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Lighting for Circadian Health: Survey Module and Non-Invasive Open-Source Wearable Sensor System

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1. OBJECTIVES

This project had two primary objectives: (1) develop a lighting and circadian health module for CBE's Occupant IEQ survey for use as an ASHRAE/USGBC/CIBSE Performance Measurement Protocol for commercial building basic level assessment; and (2) conduct a feasibility study that looks into the strengths and weaknesses of using an open-source wearable sensor system that measures skin temperature (ST), illuminance levels, and user activity for possible use in an ASHRAE advanced level assessment.

2. BACKGROUND

In the last 25 years, lighting energy-efficiency and life-cycle cost have improved dramatically, but less attention has been given to improving lighting for human well-being and performance. Additionally, assessment tools have generally been developed based on a two category lighting and human health model: visual health (e.g. glare and flicker) and perceptual health (i.e. the meaning that occupants give lit environments). A third category, circadian health, has recently been disambiguated and has yet to be absorbed in any assessment procedures. Such methods would focus on characterizing the influence of indoor lighting on sleep quality, a variable that has been tied to an extensive list of negative health impacts (e.g. immune system functions, obesity, cognitive performance, cancer, heart disease, dementia, and Alzheimers).

Juxtaposed to this, the need for standardizing performance measurement procedures has been collectively acknowledged by ASHRAE, USGBC, and the CIBSE. They recognized that, without a protocol that could be applied consistently across buildings, claims around “high performance,” “green,” and/or “low-energy” could not be substantiated. As such, in 2010, these three organizations released the Performance Measurement Protocols (PMP) for Commercial Buildings. Six performance categories were developed under a three-level structure: basic, intermediate, and advanced. They were meant to be deployed sequentially and setup to reinforce subsequent levels. This integrated approach was adopted to complement existing IEQ assessment methods such as CBE’s Occupant IEQ Survey, which today stands as the backbone of the basic level assessment. But whether at the basic or advanced level, current IEQ assessment protocols have yet to absorb issues around circadian health. Fortunately, several methods for evaluating

circadian effects already exist in the medical research community, in the form of sleep quality surveys and wearable sensor systems, such as Philips Respironics' Actiwatch, CamNtech Watch 8, and GENEActiv devices . However, these methods were developed for clinical settings and were not intended to characterize environmental parameters, specifically lighting, and/or patterns of user activity that would be needed in assessing IEQ.

4. METHODS

A variety of methods were used on this project. The first objective utilized a systematic literature review of 102 sleep quality scales and stakeholder interviews to the develop a specialty module for lighting and circadian health. The second objective utilized several methods that included: bench testing, surveying, and prototyping to explore the possibility of using a wearable platform in an advanced level IEQ assessment.

5. RESULTS

Survey Module: Literature Review

A multitude of sleep quality scales are currently in use for different purposes and target populations, from sleep apnea research focused on 5-13 year olds to Restless Leg Syndrome screening focused on adult hospital patients. Surveying the literature revealed circadian rhythm related scales are only one of many in use for evaluating sleep quality. Case in point, out of the 102 sleep quality scales reviewed, only six address circadian rhythmicity. Table 1 below provides a comparison of those six scales and their salient features. In all cases, scales are popular because they provide a quick assessment of complex situations. In just three to four minutes, an evaluator can come to a broad understanding of the individual's sleep-related condition. The following are insights from the literature review that are worth noting:

- Sleep quality scales generally serve as tools for research and/or clinical screening in hospitals. The latter contributes to diagnosis of sleep related disorders but is not a diagnosis in itself.
- Existing circadian rhythm scales focus on measuring subjective patterns around sleep but little or no attention is given to characterizing external factors influencing it, such as lighting parameters.
- The scales that include questions on lighting are ambiguous. They neither identify type of light source(s), the time of day in which the exposure occurs, intensity, nor duration.

| | Name | Purpose | Pop. | Admin. | Reliability & Validity |
|----|---|--|---------|--|--|
| 47 | Karolinska Sleepiness Scale (KSS) (Akerstedt and Gillberg 1990) | Designed to measure subjective level of situational sleepiness in the last 10 minutes. It is often used in assessing changes in environmental factors. | General | self-reported; 5 mins. | Validity was highly correlated to EEG and behavioral variables. |
| 66 | Pictorial Sleepiness Scale Based on Cartoon Faces (Maldonado et al. 2004) | Developed as an alternative to traditional subjective measures of sleepiness, this instrument address minimal literacy scales. | General | self-reported; pencil & paper; 3 mins. | Psychometric evaluation conducted by developers indicate high correlation with other scales. |

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| 89 | St. Mary's Hospital Sleep Questionnaire (Ellis 1981) | Designed to evaluate subjective quality over the duration over a study/treatment period, it is well suited for repeated use. | General ; 15-80 years of age | 14 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation conducted found test-retest range of good to excellent in reliability. |
| 91 | Stanford Sleepiness Scale (SSS) (Hoddes et al. 1972) | Designed as a subjective measure of sleepiness at a specific moment in time, the instrument is used both in research and clinical settings. | General | 1 item; self-reported; pencil & paper; 1-2 mins. | Though widely used in research settings, some have taken issue with the scale and its unidimensional quality. |
| 100 | Visual Analogue Scale to Evaluate Fatigue Severity (VAS-F) (Lee et al. 1991) | Designed to relate subjective experience of fatigue to sleep quality, this instrument uses a visual analogue scale. | Adults | 18 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluations demonstrated high internal reliability. |
| 102 | ZOGIM-A (Alertness Questionnaire) (Shapiro et al. 2006) | Created to efficiently and inexpensively evaluate alertness over the course of the day, it queries subjective impact of environmental factors. | General | 10 items; self-reported; pencil & paper; 5 mins. | Psychometric evaluation found an internal consistency ranging from .93 to .95. |

Table 1: Six sleep quality scales relevant to circadian rhythmicity and their Salient Features

The table of all 102 sleep quality scales compared can be referenced in the Appendix.

Survey Module: Stakeholder Interviews

We conducted stakeholder interviews with circadian rhythm researchers, and industry members (e.g. manufacturers and portfolio managers) to solicit general feedback on a lighting and circadian health survey module.

- **Researchers.** The consensus is that these class of surveys are best deployed as screening devices that contribute to diagnostics rather than methods for assessing interventions. The multitude of outside factors that cause distortion on outcomes are too many to account for in a short questionnaire. In clinical settings, assessing interventions are conducted by certified sleep specialists that use objective measurements, along with information gained from screening devices.
- **Industry Stakeholders.** A general emphasis was conveyed that any survey developed should be actionable and take survey fatigue into account. With regards to a specific lighting and circadian health module, the consensus was that the general topic is early in its maturity; as such, the building operator/portfolio manager deploying the survey may require additional background context to take action on results.

Survey Module: Development

Our initial plan was to develop this module to complement the existing format and language contained within the core survey. Fortunately, the "core" was going through an update this summer, so we were able to unify a format and language that could be used across all lighting related survey questions. In addition, background questions around ceiling height and age were suggested in the core update to better characterize both the building and user.

In general, the lighting and circadian health module was developed as a screening device to characterize patterns of user activity, light exposure, and sleep. It totals 17 questions, 12 primary + 4 conditional + 1 optional, and was designed to be administered in 5-10 minutes.

Wearable Platform: Preliminary Assessment

Wearable technologies are under the general classification of Internet of Things (IoT) and specifically fall under worn ubiquitous computing for use in daily life. The focus of this project was to evaluate the strengths and weaknesses of a wearable prototype currently in development by researchers at the Helen Wills Neuroscience Institute and CITRIS for our use in advanced level IEQ assessments. This particular novel prototype measures ST, along with visual light and activity, to shorten the time required to estimate circadian rhythm stability.



Figure 1: Prototype Wearable Platform, top view (L), bottom view (center), and worn (right).

In general, the inclusion of a third category of data, ST, is promising, as it would shorten the time required to estimate circadian rhythm stability, research suggests two days rather than seven (Smarr 2016). However, the existing platform has a major shortcoming that would make it difficult for use in IEQ assessments for circadian health. The existing photodiode based light sensor is weighted for visual light, something that is common in wearable platforms and IoT devices. As lighting influencing circadian rhythms was functionalized in 2014 under a non-visual spectral efficiency function, labeled equivalent melanopic lux (EML), the light sensing data from this wearable would be considered qualitative. In summary, this wearable as a conceptual platform that integrates ST is promising; however, the shortcoming in the light sensor renders this system currently inadequate for advanced level lighting IEQ assessments.

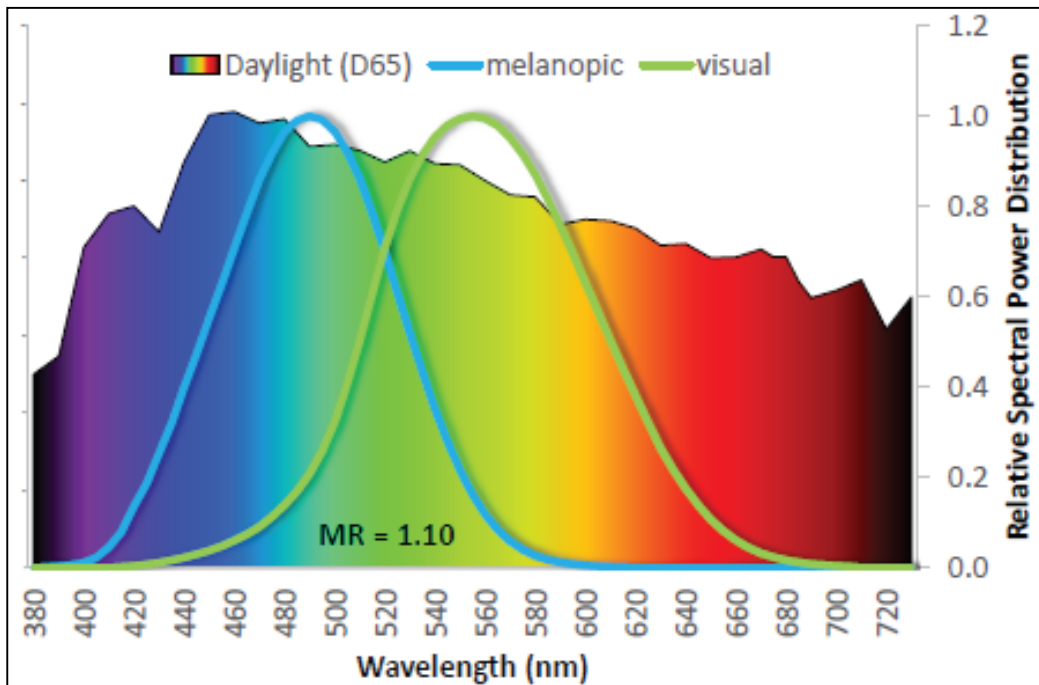


Figure 2: Visual and melanopic weighting function of daylight

Wearable Platform: Survey of Wearable Platforms

We surveyed wearable platforms currently available. This was done to explore possible solutions research groups or industry, have considered. Only two wearable platforms were found that made attempts to address this shortcoming in light sensing:

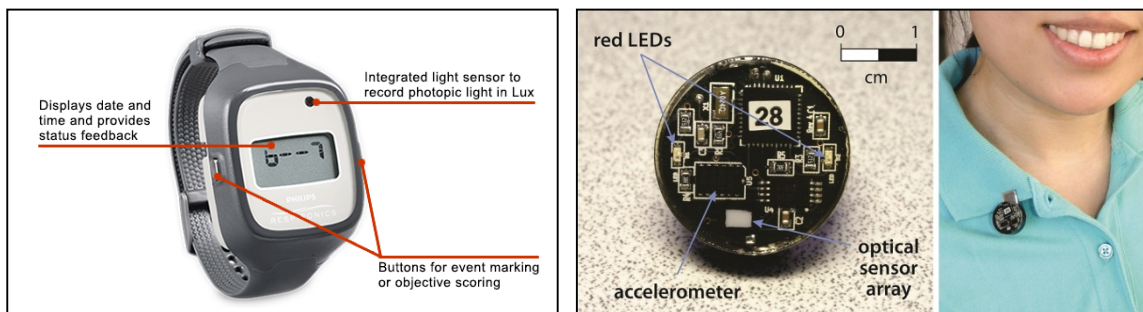


Figure 3: Actiwatch Spectrum (left) and Daysimeter (right)

- Actiwatch Spectrum.** This is a medical grade platform currently available through Philips Respironics. It uses three photodiodes (labelled red, blue, and green) with the intention to control confounding from light sources with different correlated color temperatures (CCT). As it is not calibrated to any known reference standard, the light sensing data from this device remains qualitative. Additionally, calibration reports conducted by the Danish Building Research Institute indicate a significant amount of inter-equipment variability. There side by side calibration test of 48 devices reported a ~60% variability (Markvart 2015).
- Daysimeter.** This research platform was developed by the Lighting Research Center at the Rensselaer Polytechnic Institute (RPI) and is not currently available for purchase. The platform uses three photodiodes (labelled red, blue, and green) as a way of controlling for

possible confounding from light sources with varying spectral power distributions. Though their sensors are calibrated to their own standard, labelled circadian stimulus, there is some concern, as it is a competing standard not often used by researchers outside of RPI.

| | Name | Use Category | Pros | Cons | Cost |
|---|---|--------------|---|---|--|
| 1 | Daysimeter by RPI (Figueiro 2013) | Research | -contains calibrated light sensors to measure different types of light sources | -calibration of light sensors are to a standard not often referenced by researchers outside of RPI -accuracy drops dramatically when measuring not commonly used white light sources | Not available for purchase. Can be lent out as part of research collaboration but may have significant cost implications |
| 2 | Actiwatch Spectrum by Philips Resperonics | Clinical | -analysis software is well developed and used extensively by sleep clinicians | -calibration of light sensors are set to an unknown standard -varying levels of accuracy dependent on light source being measured -field calibration studies suggest a significant level of inter-equipment variability | ~\$2,400 per unit w/out analysis software |
| 3 | Actiwatch 2 by Philips Resperonics | Clinical | -designed for extended use -analysis software is well developed and used extensively by sleep clinicians | -uses only a single photodiode weighted for visual light | ~\$1,800 per unit w/out analysis software |

Table 2: Three Wearable Platforms focused on sleep quality and their Salient Features

In summary, there are no viable options currently that address this shortcoming. Both platforms mentioned took the approach of using three readily available photodiodes as a way to measure the spectrum of light influencing circadian rhythms. One platform lacked a calibration to any known standard, while the other is generally not accessible for use and also calibrated to a competing standard not often used by researchers outside of RPI. In either case, a three photodiode approach focuses on using data from additional channels to control for error from light sources with varying spectral power distributions. This approach will affect accuracy between different light sources. For example, the Daysimeter is reported to hold error to less than 5% for most commonly used white light sources and up to ~19% for non-white light sources. A possible alternative approach worth looking into is a one photodiode solution. This would require a reengineering of the optical filter weighted for a reference standard, like EML.

Wearable Platform: Exploratory of One Photodiode Approach

We initiated conversations with International Lighting Technologies, an ISO 9001:2008 certified and ISO 17025:2005 accredited company that specializes in light measurement systems, specialty light sources, and LED lighting. This was done to explore the possibility of a one photodiode approach. As of this writing, bench testing of a handheld light meter and data logging prototypes

are in process and should conclude by end of October 2016. Beyond validating the possibility of a one photodiode approach, these two prototype tools could also support an intermediate level IEQ lighting assessment.



Figure 4: Photodiode-based handheld light meter and data logging device w/ optical filter engineered for EML.

6. CONCLUSIONS

The lighting and circadian health survey module was developed as a screening device that characterizes patterns of user activity, light exposure, and sleep. Totalling 17 questions, 12 primary + 5 conditional + 1 optional, it was designed to be administered in 5-10 minutes and intended for use as a basic level IEQ assessment tool for lighting and circadian health. The wearable platform, though promising as a potential advanced level assessment, requires further development. The shortcoming in the light sensing device could possibly be addressed by engineering an optical filter weighted for a melanopic efficiency function. We will be testing this one photodiode approach on handheld and logging radiometer/photometer devices in the coming weeks, as part of our next steps.

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8. APPENDIX

Summary Table of 102 Sleep Related Quality Scales (Shahid et al. 2012)

| | Name | Purpose | Population | Administration | Reliability & Validity |
|---|--|---|--------------------------------|---|--|
| 1 | Adolescent Sleep Habits Survey (KIDZZZSLEEP 2009) | Designed as a qualitative survey, it is predominantly used for clinical screening and not often used for research. | Adolescent; 9-17 years of age | 61-65 items; self-reported; pencil & paper; 20-30 mins. | The psychometric properties of the scale have not been analyzed |
| 2 | Adolescent Sleep-Wake Scale (LeBurgeois et al. 2005) | Designed to assess overall sleep quality, it measures 5 behavioral dimensions using a 6-point Likert type scale. | Adolescent; 12-18 years of age | 28 items; self-reported; pencil & paper; 10-15 mins. | Psychometric evaluation found good internal consistency and reliability. |
| 3 | Apnea Beliefs Scale (Smith et al. 2004) | Designed to link compliance and positive attitudes with obstructive sleep apnea (OSA), the instrument focuses around nine dimensions of belief around the disorder. | General | 24 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation found moderate internal reliability. |
| 4 | Apnea Knowledge Test (Smith et al. 2004) | Designed to assess the respondent's knowledge of OSA, it is administered before and after patient education programs. | General | 17 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation found low-moderate internal consistency. |
| 5 | Athen Insomnia Scale (AIS) (Soldatos et al. 2000) | Designed to assess the severity of insomnia, it uses the diagnostic criteria defined by the International Classification of Diseases (ICD-10). | Adults; 18-79 years of age | 8 items; self-reported; pencil & paper; 3-5 mins. | Psychometric evaluation found high internal consistency and reliability. |

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| 6 | Basic Nordic Sleep Questionnaire (BNSQ) (Partinen et al. 1995) | Designed as a standardized questionnaire to assess a variety of sleep complaints, it is part research instrument and part screening tool. | Adults | 27 items; self-reported/interview; pencil & paper; 5-10 mins. | No reliability or validity data has been made available. |
| 7 | BEARS Sleep Screening Tool (Owens et al. 2005) | Designed as a quick screening tool for primary school children, it covers bedtime issues, excessive daytime sleepiness, night awakenings, regularity and duration of sleep/snoring. | Children; 2-12 years of age | 5 items; clinical interview; varies | Not yet evaluated for its psychometric properties. |
| 8 | Beck Depression Inventory (Vandeputte et al. 2003) | Designed to rate the severity of respondents' level of depression connected to sleep quality, it is used to diagnose and treat sleep disorders. | General; 13-80 years of age | 21 items; self-reported/interview; pencil & paper; 5-10 mins. | Psychometric evaluation found high internal consistency. |
| 9 | Behavioral Evaluation of Disorders of Sleep (BEDS) (Schreck et al. 2003) | Designed to evaluate the presence of four distinct types of sleep problems in elementary-school-aged children, this instrument is used for research purposes and not qualified clinical diagnosis. | Children; 5-12 years of age | 28 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation found good internal consistency. |
| 10 | Berlin Questionnaire (Chung et al. 2008) | Designed to identify individuals at high risk for sleep apnea, the instrument can be used both for clinical screening or research tool for recording risk factors. | Adults; patients 18 years of age and older | 11 items; self-reported; pencil & paper; 5-10 mins.; optional biometric measurements | The sensitivity and efficacy of measures are variable enough to make clinical benefits unlikely. |
| 11 | Brief Fatigue Inventory (Mendoza et al. 1999) | Designed to quickly assess the severity of fatigue, this instrument focuses on the experience of cancer patients before, during, and after treatment. | General; cancer patients | 9 items; self-reported/interview; pencil & paper; 2-3 mins. | Psychometric evaluation found high validity and consistency. |
| 12 | Brief Infant Sleep Questionnaire (BISQ) (Sadeh et al. 2004) | Designed to serve as a screening tool in a variety of pediatric settings, it is both used for clinical and research purposes. | Infants; 0-3 years of age | 18 items; parent-reported; pencil & paper; 5-10 mins. | High test-retest correlations were found |

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| 13 | Brief Pain Inventory (BPI) (Tittle et al. 2003) | Designed to query the relationship between pain and other impacts factors (one of them being sleep), it is used both in research and clinical settings. | General; pain sufferers | 12 items; self-reported/interviewed; pencil & paper; 5 mins. | Psychometric evaluation found high reliability and consistency. |
| 14 | Calgary Sleep Apnea Quality of Life Index (SAQLI) (Flemons and Reimer 1998) | Designed to evaluate four domains of quality of life associated with sleep apnea, it's often used to monitor efficacy of different apnea treatments. | General; sleep apnea sufferers | 35 items; clinician interviewed; pencil & paper; 10-15 mins. | Psychometric evaluation found good reliability and validity. |
| 15 | Cataplexy Emotional Trigger Questionnaire (CETQ) (Moore et al. 2007) | Designed to be a very brief measure of cataplexy, it was inspired by observations of muscle weakness during laughter. | Adults; 20-84 years of age; narcolepsy patients | 5 items; self-reported/interviewed; pencil & paper; 2 mins. | During validity testing, this 51 item questionnaire was reduced to 3 as it was sufficient for reliability. |
| 16 | Center for Epidemiological Studies Depression Scale for Children (CES-DC) (Ivanenko et al. 2005) | Designed to screen for depression in children, it uses a Likert-type scale to connect sleep/fatigue with outcomes. | Children; 6-23 years of age | 20 items; self-reported; pencil & paper; 5 mins. | Psychometric evaluation found good internal consistency and sensitivity. |
| 17 | Chalder Fatigue Scale (Chalder et al. 1993) | Designed to measure the severity of fatigue in adults, it is used both in clinical and research settings. | Adults; 18-45 years of age | 14 items; self-reported/interviewed; pencil & paper; 3-5 mins. | Psychometric evaluation found good internal consistency and validity. |
| 18 | Child Behavior Checklist (CBCL), 1.5 - 5 (Chervin et al. 1997) | Designed to evaluate behavioral problems and competencies in young children, several items relate directly to sleep issues/problems. | Young children; 1.5-5 years of age | 99 items; parent-reported; pencil & paper; 15-20 mins. | Studies assessing the psychometric properties have been numerous and have included cross-cultural correlation. |
| 19 | Child Behavior Checklist (CBCL), 6 - 18 (Ohayon et al. 1998) | Designed to evaluate behavioral problems and competencies in children and young adults, several items relate directly to sleep issues/problems. | Young children; 6-18 years of age | 99 items; parent-reported; pencil & paper; 15-20 mins. | Studies assessing the psychometric properties have been numerous and have included cross-cultural correlation. |

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| 20 | Children's Morningness-Eveningness Scale (Carskadon et al. 1993) | Designed to evaluate circadian rhythms shifts that occur between childhood and adolescence, it examines sleep-schedule inclinations and subjective experiences of fatigue and alertness. | Adolescents; 12-16 years of age | 10 items; self-reported, pencil & paper; 3-5 mins. | Internal psychometric evaluation found a significant correlation between scaled results and sleep/rise schedules. |
| 21 | Children's Sleep Habits Questionnaire (CSHQ) (Owens et al. 2000) | Designed for screening for sleep problems in children, it also provides other useful information about respondents. | Children; 4-12 years of age | 33 items; parent-reported, pencil & paper; 10-15 mins. | Psychometric evaluation found good internal consistency and test re-test reliability. |
| 22 | Circadian Type Inventory (CTI) (Fokard and Monk 1979) | Developed to identify individuals capable of adapting to shift work, the scale focuses on two factors: rigidity/flexibility of sleeping habits and ability/inability of overcome drowsiness. | Adults; shift workers | 30 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation found moderate internal consistency. |
| 23 | Cleveland Adolescent Sleepiness Questionnaire (CASQ) (Spilsbury et al. 2007) | Designed to evaluate adolescent experiences of sleepiness and alertness, the instrument focuses around school settings, home during evening, and transit in between. | Adolescents; 11-17 years of age | 16 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation found high internal consistency. |
| 24 | Columbia-Suicide Severity Rating Scale (C-SSRS) (Gangwisch and Jacobson 2009) | Designed to provide standardized measure of suicidality, it allows both clinicians and researchers to assess the severity and lethality to monitor treatment and assess risk. | General | 14 items; self-reported/interviewed; pencil & paper; 5 mins. | Has not been validated, but was developed as a counterpart to Columbia's Classification Algorithm for Suicide Assessment. |
| 25 | Composite Morningness Questionnaire (Smith et al. 1989) | Developed using factor analysis to address gaps in existing questionnaires, this instrument focuses on morning activities, morning affect, and eveningness. | General | 13 items; self-reported; pencil & paper; 3-5 mins. | Psychometric evaluation found good internal consistency. |

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| 26 | CPAP Use Questionnaire (Olsen et al. 2010) | Designed to assess "cues to action" -- that can affect patients' perceptions of CPAP, the scale evaluates the utility in predicting CPAP compliance. | General; CPAP users | 9 items; self-reported; pencil & paper; 2-5 mins. | Due to the novelty of such a scale, constructing validity could not be fully assessed. |
| 27 | Depression and Somatic Symptoms Scale (DSSS) (Hung et al. 2006) | Developed as a simultaneous measure of depression and somatic symptoms, this instrument specifically is concerned with the relationship between the two. | Adults; 18-65 years of age; patients w/ major depressive episodes | 22 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation found good internal consistency. |
| 28 | Dysfunctional Beliefs and Attitudes about Sleep Scale (DBAS) (Morin et al. 1993) | Designed to evaluate sleep-related beliefs, the scale may be valuable in the formation of cognitive approaches to treatment. | General; 55-88 years of age | 28 items; self-reported; pencil & paper; 10-15 mins. | Psychometric evaluation shows high internal consistency. |
| 29 | Epworth Sleepiness Scale (ESS) (Johns 1991) | Designed to evaluate overall daytime sleepiness, it focuses on rating how likely individuals are to fall asleep under different situations. | Adults; 18-78 years of age | 9 items; self-reported; pencil & paper; 2-5 mins. | |
| 30 | Espie Sleep Disturbance Questionnaire (SDQ) (Espie et al. 1989) | Designed to evaluate subjective experiences of insomnia, it focuses on 4 specific areas: restlessness, mental over activity, consequences, and sleep readiness. | Adults; insomniac patients | 12 items; self-reported; pencil & paper; 3-5 mins. | |
| 31 | FACES (Fatigue, Anergy, Consciousness, Energy, Sleepiness) (Shapiro et al. 2002) | Designed to distinguish between tiredness, sleepiness, and fatigue using a adjectival checklist, it focuses on experiences relating to states of energy deficiency. | General; insomniac patients | 50 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation found good internal consistency. |
| 32 | Fatigue Assessment Inventory (FAI) (Schwartz et al. 1993) | Designed to evaluate four domains of fatigue, it surveys severity, pervasiveness, associated consequences, and response to sleep. | General; fatigued patients | 29 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation found good internal consistency. |

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| 33 | Fatigue Assessment Scale (FAS) (Michielsen et al. 2003) | Designed to evaluate symptoms of chronic fatigue, its uni-dimensional construct is meant to represent both physical and mental symptoms. | General; fatigued patients | 10 items; self-reported, pencil & paper; 2 mins. | Psychometric evaluation found high internal consistency and reliability. |
| 34 | Fatigue Impact Scale (FIS) (Fisk et al. 1994) | Developed to assess the symptoms of fatigue, it focuses on characterizing the underlying chronic disease or condition. | Adults; fatigued patients | 40 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation found good internal consistency. |
| 35 | Fatigue Severity Scale (FSS) (Kleinman et al. 2000) | Designed to assess fatigue as a symptom, the scale measures its relationship to motivation, physical activity, work, family, and social life. | Adults; fatigued patients | 9 items; self-reported; pencil & paper; 2-3 mins. | Psychometric evaluation found good internal consistency. |
| 36 | Fatigue Symptom Inventory (FSI) (Hann et al. 1998) | Designed to evaluate multiple aspects of fatigue, it measures perceived severity, frequency, and interference with daily activity. | Adults | 14 items; self-reported; pencil & paper; 5-10 mins. | Psychometric properties found an excellent internal consistency. |
| 37 | FibroFatigue Scale (Zachrisson et al. 2002) | Designed to measure the fatigue severity of symptoms in fibromyalgia patients, this instrument uses an observer rated scale. | Adults; fatigued fibromyalgia patients | 12 items; self-reported; pencil & paper; 10-15 mins. | Psychometric evaluation found excellent reliability. |
| 38 | Frontal Lobe Epilepsy and Parasomnias (FLEP) Scale (Derry et al. 2006) | Designed to aid clinicians in distinguishing frontal lobe seizures from parasomnias, this scale is intended for efficient, cost-effective alternatives to more elaborate diagnosis methods. | General; patients experiencing unknown nocturnal episodes | 11 items; interviewed by trained admin.; 10 mins. | Psychometric evaluation, reliability, and sensitivity were all found excellent. |
| 39 | Functional Outcomes of Sleep Questionnaire (FOSQ) (Chasens et al. 2009) | Designed to evaluate respondent's quality of life as it relates to disorders of excessive sleepiness, it focuses on effects of fatigue on daily activities. | Adults; suffering from sleep disorders | 30 items; self-reported; pencil & paper; 10-15 mins. | Psychometric study demonstrated a high internal reliability. |

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| 40 | General Sleep Disturbance Scale (GSDS) (Lee 1992) | Designed to evaluate the incidence and nature of sleep disturbances in employed women, it focuses on questions pertain to a variety of general sleep issues. | Adult females | 21 items; self-reported; pencil & paper; 5-10 mins. | Initial psychometric evaluations found good internal consistency. |
| 41 | Glasgow Content of Thoughts Inventory (GCTI) (Harvey 2004) | Developed to evaluate the content, character, and intrusiveness of cognitions in adults in the moments prior to sleep onset, it focuses on assessing processes of individuals with insomnia. | Adults: sufferers of insomnia | 25 items; self-reported; pencil & paper; 5-10 mins. | Have been validated on a variety of psychometric measures. |
| 42 | Hamilton Rating Scale for Depression (HAM-D) (Hamilton 1960) | Designed to evaluate depression in adults, this questionnaire is one of the most frequently used by clinicians to assess the nature and severity of mood disorders. | Adults; major depressive disorder patients | 21 items; interview conducted by trained clinician; 10-15 mins. | Psychometric properties have been examined in a wide array of studies since its creation by Hamilton in 1960 |
| 43 | Insomnia Severity Index (ISI) (Bastien 2001) | Designed as a screening tool for insomnia, it asks to rate the nature and symptoms of their sleep problems. | Adults; 17-84 years of age | 7 items; self-reported; pencil & paper; 5 mins. | Psychometric evaluations found moderate internal consistency and correlation to be highly variable. |
| 44 | International Restless Legs Syndrome Study Group Rating Scale (Walters et al. 2003) | Designed to assess the severity of Restless Legs Syndrome (RLS), it focuses on how acutely the disorder affects respondent over the course of a week. | Adults; RLS patients | 10 items; self-reported; pencil & paper; 5-10 mins. | Psychometric studies show excellent internal consistency and reliability. |
| 45 | Jenkins Sleep Scale (Jenkins 1988) | Designed as an efficient and quick instrument for use in research and clinical screening, the instrument evaluates certain sleep difficulties in respondents. | Adults | 4 items; self-reported/interviewed; pencil & paper; 2-5 mins. | Initial psychometric analysis showed a moderate internal consistency. |
| 46 | Johns Hopkins Restless Legs Severity Scale (JHRLSS) (Allen and Early 2001) | Designed to be used by trained clinicians for quick screening, it is also useful for longitudinal research to evaluate treatment outcomes. | Adults; RLS patients | 5 items; interviewed by trained clinician; 5-10 mins. | Psychometric properties demonstrate excellent reliability. |

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| 47 | Karolinska Sleepiness Scale (KSS) (Akerstedt and Gillberg 1990) | Designed to measure subjective level of sleepiness at a particular time during the day, this scale is a measure of situational sleepiness in the last 10 mins. and is often used in assessing changes in response to environmental factors. | General | self-reported; 5 mins. | Validity was highly correlated to EEG and behavioral variables. |
| 48 | Leeds Sleep Evaluation Questionnaire (LSEQ) (Parrott and Hindmarch 1978) | Designed to assess changes in sleep quality over the course of a treatment intervention, it is often used in assessing psychopharmacological. | Adults | 10 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation was conducted through correlated studies of other wakefulness-based scales. |
| 49 | Maastricht Vital Exhaustion Questionnaire (MQ) (Appels et al. 1987) | Designed to assess feelings of "vital exhaustion" prior to myocardial infarction, the scale can help predict future coronary events. | General | 21 items; self-reported; pencil & paper; 5-10 mins. | Initial validation was found to possess a high internal consistency. |
| 50 | Medical Outcomes Study Sleep Scale (MOS-SS) (Hays and Stewart 1992) | Developed to evaluate the health status of a large population, it is part of a larger patient assessment questionnaire. | Adults | 12 items; self-reported; pencil & paper; 5 mins. | Psychometric evaluation indicates moderate internal consistency. |
| 51 | Mini-Mental State Examination (MMSE) (Folstein et al. 1975) | Designed as a simplified version to assess cognitive mental status, this instrument accommodates patients who cannot maintain attention for long periods. | Elderly; dementia, or delerium patients | 11 items; interviewed by trained admin.; 10-15 mins. | Psychometric evaluation showed high reliability. |
| 52 | Modified Checklist for Autism in Toddlers (M-CHAT) (Johnson 1996) | Designed to screen/access the risk for autism spectrum disorders (ASD), it focuses on behavioral reports of parents to make it easily deployable. | Toddlers | parent-reported; 5-10 mins. | Psychometric evaluation shows good internal reliability, sensitivity, and predictive power. |

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| 53 | Mood Disorder Questionnaire (MDQ) (Hirschfeld 2000) | Designed to screen for bipolar spectrum disorders using DSM-IV criteria, it uses sleeping behavior as 1 of 6 manifestations of mania. | Adults | 13 items; self-reported; pencil & paper; 3-5 mins. | Psychometric evaluation shows excellent internal consistency. |
| 54 | Morningness-Eveningness Questionnaire (Horne 1976) | Designed to assess individual differences in morningness and eveningness, it scales the degree of activity and alertness at certain times of the day. | Adults | 19 items; self-reported; pencil & paper; 10-15 mins. | Psychometric evaluation shows moderate correlation with biometrics. |
| 55 | Motivation and Energy Inventory (MEI) (Fehnel 2004) | Designed to assess fatigue and lassitude, this instrument focuses on measuring motivation and energy in patients with depression to improve intervention effectiveness. | Adults | 27 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation shows moderate to good internal consistency. |
| 56 | Multidimensional Dream Inventory (MDI) (Kallmeyer and Chang 1997) | Designed to assess individual differences in four separate domains of dream experience, it functions as a tool for "studying the consequences and correlates of dreams." | Adults | 12 items; self-reported; pencil & paper; 3-5 mins. | Psychometric evaluation shows moderate internal consistency. |
| 57 | Multidimensional Fatigue Inventory (MFI) (Smets et al. 1995) | Designed to evaluate 5 dimensions of fatigue, it was developed as a research tool to better characterize fatigue. | Adults | 20 items; self-reported; pencil & paper; 5 mins. | Psychometric evaluation shows low to moderate internal consistency. |
| 58 | Munich Chronotype Questionnaire (MCTQ) (Roennebert et al. 2003) | Developed to assess individuals' chronotypes, it is used primarily in research settings to investigate how types relate to age, sex, and external environment. | Adults | 19 items; self-reported; web based questionnaire; 5-10 mins. | Psychometric evaluation through large scale correlated studies indicates high reliability. |
| 59 | Normative Beliefs About Aggression Scale (Huesmann et al. 1992) | Developed to study attitudes towards aggression in children and young adults, it relates sleep disturbances to behavioral issues. | Adults; 6-30 years of age | 20 items; interviewed by trained admin.; 5-10 mins. | Psychometric evaluation shows moderate to good internal consistency. |

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| 60 | Parkinson's Disease Sleep Scale (PDSS) (Chaudhuri et al. 2002) | Designed to evaluate sleep quality of individuals with Parkinson's, the instrument is used primarily in research. | Adults; Parkinson's patients | 15 items; self-reported; pencil & paper; 5 mins. | Psychometric evaluation found excellent test-retest reliability. |
| 61 | Pediatric Daytime Sleepiness Scale (PDSS) (Drake 2003) | Designed to evaluate subjective experiences of daytime sleepiness of young students, the instrument is predominantly used in research. | Children; 11-15 years of age | 8 items; self-reported; pencil & paper; 3-5 mins. | Psychometric evaluation conducted demonstrated a moderate internal consistency. |
| 62 | Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale (Varni 2002) | Developed to evaluate subjective experiences of fatigue, it borrows protocols from other versions of PedsQL that focus on other health-related quality measures. | Children; 2-18 years of age | 18 items; self-reported/parent completed; pencil & paper; 10-15 mins. | Psychometric evaluation conducted by developers demonstrated a moderate to high internal consistency. |
| 63 | Pediatric Sleep Questionnaire (PSQ) (Chervin 2000) | Designed to evaluate sleep-disordered breathing (SDB) in children, the instrument is predominantly used as a screening tool. | Children; 2-18 years of age | 22 items; self-reported/parent reported; 5-10 mins. | Psychometric evaluation conducted by developers shows moderate to good internal consistency. |
| 64 | Perceived Stress Questionnaire (PSQ) (Levenstein et al. 1993) | Developed to assess the stressful life events and circumstances that trigger or exacerbate disease symptoms, it focuses on connecting stress and the quality and consistency of the sleep cycle. | General | 30 items; self-reported; pencil & paper; 10-15 mins. | Psychometric evaluation conducted by developers show excellent internal consistency. |
| 65 | Personal Health Questionnaire (PHQ) (Rizzo 2000) | Developed to screen for depression, this instrument was designed as a simple and inexpensive tool for clinicians. | Adults | 10 items; self-reported; pencil & paper; 5 mins. | Psychometric evaluations conducted by developers indicate low to moderate test-retest reliability. |
| 66 | Pictorial Sleepiness Scale Based on Cartoon Faces (Maldonado et al. 2004) | Developed as an alternative to traditional subjective measures of sleepiness, this instrument address minimal literacy scales. | General | self-reported; pencil & paper; 3 mins. | Psychometric evaluations conducted by developers indicate high correlation with |

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| | | | | | other scales. |
| 67 | Pittsburgh Sleep Quality Index (PSQI) (Buysse et al. 1989) | Designed to evaluate psychiatric disorders connected through sleep disorders, it is predominantly used in clinical settings. | General; patients with psychiatric disorders | 19 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation conducted found good initial internal reliability. |
| 68 | Profile of Mood States (POMS) (Terry et al. 1999) | Designed to evaluate individuals during treatment, the scale measures affective mood domains. | Adults | 65 items; self-reported, pencil & paper; 5-10 mins. | Psychometric evaluation conducted found good to excellent internal consistency. |
| 69 | Psychosocial Adjustment to Illness Scale (PAIS) (Derogatis 1986) | Designed to assess the social and psychological factors associated with living with an illness, this instrument is meant to evaluate functioning related to illness adjustment. | General; patient with illness | 46 items; interviewed by trained clinician; self-reported, pencil & paper; 20-30 mins. | Psychometric evaluation conducted found a wide internal consistency. |
| 70 | Quebec Sleep Questionnaire (QSQ) (Lacasse 2004) | Designed to assess health-related quality of life in patients with obstructive sleep apnea, the instrument was developed for use in clinical trials to evaluate treatment-induced changes. | General; sleep apnea patients | 32 items; self-reported; pencil & paper; 10-15 mins. | Psychometric evaluation conducted found excellent internal test-retest consistency. |
| 71 | Resistance to Sleepiness Scale (RSS) (Violani et al. 2003) | Designed to query involuntary experiences of somnolesence, this scale assesses daytime sleepiness by rating individuals likelihood of falling asleep. | Adults; 18-71 years of age | 12 items; self-reported; pencil & paper; 5 mins. | Psychometric evaluation conducted found excellent internal consistency. |
| 72 | Restless Legs Syndrome Quality of Life Questionnaire (RLSQoL) (Abetz 2005) | Designed to assess quality of life of patients with restless legs syndrome (RLS), the instrument connects sleep quality with daily activity. | Adults; patients with RLS | 18 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation conducted by developers found excellent internal consistency. |

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| 73 | Richards-Campbell Sleep Questionnaire (RCSQ) (Richards et al. 2000) | Designed as an outcome measure for assessing the perception of sleep in critically ill patients, the scale characterizes various sleep quality parameters. | Adults; critical care patients | 5 items; self-reported; pencil & paper; 2 mins. | Psychometric evaluation conducted shows high internal consistency. |
| 74 | School Sleep Habits Survey (Wolfson 1998) | Designed to assess the sleep-wake habits of high school students, this instrument is a thorough method of evaluating sleep habits and daytime functioning. | Children; high school students | 63 items; self-reported; pencil & paper; 20 mins. | This is a general survey designed for data collection and not diagnostic or evaluative purposes. |
| 75 | Self-Efficacy Measure for Sleep Apnea (SEMSA) (Weaver et al. 2003) | Developed in response to research indicating cognitive factors ability to significantly predict compliance with continuous positive airway pressure (CPAP), the instrument measures efficacy levels. | Adults; patients using CPAP | 26 items; self-reported; pencil & paper; 15 mins. | Psychometric evaluation conducted found high internal consistency. |
| 76 | SF-36 Health Survey (McHorney 1994) | Designed to assess functional health and well-being in a variety of populations, it was developed to assess treatment outcomes. | Adults | 36 items; self-reported/interviewed; pencil & paper/online; 5-10 mins. | Psychometric evaluation conducted found good internal consistency. |
| 77 | Sleep-50 Questionnaire (Spoomaker et al. 2005) | Designed to screen for a variety of sleep disorders in the general population, the instruments focuses on impact of sleep complaints on daily functions. | Adults | 50 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation conducted found good internal consistency. |
| 78 | Sleep Beliefs Scale (SBS) (Adan et al. 2006) | Designed to be a simplified version of the Sleep Hygiene Awareness and Practice Scale, it assesses the beliefs and attitudes of respondents. | Adults | 20 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation demonstrated moderate internal consistency. |
| 79 | Sleep Disorders Inventory for Students - Adolescent Form (SDIS-A) (Luginbuehl | Designed to screen for a variety of sleep disorders in adolescents, the instrument is brief and not a substitute for clinical diagnosis. | Adolescent | 35 items; interviewed; pencil & paper; 5 mins. | Psychometric evaluation found predictive validity of 96%. |

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| | 2003) | | | | |
| 80 | Sleep Disorders Inventory for Students - Children's Form (SDIS-C) (Luginbuehl 2003) | Developed as a screening tool for sleep disorders in children, the instrument is not meant to be substituted for clinical diagnosis. | Children; 2-18 years of age | 30 items; parent-reported; pencil & paper; 10-15 mins. | Psychometric evaluation found predictive validity of 86%. |
| 81 | Sleep Disorders Questionnaire (SDQ) (Douglas et al. 1986) | Designed to identify populations with high risk for possessing a sleep disorder, the instrument was created by selecting the best and most salient questions from the Sleep Questionnaire and Assessment of Wakefulness (SQAW). | General | 45 items; self-reported; pencil & paper; 15 mins. | Psychometric evaluation found average test-retest reliability. |
| 82 | Sleep Disturbance Scale for Children (SDSC) (Bruni et al. 1996) | Designed both to evaluate specific sleep disorders in children and provide overall measure of sleep disturbance in clinical and research settings, it uses factor analysis in characterizing 6 categories of sleep disturbance. | Children; 6-15 years of age | 26 items; parent-reported; pencil & paper; 10-15 mins. | Psychometric evaluation found moderate internal consistency. |
| 83 | Sleep Locus of Control Scale (SLOC) (Vincent 2004) | Designed to evaluate a respondents sleep-related locus of control to sleep, this research instrument attempts to connect internally oriented beliefs and sleep responsibility. | Adults; insomnia patients | 8 items; self-reported; pencil & paper; 3-5 mins. | Psychometric evaluation found internal consistency wide ranging. |
| 84 | Sleep Preoccupation Scale (SPS) (Ellis 2007) | Designed to assess daytime cognitions in patients with insomnia, this research instrument focuses on characterizing daytime beliefs about sleep. | Adults; insomnia patients | 22 items; self-reported; pencil & paper; 10-15 mins. | Psychometric evaluation found excellent reliability. |
| 85 | Sleep Quality Scale (SQS) (Yi et al. 2006) | Designed to evaluate 6 domains of sleep quality, it was meant to be an all-inclusive assessment tool. | General | 28 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation conducted found excellent internal consistency. |

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| 86 | Sleep Timing Questionnaire (STQ) (Monk 2003) | Designed to gain an accurate sketch of an individual's typical sleep schedule, the instrument functions as a quick alternative to a sleep diary. | Adults | 18 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation conducted found a moderate to good test-retest range. |
| 87 | Sleep-Wake Activity Inventory (SWAI) (Rosenthal et al. 1993) | Designed to screen for excessive daytime sleepiness in a clinical setting, this instrument is an inexpensive method for assessment. | General | 59 items; self-reported; pencil & paper; 10-15 mins. | Psychometric validations demonstrated a moderate to excellent range for internal consistency. |
| 88 | Snore Outcomes Survey (SOS) (Gliklich and Wang 2002) | Designed to evaluate sleep-related quality of life in patients with sleep-disordered breathing (SDB), the instrument may be useful in measuring changes in quality of life connected to snoring. | Adults; patients with SDB | 8 items; self-reported; pencil & paper; 5 mins. | Psychometric development found test-retest reliability to be high to excellent. |
| 89 | St. Mary's Hospital Sleep Questionnaire (Ellis 1981) | Designed to evaluate subjective quality over the duration over a study/treatment period, it is well suited for repeated use. | General; 15-80 years of age | 14 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation conducted found test-retest range of good to excellent in reliability. |
| 90 | State-Trait Anxiety Inventory (STAI) (Spielberger et al 1983) | Designed to measure two aspects of anxiety, it is both a widely used research and clinical tool, the instrument focuses on connecting anxiety problems with sleep quality. | Adults; 19-69 years of age | 40 items; self-reported; pencil & paper; 10-15 mins. | Studies suggest reliability and internal consistency to be excellent. |
| 91 | Stanford Sleepiness Scale (SSS) (Hoddes et al. 1972) | Designed as a subjective measure of sleepiness at a specific moment in time, the instrument is used both in research and clinical settings. | General | 1 item; self-reported; pencil & paper; 1-2 mins. | Though widely used in research settings, some have taken issue with the scale and its uni-dimensional quality. |

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| 92 | STOP-Bang Questionnaire (Farney et al. 2011) | Designed to screen symptoms of obstructive sleep apnea (OSA) in surgical patients, the instrument is specific to preoperative settings. | General; surgical patients | 5 items; self-reported; pencil & paper; 1 min. | This questionnaire possesses both excellent sensitivity and specificity. |
| 93 | Tayside Children's Sleep Questionnaire (TCSQ) (McGreavey et al. 2005) | Designed to assess disorders of initiating and maintaining sleep (DIMS) in children, TCSQ consists of 10 parent-reported items connected to sleep onset. | Children; 1-5 years of age | 10 items; parent-reported; pencil & paper; 5 mins. | Psychometric evaluation found good internal consistency. |
| 94 | Teacher's Daytime Sleepiness Questionnaire (TDSQ) (Owens et al. 2000) | Developed to assess evidence of sleep disturbances in children, the instrument focuses on observations made from teachers. | Children; 4-11 years of age | 15 items; teacher-reported; pencil & paper; 3-5 mins. | Psychometric evaluations have not been conducted. |
| 95 | Time of Day Sleepiness Scale (TODSS) (Dolan et al. 2009) | Constructed using items taken from the Epworth Sleepiness Scale, the instrument is a more efficient measure of assessment. | Adults | 8 items; self-reported; pencil & paper; 5 mins. | Psychometric evaluation found excellent internal consistency. |
| 96 | Toronto Hospital Alertness Test (THAT) (Shapiro et al. 2006) | Designed as a brief instrument to assess several psychological states relating to alertness, it acts similar to a sleep latency test. | Adults; patients with sleep disorders | 10 items; self-reported; pencil & paper; 5 mins. | Psychometric evaluation demonstrated excellent internal consistency. |
| 97 | Twenty-Item Toronto Alexithymia Scale (TAS-20) (Bagby et al. 1994a) | Developed as a revised measure to test domains of alexithymia, it is best used for identifying underlying causes of sleep complaints. | Adults | 20 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluation showed good internal consistency. |
| 98 | Ullanlinna Narcolepsy Scale (UNS) (Hublin et al. 1994) | Designed to evaluate variety of symptoms relating to narcolepsy, this instrument has demonstrated a high specificity. | Adults | 11 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluations demonstrated excellent specificity. |

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| 99 | Verran and Synder-Halpern Sleep Scale (VSH) (Snyder-halpern and Verran 1987) | Developed to assess subjective sleep quality of hospitalized individuals, this new version has not yet been validated. | Adults; patients with sleep difficulties | 14 items; self-reported; pencil & paper; 10-15 mins. | A validation study demonstrated good internal consistency. |
| 100 | Visual Analogue Scale to Evaluate Fatigue Severity (VAS-F) (Lee et al. 1991) | Designed to relate subjective experience of fatigue to sleep quality, this instrument uses a visual analogue scale. | Adults | 18 items; self-reported; pencil & paper; 5-10 mins. | Psychometric evaluations demonstrated high internal reliability. |
| 101 | Women's Health Initiative Insomnia Rating Scale (Levin et al. 2003) | Designed to evaluate insomnia symptoms, this instrument focuses on connecting sleep quality and sleep problems with postmenopausal women. | Adults; Postmenopausal women | 5 items; self-reported; pencil & paper; 3-5 mins. | Psychometric evaluation found internal consistency ranging from .70 to .85. |
| 102 | ZOGIM-A (Alertness Questionnaire) (Shapiro et al. 2006) | Created to efficiently and inexpensively evaluate alertness over the course of the day, it queries subjective impact of environmental factors. | General | 10 items; self-reported; pencil & paper; 5 mins. | Psychometric evaluation found an internal consistency ranging from .93 to .95. |