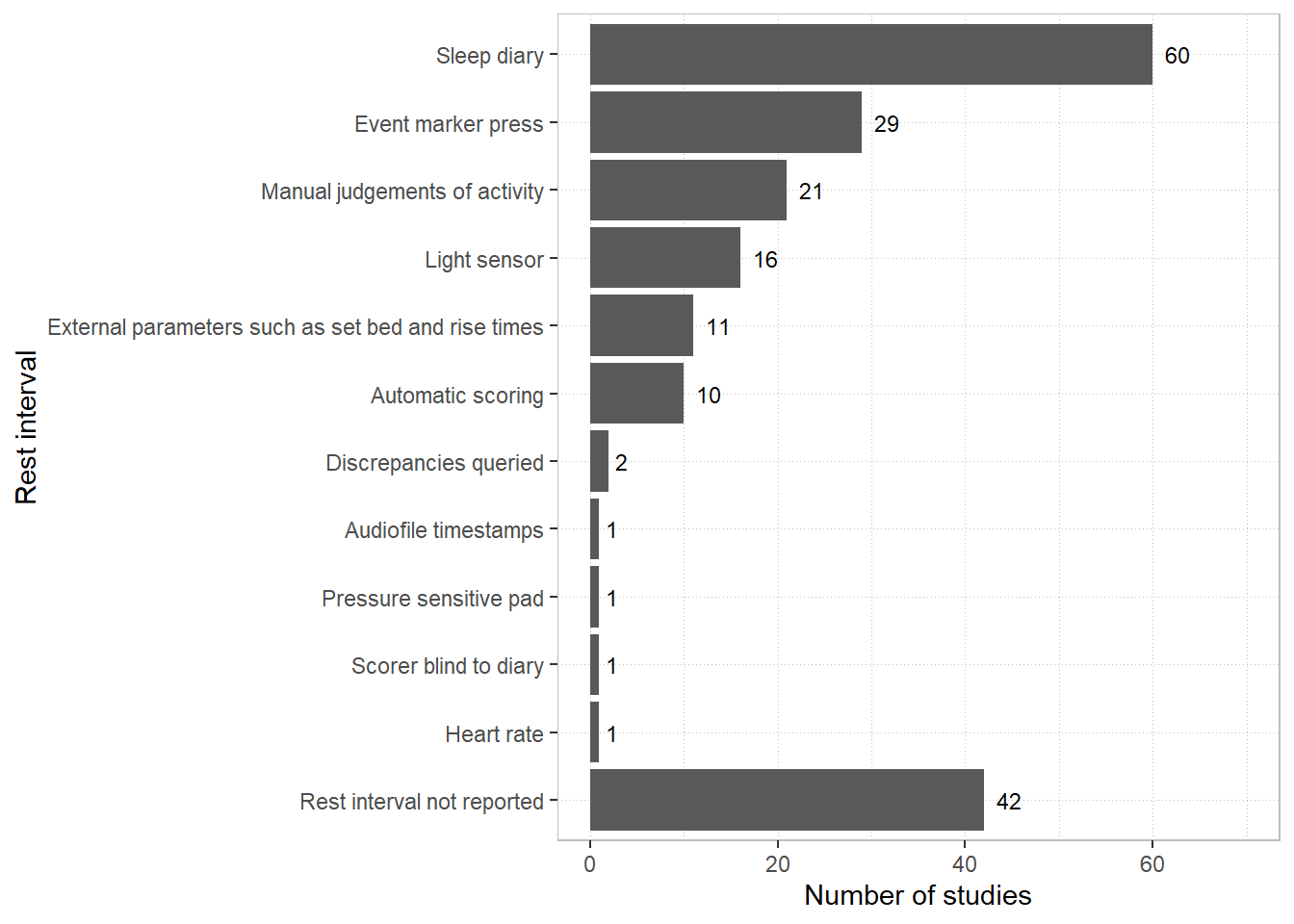


Figure 4.5: Methods for defining rest intervals in actigraphy

The precise combinations or orders of priority of methods in each study varied markedly. See Table [10.5](http://127.0.0.1:32157/rmd_output/1/#tab:bigacti) 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

Nine types of self-report sleep measure were identified: sleep diaries such as the consensus sleep diary (Carney et al., 2012), where data are entered in a numerical format (n = 102); graphical sleep diaries (also known as raster plots), where responses are drawn on scales comprising discrete blocks of time (n = 10); morning questionnaires, single-night estimates of self-report sleep typically administered following PSG (n = 72); habitual sleep questionnaires such as the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989), where respondents provide information on their usual sleep over a period of weeks (n = 17); morning questionnaires, where participants are queried directly by experimenters about their sleep (n = 3); graphical post-nap questionnaires that require graphical responses such as shading blocks of time (n = 1); and post-wake interviews where participants are queried about their sleep directly following natural or induced awakenings (n = 4). The specific self-report sleep questionnaire used in each study was recorded when this information was available. See supplemental materials for a qualitative overview of sleep questionnaires. We also recorded whether self-report sleep measures aimed to capture *habitual sleep*, an individual’s typical sleep over a period of weeks to a month, or sleep occurring night-by-night or sleep episode-by-sleep episode at the same time as objective measures, referred to here as *episodic* sleep. In the present review, 51 studies measured habitual sleep, 187 studies measured episodic sleep, and 7 measured both.

4.3 Sleep variables

A range of variables were used to measure sleep discrepancy. These are depicted below in Table [4.1](http://127.0.0.1:32157/rmd_output/1/#tab:variables).

| Table 4.1: Sleep variables used for operationalising sleep discrepancy | | | | |
| --- | --- | --- | --- | --- |
| **Variable name** | **Abbreviation** | **Calculation** | **Equivalent terms** | **Number of studies** |
| Total sleep time | TST | Varied (Objective, Self-report) | Sleep duration | 197 |
| Sleep onset latency | SOL | Varied (Objective) | Sleep latency (SL) | 142 |
| Wake after sleep onset | WASO | Varied (Self-report) |  | 73 |
| Sleep efficiency | SE | Varied (Self-report, Objective) | Sleep efficiency index (SEI) | 65 |
| Time in bed | TIB | BT - RT |  | 21 |
| Number of awakenings | NWAK |  |  | 27 |
| Total wake time | TWT | SOL + WASO + terminal wakefulness (TWAK) |  | 7 |
| Sleep period time | SPT | BT - FWT |  | 5 |
| Sleep onset time | SOT | Time at sleep onset | Sleep onset (actigraphy) | 13 |
| Final wake time | FWT | Time at final awakening |  | 19 |
| Bed time | BT | Time where participant is in bed trying to sleep | Lights off (PSG) | 14 |
| Rise time | RT | Time getting out of bed | Sleep offset (actigraphy), lights on (PSG) | 2 |
| Sleep midpoint |  | (FWT - BT)/2 |  | 2 |
| Sleep wake agreement (one possible objective sleep state) |  |  |  | 6 |
| Sleep wake agreement (two possible objective sleep states) |  |  |  | 4 |
| Latency to persistent sleep | LPS | Latency to 10 minutes of uninterrupted sleep |  | 3 |
| Sleep during subjective latency | SDSL | Minutes of objective sleep during period defined by self-report sleep latency |  | 2 |
| Latency-adjusted total sleep time | LA-TST | Objective total sleep time following the point of subjective sleep onset |  | 1 |
| Effective sleep time | EST | TST - WASO - SOL |  | 1 |
| Subjective wake time | SWT | WASO + SOL |  | 1 |
| Terminal wakefulness | TWAK | RT - FWT | Wake after sleep offset (WASF) | 0\* |
| Intermittent wake time | IWT | No definition reported |  | 1 |
| *Note:* Sleep wake agreement (one possible objective sleep state) 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, sleep wake agreement (two possible sleep states) 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 former approach produces a binary outcome whereas the latter produces a confusion matrix.  \* TWAK was not used to define sleep discrepancy directly by any of the included studies but is included in the table for clarity | | | | |

Sleep time variables including TST, SOL, WASO, SE, and TIB preponderated in the identified studies. Agreement in sleep states was also measured but far less commonly. Discrepancy was investigated in variables outside of conventional sleep time parameters in a handful of studies. Al Lawati et al. (2021) compared self-report and actigraphic measures of sleep patterns including monophasic, biphasic dawn, biphasic siesta, and polyphasic. Lockley et al. (1999), Dautovich et al. (2008), Hanisch et al. (2011), and 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 sleep variables total sleep time (TST), wake after sleep onset (WASO), sleep efficiency (SE), and time in bed (TIB) varied across studies. Three types of self-report TST were observed: TST queried directly (e.g., “how many minutes did you sleep last night”; n = 115); TST calculated from other parameters such as TIB, SOL, and WASO (n = 47); and TST calculated from graphical responses (n = 7). Definitions for WASO included direct query (n = 39), calculation from numerical or graphical responses (n = 7), or the definition was not reported (n = 30). Definitions for self-report TIB included RT-LO (n = 46), FA-LO (n = 4), TST + WASO + SOL (n = 1) or definition was not reported (n = 12). 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

Definitions of objective TST, SOL, and number of awakenings differed across studies. Sinclair et al. (2014), 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 and these are depicted in Figure [4.6](http://127.0.0.1:32157/rmd_output/1/#fig:SOL) below.

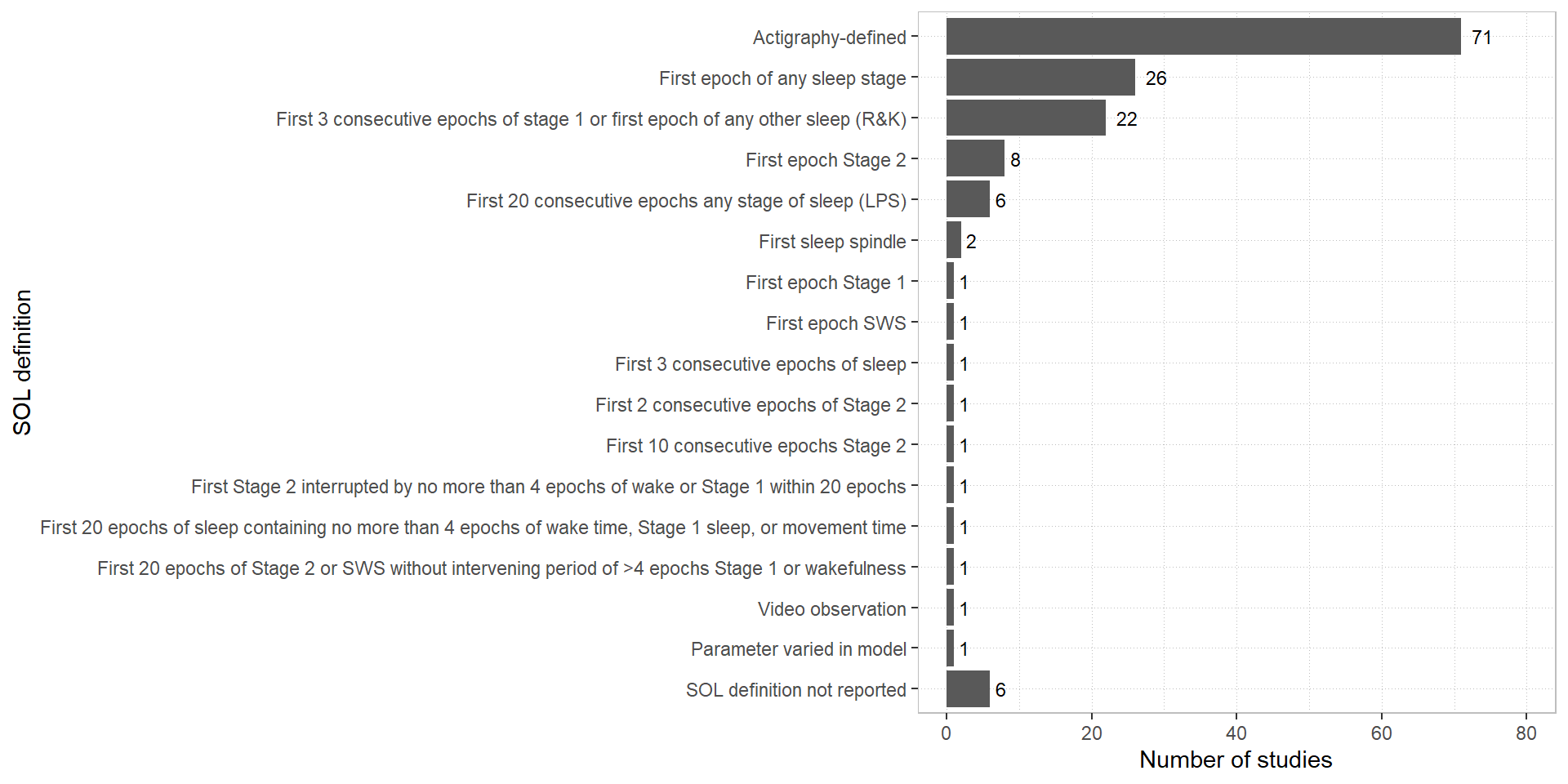


Figure 4.6: Definitions of objective sleep onset latency

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 (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 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. The most common methods for handling repeated measures included calculating mean values across multiple instances of recording (n = 96), pooling data across multiple instances of recording (n = 13), using repeated measures ANOVA for analyses (n = 13), calculating mean derived score values across multiple instances of recording (n = 12), using linear mixed models for analyses (n = 10), and conducting analyses separately for each instance of recording (n = 8). A total of (n = 75) studies included only a single instance of recording where no method of dealing with repeated measures was necessary. Less common methods included taking modal values (Al Lawati et al., 2021) or median values (Bianchi et al., 2012; Lubas et al., 2022) of multiple instances of recording, calculating the standard deviation of derived index across multiple instances of recording (Kay et al., 2013), using generalised estimating equations (Lauderdale et al., 2008), and using structural equation modelling (Friedmann et al., 2022). Mean values were a common way of handling repeated measurements for actigraphy studies (n = 85) and to a lesser extent PSG (n = 11).

Some studies measuring naturalistic sleep in the home environment took day of week into consideration for analyses. A total of 3 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 [4.7](http://127.0.0.1:32157/rmd_output/1/#fig:group)

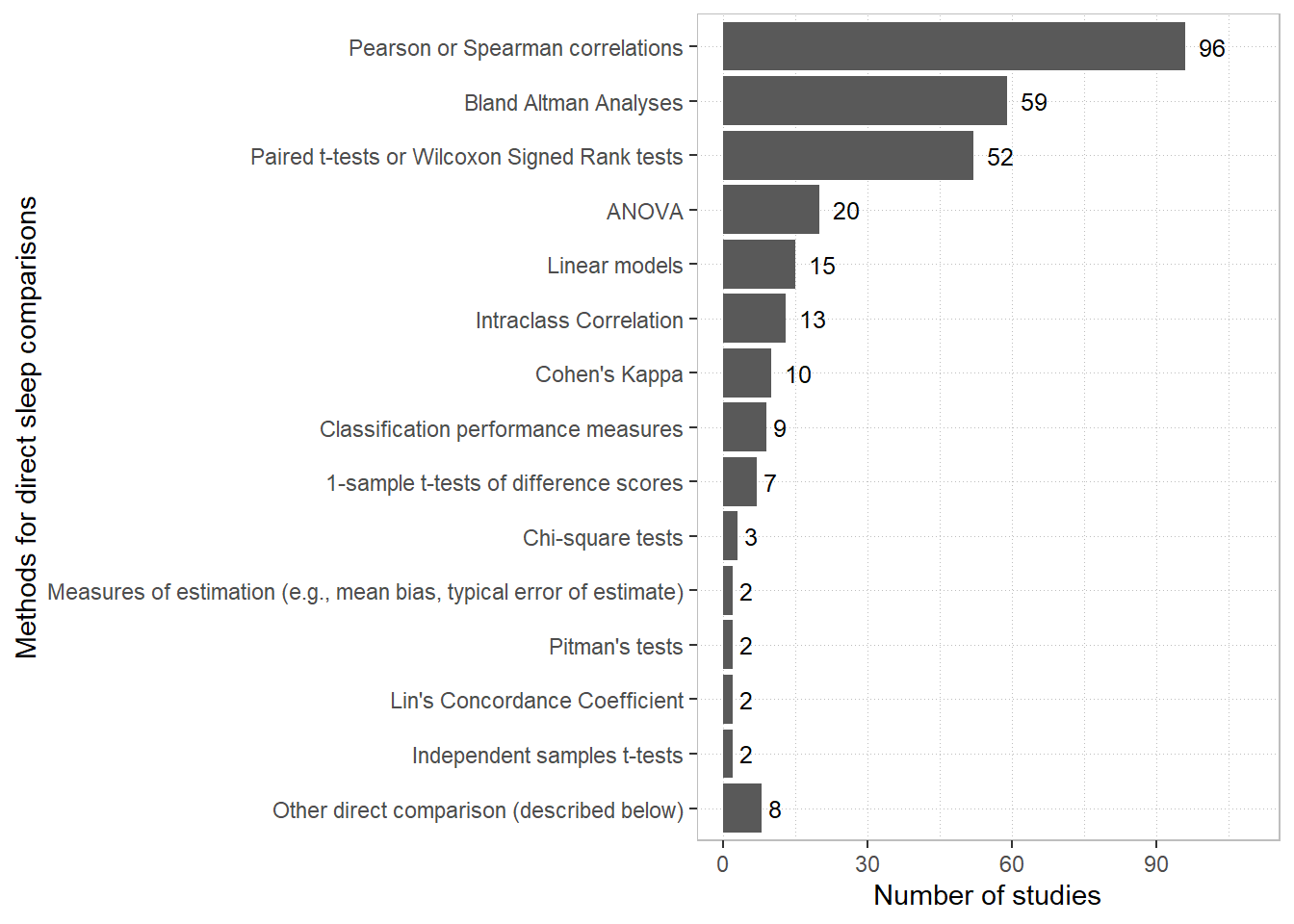


Figure 4.7: Statistical methods for comparing self-report and objective sleep

Note, Bland Altman analyses include Bland Altman plots and the reporting of 95% limits of agreement (see: 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. 1-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 on 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 [4.8](http://127.0.0.1:32157/rmd_output/1/#fig:derived) below.

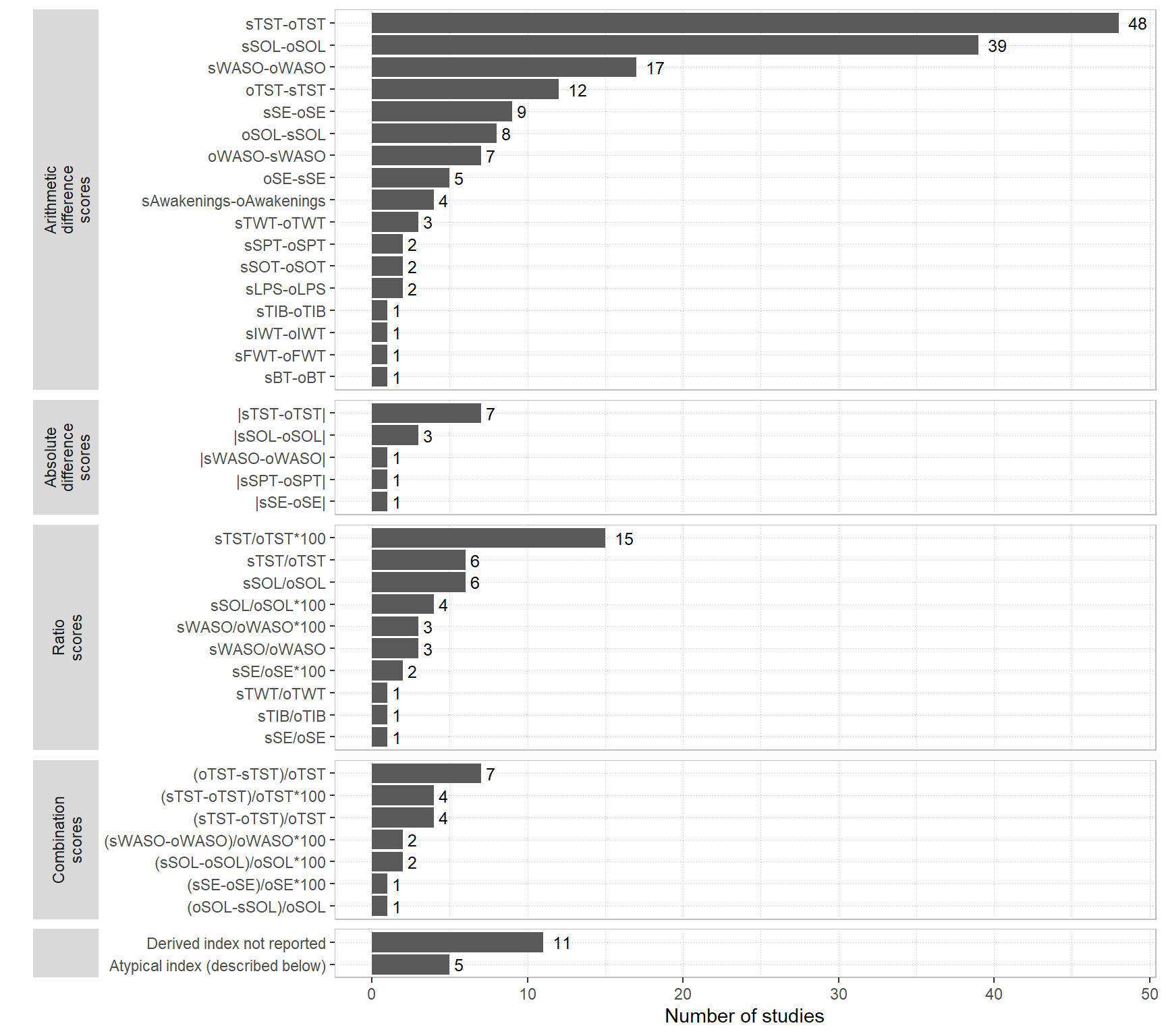


Figure 4.8: Derived indices used for operationalising sleep discrepancy

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. This method of deriving scores was first devised by Manconi et al. (2010). Their index was named the misperception index (MI) in its first iteration, is defined as oTST-sTST)/oTST, and was the most common combination score we identified. The MI was constructed to reproduce the bimodal distribution observed with OSE in insomnia patients whilst providing a strong correspondence to the difference score oTST-sTST. Possible values for the MI range from −∞−∞ (extreme over-estimation) to +1 (extreme underestimation), although Manconi et al. (2010) recommends trimming the lower limit to -1. The principle of dividing an existing difference score by the objective component has since been extended by successive authors to other sleep variables (see the “Combination scores” facet in Figure [4.8](http://127.0.0.1:32157/rmd_output/1/#fig:derived) above).

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. 7 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. 10 studies used percentage agreement for sleep or other classification performance metrics in subsequent statistical analyses with other variables. 3 studies tested the differences between correlations amongst self-report and objective sleep between groups with bootstrapped confidence intervals Jackson et al. (2020), or the Fisher transformation (De Francesco et al., 2021). 4 studies 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.

4.7 Miscellaneous methodological features

Lastly, we recorded some other methodological features of studies that appeared pertinent to the study of sleep discrepancy. 11 studies investigated sleep discrepancy during, as a predictor of response to, or as an outcome of, cognitive behaviour therapy for insomnia (CBT-I). 15 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 systematically reviewed ways of measuring, conceptualising, and analysing sleep discrepancy. Studies varied considerably across the broad range of recorded methodological characteristics and the number of studies identified indicated a vast literature. Our findings are discussed below with recommendations for futher research where relevant.

5.1 Research in sleep discrepancy in marked by considerable methodological diversity

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 algorithms and procedures to process data. Sleep time-related metrics (e.g., TST, SOL, WASO) preponderated in the identified studies, with a only 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 and TIB. An exception to this general rule on the objective side was SOL, which 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 employed. This is unsurprising–after all, there are many ways to measure and analyse sleep– but it does have some interesting consequences for how we view sleep discrepancy.

In attempting to measure the discrepancy between two concepts it is useful to know the “discrepancy” within each concept itself. This is so that it can be certain that the discrepancy being measured can’t be accounted for by the amount of variation within each concept. It would appear 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 it follows from this that the two forms of objective sleep measurement will form different kinds of sleep discrepancy.

This issue continues through finer methodological distinctions. For example, estimation of actigraphic sleep can vary substantially according to scoring algorithm and the concordance of actigraphy to PSG by algorithm can vary according to the sample in question. Actiware algorithms with the medium threshold may perform better than Cole-Kripke in healthy young adults (Gao et al., 2022), the Sadeh algorithm has demonstrated higher specificity than UCSD and Cole-Kripke (Haghayegh et al., 2019; Quante et al., 2018; Souza et al., 2003) but may be less appropriate for assessment of sleep in those with severe obstructive sleep apnoea (Kim et al., 2013). Further complicating the picture is the fact that algorithm performance will also differ according to the actigraph device used (Kripke et al., 2010). Distinctions continue along the process of conducting a sleep discrepancy study. The range of sleep variables available to operationalise sleep discrepancy is immense. What would it mean if WASO discrepancy was associated with a particular aspect of insomnia symptomatology but not number of awakening discrepancy? Castelnovo et al. (2019) highlighted this issue in a review of definitions for paradoxical insomnia where little overlap was found between individuals that misperceive TST and misperceive SOL.

The distinctions continue even within sleep variables themselves. We identified two principal ways of calculating self-report TST from diaries and sleep questionnaires: querying participants directly about how much sleep they had (e.g., “how many hours did you sleep last night?”) and calculating TST from other parameters that were queried directly (e.g., TST = TIB - SOL - WASO - TWAK). The latter method is recommended by Buysse et al. (2006) and is the usual practice when using the Consensus Sleep Diary (Carney et al., 2012), a questionnaire that does not contain a direct query for TST in its standard version. Alameddine et al. (2015) compared direct and indirect (i.e., calculated) self-report measures of TST and found that indirect estimates tended to exceed direct estimates. In this study, sleep discrepancy was overall negative across the 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 (i.e., reduced sleep discrepancy). For each of these examples, differences in sleep discrepancy are observed across varied methodological approaches in ways that are likely to be systematic. This is a very real issue for studies investigating the relationship between sleep discrepancy and another construct as the variance accounted for by the span of possible approaches may well exceed that of the effect the researchers are looking for.

This issue extends beyond the status of sleep discrepancy as a concept and affects the pragmatics of research in the area. 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 the methodological diversity highlighted in 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 in Table [4.1](http://127.0.0.1:32157/rmd_output/1/#tab:variables) 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 extends beyond 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.

Addressing these issues may take a number of approaches. A stronger research focus on methods, investigating the impact of changes in methodology would be helpful overall. Specific tools such as structural equation modelling could be used to to account for the variance represented by various methodological choices alone or in relation to other constructs. Theoretical justification or similar 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 reduce methodological variance in this particular area, although the large range of available devices (see [10.5](http://127.0.0.1:32157/rmd_output/1/#tab:bigacti)) and proprietary nature of some algorithms (e.g., Boyne et al., 2013) may prove an impediment to this. For the time-being, in light of the large amount of unreported features of actigraphy found in this review, it would be helpful to follow the recommendations of (Ancoli-Israel et al., 2015) to report device manufacturer, device model, name and version of software, parameters of data collection including epoch length and sampling rate, and algorithms used. Finally, 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.

5.2 Definitions of objective sleep onset latency are multifarious and mostly abritrary

Definitions of objective SOL vary considerably in the sleep discrepancy literature. Among PSG studies, the two most common approaches were dependent on standard definitions provided by scoring guidelines: Rechstaffen & Kales (R&K) and the American Academy of Sleep Medicine (AASM). In R&K, sleep onset is defined by three consecutive epochs of stage 1 sleep or one epoch of stage 2 sleep (Rechtschaffen & Kales, 1968). For AASM, by contrast, an epoch of any stage of sleep indicates sleep onset (Berry et al., 2012). Subjective 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 (2003) and Lehrer et al. (2022) are expected to have the closest correspondence to self-report SOL, in light of research indicating 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).

Saline et al. (2016) noted a potential problem 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).

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.

In view of these issues, three options are recommended in the context of sleep discrepancy research. The first is to 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 (see Hermans, Nano, et al. (2020)) and the rarity and limited magnitude of SOL underestimation (see 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 some alternatives (see [4.6](http://127.0.0.1:32157/rmd_output/1/#fig:SOL)). The second option is to 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. The third option is to avoid SOL as a sleep variable and to model sleep perception parameters during the sleep onset period according to Hermans, Nano, et al. (2020). The latter two options have the added advantage of operationalising sleep discrepancy without the use of derived scores–the problems with which are discussed in the following paragraph.

5.3 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 interchangeable 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 knows 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 more subtler systems exist, including the cyclic alternative 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 to 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 5 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 [5.2](http://127.0.0.1:32157/rmd_output/1/#sol). 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 & Tang (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 yet sleep discrepancy 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.

5.4 Derived variables are extremely 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. A detailed treatment of these problems is beyond the scope of this discussion. Stated briefly, in a relationship with another variable, the effect of each component of a derived (e.g., the difference between self-report and objective sleep) is confounded such that it is not possible to determine whether self-report sleep, objective sleep, or some combination of the two are driving the relationship (Edwards, 2002). Moreover, derived scores impose inappropriate constraints on relationships between other variables that are often not entailed by, or else completely 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 (see [4.6.2](http://127.0.0.1:32157/rmd_output/1/#altdisc)).

5.5 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 nightly or episodic 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 and some individuals will overestimate sleep Lindert et al. (2020). 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 nightly level. In other cases, linear mixed models, generalised estimating equations, and structural equation models were methods identified in this review that do not inherit the same problems with averaging across repeated measures.

5.6 Correlations have sometimes been used inappopriately 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 (Jinyuan 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.

5.7 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 review of methods for measuring sleep quality was conducted by Mendonça et al. (2019) and the scope and number of strategies identified was immense–especially for objective measures. 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 isn’t 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.

5.8 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.

5.9 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. A prior review of paradoxical insomnia and subjective-objective sleep discrepancy (Rezaie et al., 2018) identified a total of 40 records. Although conducted four years prior, this review used broader inclusion criteria extending to paradoxical insomnia, the parameters for which do not typically involve direct comparisons of self-report and objective sleep. A corollary to this underestimation of breadth is 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).

5.10 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.

5.11 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.

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9 Declaratation of competing interest

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

10 Appendices

10.1 Search strategies

Search strategies for databases searched using the Ovid system are available in Table [10.1](http://127.0.0.1:32157/rmd_output/1/#tab:ovid). Search strategies for other databases are listed in Table [10.2](http://127.0.0.1:32157/rmd_output/1/#tab:databases).

| Table 10.1: 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 |

| Table 10.2: Search strategy for other databases | |
| --- | --- |
| **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 Plus** | |
| (“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 |

10.2 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)

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

10.3 PRISMA-ScR checklist

| Table 10.3: 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](http://127.0.0.1:32157/rmd_output/1/#abstract) |
| **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](http://127.0.0.1:32157/rmd_output/1/#abstract) |
| **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](http://127.0.0.1:32157/rmd_output/1/#introduction) |
| 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](http://127.0.0.1:32157/rmd_output/1/#introduction) |
| **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](http://127.0.0.1:32157/rmd_output/1/#protocol) |
| 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](http://127.0.0.1:32157/rmd_output/1/#item6) |
| 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](http://127.0.0.1:32157/rmd_output/1/#item7) |
| 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](http://127.0.0.1:32157/rmd_output/1/#tab:egsearch) |
| 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](http://127.0.0.1:32157/rmd_output/1/#item9) |
| 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](http://127.0.0.1:32157/rmd_output/1/#item10) |
| Data items | 11 | List and define all variables for which data were sought and any assumptions and simplifications made | [3.7](http://127.0.0.1:32157/rmd_output/1/#item11) |
| 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](http://127.0.0.1:32157/rmd_output/1/#item13) |
| **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](http://127.0.0.1:32157/rmd_output/1/#item14) |
| Characteristics of sources of evidence | 15 | For each source of evidence, present characteristics for which data were charted and provide the citations. | [4.1](http://127.0.0.1:32157/rmd_output/1/#item15) |
| 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](http://127.0.0.1:32157/rmd_output/1/#resultsandsynthesis) |
| Synthesis of results | 18 | Summarize and/or present the charting results as they relate to the review questions and objectives. | [4.2](http://127.0.0.1:32157/rmd_output/1/#resultsandsynthesis) |
| **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](http://127.0.0.1:32157/rmd_output/1/#item19) |
| Limitations | 20 | Discuss the limitations of the scoping review process. | [5.10](http://127.0.0.1:32157/rmd_output/1/#item20) |
| 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. | [5.11](http://127.0.0.1:32157/rmd_output/1/#item21) |
| **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. | [8](http://127.0.0.1:32157/rmd_output/1/#item22) |

10.4 Additional tables

Full descriptions of study characteristics are available in Table [10.4](http://127.0.0.1:32157/rmd_output/1/#tab:studychar).

| Table 10.4: Characteristics of included studies | | | |
| --- | --- | --- | --- |
| **Study** | **Country of origin** | **Sample characteristics** | **Sample size** |
| Chou et al. (2020) | USA | Cognitively normal and mildly impaired older adults | 293 |
| Hermans, Van Gilst, et al. (2020) | Netherlands | Insomnia patients and healthy controls | 231 |
| Janků et al. (2020) | Czech Republic | Insomnia patients | 36 |
| King et al. (2017) | USA | Female undergraduates enrolled in an interior design programme | 28 |
| Lehrer et al. (2022) | USA | Middle-aged community-dwelling women | 323 |
| Provencher et al. (2020) | Canada | Individuals with psychophysiological insomnia, paradoxical insomnia, and good sleepers | 67 |
| Segura-Jiménez et al. (2015) | Spain | Women with fibromyalgia and healthy controls | 198 |
| Slightam et al. (2018) | USA | Veterans with PTSD and demographically similar controls | 120 |
| Trimmel et al. (2021) | Austria | Patients with a range of sleep disorders who underwent laboratory or ambulatory PSG | 303 |
| Williams et al. (2013) | USA | Community-dwelling older adults | 142 |
| Al Lawati et al. (2021) | Oman | Healthy Omani nationals | 321 |
| 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 |
| Auger et al. (2013) | USA | Patients referred to an academic sleep centre | 84 |
| 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 |
| Bianchi et al. (2013) | USA | Patients referred to a sleep centre | 312 |
| Billings (2022) | USA | Firefighters | 24 |
| Brychta et al. (2019) | Iceland | 15-year, then 17-year old students of the same cohort | 144 |
| Cederberg et al. (2022) | USA | Patients with multiple sclerosis | 49 |
| Chan et al. (2018) | USA | Individuals with fibromyalgia and Insomnia | 223 |
| S. J. Choi et al. (2016) | Korea | Patients referred to a sleep centre for PSG in addition to healthy volunteers | 420 |
| Combertaldi & Rasch (2020) | Switzerland | Young healthy students | 24 |
| Conroy et al. (2006) | USA | Individuals experiencing insomnia in recovery from alcohol dependence | 21 |
| Currie et al. (2004) | Canada | Individuals experiencing insomnia in recovery from alcohol dependence | 56 |
| Dietch & Taylor (2021) | USA | Representative community-based normative sample | 80 |
| Dittoni et al. (2013) | Italy | Chronic primary insomnia patients | 66 |
| Dunican et al. (2017) | Australia | Judo athletes | 23 |
| 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 |
| Franklin & Svanborg (2000) | Sweden | Individuals referred to sleep center for suspected OSA | 100 |
| Ghadami et al. (2014) | Iran | War veterans diagnosed with chronic PTSD | 32 |
| Girschik et al. (2012) | Australia | Women recruited from the community | 56 |
| Gooneratne et al. (2011) | USA | Older adults with and without insomnia complaint | 200 |
| Hermans, Nano, et al. (2020) | Netherlands | Participants with insomnia on a waitlist for CBT-I | 31 |
| Herring et al. (2013) | USA | Urban low-income pregnant women | 80 |
| Hoogerhoud et al. (2015) | Netherlands | Patients receiving index or maintenance ECT for a depressive episode | 12 |
| 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 |
| 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 |
| Kawada (2008) | Japan | Healthy university students | 76 |
| Kay et al. (2015) | USA | Older adults with and without insomnia | 114 |
| Kay et al. (2013) | USA | Older adults with and without sleep complaint | 103 |
| 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 |
| Kong et al. (2011) | China | Children recruited from primary and secondary schools in Hong King | 133 |
| Krahn et al. (1997) | USA | Psychiatric inpatients | 30 |
| Lastella et al. (2018) | Australia | Well-trained male soccer players | 12 |
| J. Lee et al. (2021) | Korea | Adults with insomnia | 105 |
| J. Liu et al. (2019) | China | Healthy young adults | 10 |
| Lockley et al. (1999) | United Kingdom | Blind individuals | 49 |
| 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 |
| Majer et al. (2007) | USA | Individuals with chronic fatigue and non-fatigued controls | 75 |
| Mazza et al. (2020) | France | Children aged 8-9 years recruited from elementary schools | 76 |
| Means (2003) | USA | Middle-aged and older individuals with insomnia and matched normal sleepers | 101 |
| Mendelson et al. (1986) | USA | Individuals with insomnia and age and sex matched controls | 20 |
| 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 |
| Nazem et al. (2016) | USA | Male veterans with traumatic brain injury | 19 |
| Normand et al. (2016) | Canada | Paradoxical insomnia, psychophysiological insomnia, good sleepers | 70 |
| Okifuji & Hare (2011) | USA | Patients with fibromyalgia | 75 |
| 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 |
| Perlis et al. (1997) | USA | Female fibromyalgia patients | 20 |
| Regestein et al. (2004) | USA | Healthy, postmenopausal women having hot flash activity | 88 |
| 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 |
| Sato et al. (2010) | Japan | Patients experiencing psychophysiological insomnia | 20 |
| Sharkey et al. (2011) | USA | Patients in a methadone maintenance therapy for opioid dependence | 62 |
| Sharman et al. (2022) | United Kingdom | Healthy sleepers | 16 |
| Silva & Walsleben (2007) | USA | Participants over 40 | 2113 |
| 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 |
| Trajanovic et al. (2007) | Serbia, USA | Patients referred to a sleep clinic | 136 |
| Tsuchiyama et al. (2003) | Japan | Patients with major depression admitted to a psychiatric hospital | 23 |
| W. Wang et al. (2022) | Canada | Naval sailors | 66 |
| Werner et al. (2016) | USA | Women with PTSD experiencing PTSD-related sleep disturbance | 51 |
| D. L. Wilson et al. (2013) | Australia | Women in third trimester and first trimester of pregnancy and non-pregnant women | 64 |
| Xu et al. (2022) | China | Young adults | 47 |
| Alameddine et al. (2015) | USA | Participants referred to a sleep centre for PSG | 879 |
| 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 |
| Bianchi et al. (2012) | USA | Healthy subjects undergoing in-lab sleep experiment | 44 |
| Broomfield & Espie (2003) | United Kingdom | Individuals complaining of sleep-onset insomnia | 34 |
| 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 |
| Chervin & Guilleminault (1996) | USA | Patients referred to a sleep centre for an MSLT for suspected excessive daytime somnolence | 147 |
| Chung et al. (2020) | Korea | Outpatients with schizophrenia | 66 |
| Dautovich et al. (2008) | USA | Older adults who nap habitually | 100 |
| 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 |
| Dorsey & Bootzin (1997) | USA | Undergraduate students | 31 |
| Edinger & Fins (1995) | USA | Outpatients with insomnia presenting to a sleep disorders centre | 173 |
| Espie et al. (1989) | United Kingdom | Individuals with insomnia | 20 |
| Gonzalez et al. (2013) | USA | Individuals with bipolar type I | 39 |
| 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 |
| Hanisch et al. (2011) | USA | Prostate cancer patients undergoing androgen therapy | 60 |
| Hermans et al. (2019) | Netherlands | Older adults with and without insomnia | 41 |
| Hermans et al. (2021) | Netherlands | Older adults involved in a double-blind crossover study with zopiclone and placebo | 46 |
| 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 |
| Kaufmann et al. (2019) | USA | Individuals with bopolar disorder and healthy controls | 85 |
| 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 |
| Lauderdale et al. (2008) | USA | Young adults enrolled in the Coronary Artery Risk Development in Young Adults study | 647 |
| Lubas et al. (2022) | USA | Participants enrolled in a longitudinal study of survivors of childhood cancer | 477 |
| Maich et al. (2018) | Canada | Individuals with insomnia and good sleeper controls | 74 |
| Martinez et al. (2010) | Brazil | Patients referred to a university-affiliated sleep clinic for PSG | 5764 |
| McCall et al. (1995) | USA | Individuals undergoing PSG for suspected sleep apnoea | 84 |
| Mendelson (1998) | USA | Participants who complained of poor sleep | 8 |
| Mercer et al. (2002) | USA | Individuals with insomnia and good sleepers | 22 |
| Neu et al. (2007) | Belgium | Individuals with chronic fatigue and female controls | 40 |
| Okun et al. (2021) | USA | Pregnant women | 104 |
| Park et al. (2007) | USA | Postmenopausal women | 384 |
| Perlis et al. (2001) | USA | Individuals with primary insomnia, insomnia secondary to depression, and good sleeper controls | 27 |
| Reess et al. (2010) | Germany | Patients with insomnia, sleep-related movement disorders (SMD), hypersomnia, and parasomnia | 159 |
| Saline et al. (2016) | USA | Adult patients referred to a clinical sleep laboratory | 643 |
| Scarlett et al. (2021) | Ireland | Community-dwelling older adults | 1520 |
| Schokman et al. (2018) | Sri Lanka | Sri Lankan adults | 175 |
| Stout et al. (2017) | USA | Military veterans and active-duty service members, 17 with PTSD, 20 without PTSD | 37 |
| Tang & Harvey (2004) | United Kingdom | Healthy good sleepers | 54 |
| Thun et al. (2012) | Norway | University students | 166 |
| Tomita et al. (2013) | Japan | patients complaining of excessive daytime sleepiness | 28 |
| Tremaine et al. (2010b) | Australia | Children and adolescents | 66 |
| Trimmel et al. (2021) | Austria | Patients referred to sleep clinic in a department of neurology | 303 |
| Usui et al. (2003) | Japan | Older and younger adults | 39 |
| Valko et al. (2021) | Switzerland | Patients referred to a sleep clinic for PSG | 3303 |
| Vanable et al. (2000) | USA | Patients referred to sleep clinic with various sleep disorders | 104 |
| K. G. Wilson et al. (1998) | Canada | Individuals experiencing insomnia associated with chronic musculoskeletal pain | 40 |
| Wolfson et al. (2003) | USA | High school students | 302 |
| Yamakita et al. (2014) | Japan | School-aged children | 58 |
| Yeung et al. (2015) | China | Individuals with insomnia undergoing placebo acupuncture | 86 |
| 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 |
| Baek et al. (2020) | Korea | Shiftwork nurses | 94 |
| Chan et al. (2021) | USA | Community dwelling older adults with insomnia | 62 |
| Chen et al. (2015) | Taiwan | Individuals with osteoarthritis | 30 |
| Crönlein et al. (2019) | Germany | Patients receiving CBT-I for insomnia | 92 |
| Downey & Bonnet (1992) | USA | Subjective insomniacs | 10 |
| Finan et al. (2020) | USA | Participants with opioid use disorder | 55 |
| Heath et al. (2018) | Australia | Adolescents | 385 |
| Hita-Yañez et al. (2013) | Spain | Patients with MCI and healthy elderly | 50 |
| Kobayashi et al. (2012) | USA | Urban-residing African Americans with and without trauma exposure and PTSD | 103 |
| Mccall & Mccall (2012) | USA | Patients diagnosed with current major depressive episode and chronic insomnia | 54 |
| Sprajcer et al. (2021) | Australia | Healthy adult male on-call workers | 72 |
| Vallières & Morin (2003) | Canada | Participants with chronic primary insomnia | 17 |
| B. Zhu et al. (2018) | USA | Adults with type II diabetes | 53 |
| Arditte Hall et al. (2023) | USA | Women with PTSD secondary to interpersonal violence | 45 |
| Aritake-Okada et al. (2010) | Japan | Healthy males | 22 |
| Kölling et al. (2016) | Germany | German undergraduate and graduate physical education students | 72 |
| Locihová et al. (2020) | Czech Republic | Patients admitted to an intensive care unit of a hospital | 20 |
| Nguyen-Michel et al. (2015) | France | Older adults referred for insomnia complaints or suspected sleep apnoea | 135 |
| Pinto et al. (2009) | Brazil | Individuals selected from a university sleep laboratory | 199 |
| Winer et al. (2021) | USA | Cognitively normal older adults | 89 |
| D’Aoust et al. (2015) | USA | Informal caregivers of persons with dementia | 53 |
| DiNapoli et al. (2017) | Italy | Older adults with mild cognitive impairment and subsyndromal depression | 59 |
| Dorrian et al. (2012) | Australia | Commercial passenger airline pilots | 306 |
| Manconi et al. (2010) | Italy, USA | Normal subjects | 288 |
| Matousek et al. (2004) | Czech Republic | Patients with minor depression, complaining of insomnia | 28 |
| O’Brien et al. (2016) | USA | Treatment-seeking overwieght/obese participants | 63 |
| St-Onge et al. (2019) | USA | Multi-racial, multi-ethnic sample of adults | 113 |
| Ahn et al. (2022) | Korea | Patients >55 years with insomnia disorders | 33 |
| Arora et al. (2013) | United Kingdom | Adolescents aged 11-13 | 255 |
| Bensen-Boakes et al. (2022) | Australia | Participants with comborbid insomnia and OSA | 145 |
| Bian et al. (2016) | China | Inpatients with schizophrenia | 148 |
| Cho et al. (2022) | Korea | Participants from the sleep heart health study | 2540 |
| Curtis et al. (2019) | USA | Participants with fibromyalgia and insomnia | 199 |
| Devine et al. (2020) | USA | Army Reserve Officers’ Training Corp Cadets | 286 |
| Duarte et al. (2020) | Brazil | Patients undergoing PSG for suspected sleep-disordered breathing | 727 |
| Dzierzewski et al. (2019) | USA | Older adults with insomnia | 159 |
| Etain et al. (2022) | France | Adults with bipolar disorder and healthy controls | 154 |
| Fernandez-Mendoza et al. (2011) | USA | Insomniacs and controls | 866 |
| Gibson et al. (2023) | Australia | Australian army recruits | 59 |
| Gökce et al. (2020) | Germany | Young adults in Munich | 74 |
| Herbert et al. (2017) | United Kingdom | Individuals with insomnia symptoms | 42 |
| Hodges et al. (2017) | USA | Cocaine-dependent persons admitted to an inpatient research facility | 43 |
| Hsiao et al. (2018) | Taiwan | Healthy young adults | 36 |
| Jackson et al. (2018) | USA | Adults enrolled in a large longitudinal study | 1910 |
| Kay et al. (2017) | USA | Individuals with paradoxical insomnia and good sleeper controls | 62 |
| Kung et al. (2015) | Taiwan | Taiwanese adults with major depression | 30 |
| Lan Chun Yang et al. (2021) | Canada | Participants diagnosed with mTBI/concussion | 37 |
| Lecci et al. (2020) | Switzerland | Population-based sample | 2092 |
| P. H. Lee (2022) | United Kingdom | Adults aged 20 or above | 8438 |
| S.-A. Lee et al. (2022) | Korea | Patients with OSA | 707 |
| Maric et al. (2019) | Switzerland | Healthy right-hand males | 14 |
| Meyer et al. (2018) | United Kingdom | Outpatients with schizophrenia | 14 |
| Nishikawa et al. (2021) | Japan | Outpatients with primary insomnia undergoing CBT-I | 52 |
| Santos et al. (2022) | Brazil | Participants in a longitudinal study | 2036 |
| Schneider-Helmert & Kumar (1995) | Switzerland | Participants with primary insomnia | 128 |
| Smagula et al. (2021) | USA | Males | 2850 |
| Lindert et al. (2020) | Netherlands | Individuals with insomnia disorder and individuals without sleep complaints | 236 |
| Thurman et al. (2018) | USA | Healthy participants | 30 |
| Topalidis et al. (2021) | Various | Healthy participants | 21 |
| Van Den Berg et al. (2008) | Netherlands | Community-dwelling older adults | 969 |
| Zak et al. (2022) | USA | Healthy premenopausal women | 71 |
| De Francesco et al. (2021) | United Kingdom | People with HIV and people without HIV matched on demographic variables | 461 |
| Gaina et al. (2004) | Japan | Healthy junior high school children | 42 |
| Guedes et al. (2016) | Brazil | Adolescents | 37 |
| McIntyre et al. (2016) | New Zealand | Healthy women late in third trimester | 30 |
| Sinclair et al. (2014) | Australia | Patients with traumatic brain injury and non-injured controls | 42 |
| Takano et al. (2016) | Belgium | Adults | 54 |
| Tang et al. (2007) | United Kingdom | Poor and good sleepers | 60 |
| Tang & Harvey (2006) | Various | Individuals with primary insomnia | 48 |
| M.-Y. Wang et al. (2011) | Taiwan | Heart failure patients | 43 |
| Bonnet & Moore (1982) | USA | Young adults | 12 |
| Creti et al. (2010) | Canada | Participants with chronic fatigue syndrome | 49 |
| Duarte et al. (2022) | Brazil | Individuals with sleep disorders and contrls | 2004 |
| Feng & Svetnik (2018) | United Kingdom | Primary insomnia patients | n/a |
| He et al. (2021) | China | Adults participants subject to COVID-19 lockdown provisions in China | 70 |
| Hur et al. (2022) | Canada | Patients with interstitial lung disease | 111 |
| Jungquist et al. (2016) | USA | Community-dwelling adults | 300 |
| Kundu et al. (2022) | India | Individuals with chronic insomnia and obstructive sleep apnoea | 32 |
| Laranjeira et al. (2018) | Brazil | Individuals referred to a sleep centre | 248 |
| Lewis (1969) | United Kingdom | Healthy young men | 8 |
| Y. Liu et al. (2020) | China | Patients diagnosed with OSA | 355 |
| Schulz & Walther (2017) | Germany | Individuals referred to a sleep centre for investigation of sleep disorders | 117 |
| Short et al. (2012) | Australia | Adolescents | 385 |
| 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 |
| Sun-Suslow et al. (2022) | USA | People with and without HIV | 94 |
| Tremaine et al. (2010a) | Australia | Children aged 11-16 | 65 |
| Jackson et al. (2020) | USA | African-American adults | 821 |
| Lipinska & Thomas (2017) | South Africa | Women with PTSD, trauma exposure with no PTSD, and healthy controls | 60 |
| Bean et al. (2021) | New Zealand | Chronic pain patients | 47 |
| Miner et al. (2022) | USA | Community-dwelling older adults | 5835 |
| Richardson et al. (2019) | Australia | Adolescents diagnosted with delayed sleep-wake phase disorder | 103 |
| Feige et al. (2021) | Germany | Insomnia patients and good sleeper controls | 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 |
| Yoon et al. (2022) | Korea | Patients with insomnia | 150 |
| Signal et al. (2005) | USA | Flight crew | 21 |
| Narisawa et al. (2015) | Japan | Participants with subjective sleep difficulty | 50 |
| Tang & Harvey (2004) | United Kingdom | Healthy good sleepers | 93 |
| Manconi et al. (2010) | Italy | 159 patients with primary insomnia | 159 |
| Lecci et al. (2020) | Switzerland | Insomnia patients and healthy subjects | 34 |
| Tang et al. (2007) | United Kingdom | Patients with primary insomnia split into a clock-monitoring group and display unit-monitoring group | 38 |

Full qualitative methodological details for actigraphy studies are available in Table [10.5](http://127.0.0.1:32157/rmd_output/1/#tab:bigacti).

| Table 10.5: 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-Jiménez et al. (2015) | SenseWear Pro3 Armband | SenseWear Professional | SenseWear | Lopez et al. (2018) | 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. (2013) | 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 (2022) | 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 Motionlogger | 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. (2014) | 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 | J. Liu et al. (2019) | Fitbit Alta | Fitbit software | Fitbit | Haghayegh et al. (2019) | Automatic (heart rate + activity) |
| 53 | Lockley et al. (1999) | Motionlogger, Mini Motionlogger | 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 | W. 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 Motionlogger 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. (2010b) | 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 | K. G. Wilson et al. (1998) | Mini Motionlogger | not reported | Cole-Kripke, Webster’s rescoring rules | Cole et al. (1992) | Not reported |
| 143 | Wolfson et al. (2003) | Mini Motionlogger | 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 Motionlogger | 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 | Vallières & Morin (2003) | IM Systems Actigraph | Individual Monitoring Systems | IM Systems | Individual Monitoring Systems, Inc., USA | Not reported |
| 160 | B. Zhu et al. (2018) | ActiGraph wGT3X | ActiLife | Actiware Medium (40), Cole-Kripke | Boyne et al. (2013); Cole et al. (1992) | Not reported |
| 161 | Arditte Hall et al. (2023) | Motionlogger Basic | Action W | UCSD | Jean-Louis et al. (2001) | N/a |
| 163 | Kölling et al. (2016) | SenseWear MF Armband | SenseWear Professional | SenseWear | Lopez et al. (2018) | Event marker –> activity |
| 164 | Locihová 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. (2018) | 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. (2022) | Actiwatch AW7 | Actiwatch Activity and Sleep Analysis | Actiware (not reported) | Boyne et al. (2013) | Sleep diary and event markers |
| 186 | Gibson et al. (2023) | 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 Motionlogger | Action W2 | not reported |  | Externally-defined (lights on/off times at psychiatric ward) |
| 196 | P. H. Lee (2022) | 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 | Nishikawa 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. (2022) | 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 | 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 | Russell et al. (2000) | 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 Motionlogger, 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 Motionlogger 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 Motionlogger Basic | Action W | Cole-Kripke | Cole et al. (1992) | Webster’s rules (daily sleep logs, notes, illumination channel) |
| 216 | Tang & Harvey (2006) | Mini Motionlogger Basic | Action W | Cole-Kripke | Cole et al. (1992) | Webster’s rules (daily sleep logs, notes, illumination channel) |
| 217 | M.-Y. 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); L. Choi et al. (2011); Troiano et al. (2008) | N/a or not reported |
| 223 | Hur et al. (2022) | 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. (2010a) | not reported | Actiware-Sleep | Actiware Medium (40) | Boyne et al. (2013) | Sleep diary |
| 235 | Jackson et al. (2020) | 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) | Mini Motionlogger Basic | not reported | Cole-Kripke | Cole et al. (1992) | Defined in-lab |
| 248 | Tang et al. (2007) | 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. |  |  |  |  |  |  |

| Table 10.6: Direct sleep-wake agreement studies | | | | | |
| --- | --- | --- | --- | --- | --- |
|  | **Study** | **Sample characteristics** | **Sleep variables** | **Sleep-wake agreement type** | **PSG setting** |
| 60 | mendelson\_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\_reliability\_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 | Quaternary | home-based |
| 101 | dorsey\_subjective\_1997 | undergraduate students | SOL (MSLT), sleep / wake agreement [Terminal sleep stage at each sleep latency test (objective), estimated conscious state by subject (subjective)] | Quaternary | in-lab |
| 123 | mendelson\_perception\_1998 | participants who complained of poor sleep | Participant report of having been awake/asleep following experimental awakenings | Binary | in-lab |
| 124 | mercer\_insomniacs\_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\_naps\_2003 | older and younger adults | sleep/ wake agreement, 10-minute epochs | Quaternary | n/a |
| 152 | downey\_training\_1992 | subjective insomniacs | SOL, participant sleep/wake judgement following experimental awakenings | Binary | in-lab |
| 165 | nguyen-michel\_underperception\_2015 | older adults referred for insomnia complaints or suspected sleep apnoea | Perception of sleep during nap (binary) | Binary | in-lab |
| 170 | dorrian\_predicting\_2012 | commercial passenger airline pilots | TST; sleep/wake | Quaternary | n/a |
| 229 | schulz\_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, quaternary 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 are called so as the former approach produces a binary outcome whereas the latter produces a confusion matrix. |  |  |  |  |  |

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