8 (2) | 2021

UMEDICAL REPORTS

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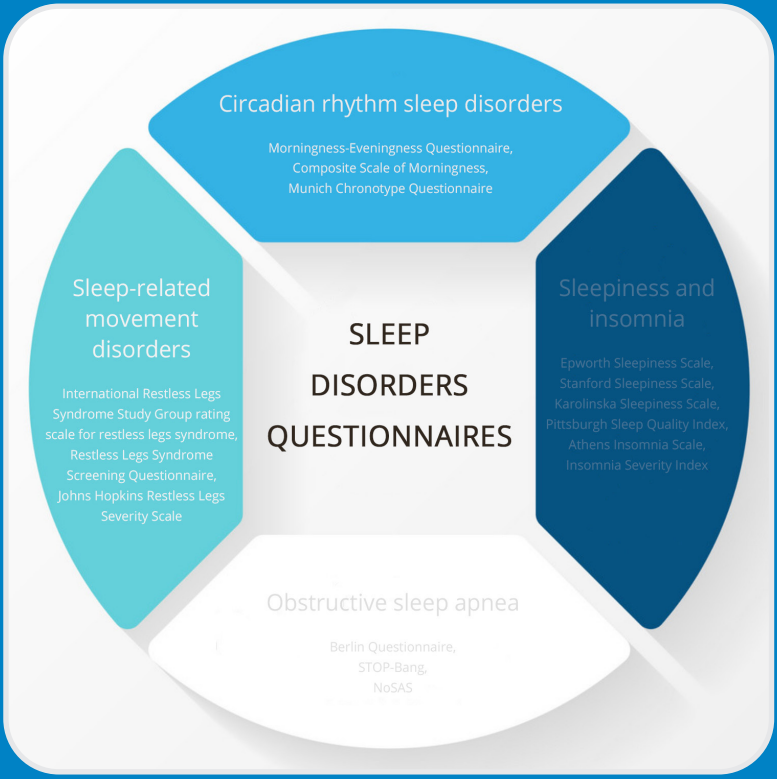

Wydawnictwo Uniwersytetu Medycznego w Łodzi

ŁÓDŹ 2021

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QUESTIONNAIRES FOR SLEEP DISORDER ASSESSMENT. PART II: SLEEP-RELATED MOVEMENT DISORDERS AND CIRCADIAN RHYTHM SLEEP DISORDERS

KWESTIONARIUSZE DO OCENY ZABURZEŃ SNU. CZĘŚĆ II: ZABURZENIA RUCHOWE W TRAKCIE SNU I ZABURZENIA CYKLU OKOŁODOBOWEGO

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Wydawnictwo Uniwersytetu Medycznego w Łodzi ŁÓDŹ 2021

UMEDICAL REPORTS 8 (2) | 2021

Seria monografii naukowych dotyczących zagadnień z zakresu dyscyplin nauk farmaceutycznych, nauk medycznych i nauk o zdrowiu.

Wydawnictwo recenzowane i punktowane na zasadach zgodnych z Rozporządzeniem MNiSW z dnia 22 lutego 2019 r. w sprawie ewaluacji jakości działalności naukowej (Dz.U. 2019 poz. 392 z późn. zm.).

QUESTIONNAIRES FOR SLEEP DISORDER ASSESSMENT PART II: OBSTRUCTIVE SLEEP APNEA, SLEEPINESS AND INSOMNIA*
Łódź 2021

* The contribution of the first and the last author is equivalent and accounts for 80% of the contribution to this research

WYDAWNICTWO UNIWERSYTETU MEDYCZNEGO W ŁODZI
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Unikatowy identyfikator Wydawnictwa: 60000
(Komunikat Ministra Edukacji i Nauki z dnia 22 lipca 2021 r. w sprawie wykazu wydawnictw publikujących recenzowane monografie naukowe)

ISBN 978-83-963099-1-4

WYDANIE PIERWSZE

Abstract: Nowadays, sleep disorders are highly common in medical practice. Undiagnosed and untreated sleep disturbances have serious implications for our physiological, psychological and social functioning. Early detection and treatment of these diseases is of paramount importance. Over the last three decades, there has been increasing interest in development of inexpensive and quick approaches to screen and assess the severity of sleep disturbances, such as the use of questionnaires.

Depending on the detected disorder, these tools can be categorized into four groups:

1) Questionnaires used to assess sleepiness and insomnia (Epworth Sleepiness Scale, Stanford Sleepiness Scale, Karolinska Sleepiness Scale, Pittsburgh Sleep Quality Index, Athens Insomnia Scale, Insomnia Severity Index).
2) Questionnaires used to assess obstructive sleep apnea (STOP-Bang, NoSAS, Berlin Questionnaire, EuroSAS).
3) Questionnaires used to assess sleep-related movement disorders (International Restless Legs Syndrome Study Group rating scale for restless legs syndrome, Restless Legs Syndrome Screening Questionnaire, Johns Hopkins Restless Legs Severity Scale).
4) Questionnaires used to assess circadian rhythm sleep disorders (Morningness-Eveningness Questionnaire, Composite Scale of Morningness, Munich Chronotype Questionnaire).

The aim of this paper was to describe, evaluate and compare the most commonly-used questionnaires designed for sleep-related movement disorders and circadian rhythm sleep disorders. Based on a detailed review of literature, this paper presents their advantages and disadvantages and subsequently, summarizes the available questionnaires.

Keywords: questionnaires, insomnia, sleepiness, obstructive sleep apnea, polysomnography, sleep-related movement disorders, restless legs syndrome, circadian rhythm sleep disorders, chronotype

Streszczenie: W obecnych czasach problemy ze snem są bardzo częste w praktyce lekarskiej. Niezdiagnozowane i nieleczone zaburzenia snu mają poważne konsekwencje dla naszego fizjologicznego, psychologicznego oraz społecznego funkcjonowania. Wczesne wykrycie i leczenie tych zaburzeń ma nadrzędne znaczenie. W ciągu ostatnich trzech dekad wzrosło zainteresowanie w kwestii opracowania niedrogich i szybkich sposobów wykrywania i oceny ciężkości zaburzeń snu, takich jak kwestionariusze.

W zależności od wykrywanego zaburzenia narzędzia te można podzielić na cztery grupy:

1) Kwestionariusze oceniające senność i bezsenność (Epworth Sleepiness Scale, Stanford Sleepiness Scale, Karolinska Sleepiness Scale, Pittsburgh Sleep Quality Index, Athens Insomnia Scale, Insomnia Severity Index).
2) Kwestionariusze do oceny obturacyjnego bezdechu sennego (STOP-Bang, NoSAS, Berlin Questionnaire, EuroSAS).
3) Ankiety oceniające zaburzenia ruchowe związane ze snem (International Restless Legs Syndrome Study Group rating scale for restless legs syndrome, Restless Legs Syndrome Screening Questionnaire, Johns Hopkins Restless Legs Severity Scale).
4) Ankiety do oceny zaburzeń rytmu okołodobowego (Morningness-Eveningness Questionnaire, Composite Scale of Morningness, Munich Chronotype Questionnaire).

Celem tej pracy była szczegółowa charakterystyka, porównanie i ocena przydatności klinicznej kwestionariuszy służących do oceny zaburzeń ruchowych związanych ze snem i zaburzeń rytmu okołodobowego. Na podstawie przeglądu literatury zaprezentowaliśmy ich zalety i wady, a następnie podsumowaliśmy dostępne kwestionariusze.

Słowa kluczowe: kwestionariusze, bezsenność, senność, obturacyjny bezdech senny, polisomnografia, zaburzenia ruchowe w trakcie snu, zespół niespokojnych nóg, zaburzenia rytmu okołodobowego, chronotyp

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Abbreviation list

AIS – Athens Insomnia Scale
AUC – Area under the curve
BQ – Berlin questionnaire
CRSD – Circadian rhythm sleep disorders
CSM – Composite Scale of Morningness
DLMO – Dim light melatonin onset
ESS – Epworth Sleepiness Scale
EuroSAS – European Sleep Apnea Syndrome
IRLS – International Restless Legs Syndrome Study Group rating scale for restless legs syndrome
ISI – Insomnia Severity Index
JHRLSS – Johns Hopkins Restless Legs Severity Scale
KSS – Karolinska Sleepiness Scale
MCTQ – Munich Chronotype Questionnaire
MEQ – Morningness Eveningness Questionnaire
MSF – Midsleep on free days
PSQI – Pittsburgh Sleep Quality Index
RLS – Restless Legs Syndrome
RLSSQ – Restless Legs Syndrome Screening Questionnaire
SBQ – STOP-BANG questionnaire
SRMD – Sleep-Related Movement Disorders
SSS – Stanford Sleepiness Scale

Number of tables: 9

1. Questionnaires used to diagnose sleep-related movement disorders

1.1. Introduction

Sleep-related movement disorders (SRMD) are characterized by simple, usually non-purposeful and stereotyped movements during sleep (Bassetti et al., 2014). SRMD include restless legs syndrome (RLS), periodic limb movement disorder, sleep-related leg cramps, sleep-related rhythmic movement disorder and sleep-related bruxism (Kudrycka et al., 2021).

The most common condition is RLS, which affects 3.9% to 14.3% of the general adult population (Ohayon et al., 2012). According to previous literature reports, the prevalence is higher in women than in men and it usually increases with age (Ohayon et al., 2012).

RLS is a neurological disorder characterized by an irresistible need to move limbs, usually accompanied by unpleasant sensations particularly in lower legs. The uncomfortable feelings tend to appear or become more intense during rest or inactivity, and are partially and temporarily relieved by movement (Trenkwalder et al., 2005). Additionally, the RLS symptoms follow a circadian rhythm, being worse during the late evening or at night (Garcia-Borreguero et al., 2004; Michaud et al., 2004).

RLS considerably impairs circadian pattern and sleep quality, resulting in daytime symptoms of disrupted sleep, increased risk of depressive disorders, anxiety and compromised quality of life (Abetz et al., 2004; Becker, 2006; Takahashi et al., 2015; Winkelmann et al., 2005). Several studies revealed that patients with RLS have higher blood pressure compared to controls; therefore, they require close observation with regard to cardiovascular risk factors (Batool-Anwar et al., 2011; Sieminski and Partinen, 2016).

Three disease-specific tools for RLS assessment have been developed and validated: The International Restless Legs Syndrome Study Group rating scale for restless legs syndrome (IRLS) [162], the Restless Legs Syndrome Screening Questionnaire (RLSSQ) (Stiasny-Kolster et al., 2009) and the Johns Hopkins Restless Legs Severity Scale (JHRLSS). The IRLS and JHRLSS were designed to assess the severity of RLS, whereas the RLSSQ was created for the purpose of screening for RLS (Table 2).

Table 2. Questionnaires used to identify the presence and severity of RLS.

Questionnaire	Evaluated aspects	Scoring	Cut-off value	Advantages	Disadvantages	Reference
International Restless Legs Syndrome Study Group rating scale for restless legs syndrome (IRLS) (Table 3)	1. Subjective assessment of primary features of RLS. 2. Intensity and frequency of symptoms. 3. Impact of RLS symptoms on daily life and mood.	10 items rated on a scale from 0 to 4 points The total score ranges from 0 to 40 points	–	1. Highly applicable for assessing the severity of RLS. 2. Appropriate tool for evaluating the treatment efficacy.	1. It is uncertain whether the IRLS is an appropriate tool for RLS screening. There is no established cut-off value that allows patients with RLS to be distinguished. 2. It consists entirely of subjective items.	Walters et al., 2003
Restless Legs Syndrome Screening Questionnaire (RLSSQ) (Table 4)	1. Presence of primary features of the RLS. 2. Presence of sleep disruption. 3. Presence of daytime sleepiness. 4. Presence of involuntary leg movements. 5. Course of the reported complaints. 6. Family history.	10 items rated from 0 to 1 point The total score ranges from 0 to 10 points	7 points	1. Very simple “yes/no” answers. 2. Seems to be an appropriate tool for screening of RLS.	1. There were no differences in the mean RLSSQ scores between the group of treated and untreated patients, therefore it is not the appropriate tool to evaluate the effectiveness of the treatment. 2. It consists entirely of subjective items.	Stiasny Kolster et al., 2009
Johns Hopkins Restless Legs Severity Scale (JHRLSS) [Table 5]	Usual time of the day for onset of RLS for at least 50% of days	1 question rated on a scale from 0 to 3 points	–	1. Easy and quick to administer. 2. Correlates well with objective sleep measures (e.g. polysomnography).	1. It is not clear whether the scale is valid for patients who have symptoms less frequently than 5 days a week.	Allen and Earley, 2001

1.2. International Restless Legs Syndrome Study Group Rating Scale for Restless Legs Syndrome

The International Restless Legs Syndrome Study Group Rating Scale for Restless Legs Syndrome (IRLS) is a tool used to evaluate the subjective severity of RLS (Walters et al., 2003). It includes 10 questions concerning the symptoms and their impact on daily activities and general sensation (Table 3). Each question has five responses, graded from 0 points (the absence of the problem) to 4 points (very severe problem) (Abetz et al., 2006; Walters et al., 2003). Accordingly, the maximum score of the test ranges from 0 to 40 points, with higher scores reflecting the greater severity of the disease.

A validation study performed by Abetz et al. (2006), including 405 patients (RLS patients and control group with other sleep disorders or from the general population) from 20 centers across six countries found the IRLS to have high levels of internal consistency, convergent validity, test-retest and inter-examiner reliability over a 2–4-week period. The researchers suggest that the IRLS may be used to evaluate the impact of treatment on both symptoms and their influence on patients with RLS (Abetz et al., 2006). Inoue et al. (2013) observed that the IRLS has good validity and test-retest reliability. The authors also showed that a change in the total score correlated with scores of the Patients Global Impressions Scale and Clinical Global Impression Improvement Scale, used to assess subjective improvement of symptoms over time. In a study carried out by Collister et al. (2018) on adult hemodialysis patients, the IRLS was used as a screening tool, not as a severity measurement instrument. The tool was found to have a sensitivity of 71% and specificity of 81% with AUC (Area under the curve) of 0.76 with a cut-off value of ≥ 20 points. However, this study is limited by the relatively small size and homogenous nature of the population (Collister et al., 2018).

Table 3. International Restless Legs Syndrome Study Group rating scale for restless legs syndrome (Walters et al., 2003).

Question		Answer
1.	Overall, how would you rate the RLS discomfort in your legs or arms?	Very severe
		Severe
		Moderate
		Mild
		None
2.	Overall, how would you rate the need to move around because of your RLS symptoms?	Very severe
		Severe
		Moderate
		Mild
		None
3.	Overall, how much relief of your RLS arm or leg discomfort do you get from moving around?	No relief
		Slight relief
		Moderate relief
		Either complete or almost complete relief
		No RLS symptoms and therefore question does not apply

Table 3. (cont.)

4.	Overall, how severe is your sleep disturbance from your RLS symptoms?	Very severe
		Severe
		Moderate
		Mild
		None
Question		**Answer**
5.	How severe is your tiredness or sleepiness from your RLS symptoms?	Very severe
		Severe
		Moderate
		Mild
		None
6.	Overall, how severe is your RLS as a whole?	Very severe
		Severe
		Moderate
		Mild
		None
7.	How often do you get RLS symptoms?	Very severe (this means 6 to 7 days a week)
		Severe (this means 4 to 5 days a week)
		Moderate (this means 2 to 3 days a week)
		Mild (this means 1 day a week or less)
		None
8.	When you have RLS symptoms how severe are they on an average day?	Very severe (this means 8 hours per 24 hours day or more)
		Severe (this means 3 to 8 hours per 24-hour day)
		Moderate (this means 1 to 3 hours per 24-hour day)
		Mild (this means less than 1 hour per 24-hour day)
		None
9.	Overall, how severe is the impact of your RLS symptoms on your ability to carry out your daily affairs, for example carrying out a satisfactory family, home, social, school or work life?	Very severe
		Severe
		Moderate
		Mild
		None
10.	How severe is your mood disturbance from your RLS symptoms – for example angry, depressed, sad, anxious or irritable?	Very severe
		Severe
		Moderate
		Mild
		None

1.3. RLS Screening Questionnaire

The Restless Legs Syndrome Screening Questionnaire (RLSSQ) is a self-administered tool developed to evaluate the presence of the most common RLS symptoms. It includes 10 short questions with "yes" or "no" answers (Stiasny-Kolster et al., 2009). The first five questions correspond to the essential criteria of the RLS (Table 4). The following two questions evaluate sleep disruption and daytime sleepiness, while the last three questions pertain to the involuntary leg movements, course of the reported complaints and family history. The overall score of the RLSSQ ranges between 0 and 10 points (Stiasny-Kolster et al., 2009).

Research conducted on 516 subjects by Stiasny Kolster et al. (2009) found a mean RLSSQ score of 8.5 (± 1.0) points in the RLS study group compared with 2.2 (± 2.1) points in the general population used as a control group. A score of 7 points was considered as a positive test result, with 97.9% sensitivity and 96.2% specificity. Consequently, the RLSSQ allowed 97% of the patients to be correctly diagnosed. The AUC was 0.995 with a 95% confidence interval of 0.992–0.999. No differences in mean RLSSQ scores were found between the group of treated and untreated patients. Moreover, the questionnaire was administered to 118 patients with Parkinson's disease, in whom RLS was excluded. The results identified substantial differences between the Parkinson's disease control group and RLS group scores. In the control group, the RLSSQ demonstrated a specificity of 93.2% with a cut-off value of 7 points.

Table 4. Restless Legs Syndrome Screening Questionnaire (RLSSQ) (Stiasny-Kolster et al., 2009).

Question		**Answer**	
1.	Do you sometimes have unpleasant sensations (i.e. twinging, stinging, crawling sensation, pain) or an unspecific disagreeable sensation in the legs or arms?	yes	no
2.	Do you often have the urge to move your legs or walk around?	yes	no
3.	Do these symptoms usually occur in relaxed situations (i.e. while lying or sitting)?	yes	no
4.	Are your symptoms or were your symptoms previously more pronounced at night than during the daytime?	yes	no
5.	Can your symptoms be relieved or do they completely disappear by activity (i.e. moving the legs, walking around)?	yes	no
6.	Do you have difficulty falling asleep or maintaining sleep?	yes	no
7.	Do you feel drowsy, fatigued, or tired in the daytime?	yes	no
8.	Do your legs sometimes twitch or move involuntarily while asleep or at rest in the daytime?	yes	no
9.	Do/did your symptoms not occur regularly, but do/did you have days or nights without any symptoms?	yes	no
10.	Are there any other persons in your family who have similar symptoms?	yes	no

1.4. Johns Hopkins Restless Legs Severity Scale

The Johns Hopkins Restless Legs Severity Scale (JHRLSS) is a clinical single-item scale adjusted to evaluate the severity of RLS (Allen and Earley, 2001). The authors of the JHRLSS aimed to simplify the clinical evaluation of RLS; therefore, in contrast to previous tools, they focused on only one of the clinical complaints – time of onset of symptoms for at least 50% of days (Allen and Earley, 2001). The scale is graded from 0 (no symptoms) to 3 points (day and night symptoms starting before 6:00 p.m.). Based on the time of the day at which the symptoms begin to emerge, RLS can be classified as mild, moderate or severe [Table 5]. The JHRLSS seems very easy and quick to administer.

The major advantage of this scale is that the time of symptom onset as a subjective measurement of RLS severity can be objectively verified by polysomnographic measures of the extent of sleep disruption. Allen and Earley (2001) showed a significant correlation between sleep efficiency and PLMS/h (periodic limb movements) and good reliability (0.91). Moreover, all patients with less than 40% of sleep efficiency were scored as most severe, while only patients with more than 90% sleep efficiency were scored as least severe. One limitation is the fact that the examination was conducted on a group of patients who demonstrated symptoms for at least 5 days a week; hence, it remains unclear whether this scale is appropriate for patients who complain for less frequent symptoms (Walters et al., 2014).

Table 5. Johns Hopkins Restless Legs Severity Scale (JHRLSS) (Allen and Earley, 2001).

Usual time of day when RLS symptoms start (after 12 noon)	Score
No symptoms	0 (Never)
At bedtime and/or during the sleep period (Symptoms may occur within 60 minutes before the usual bed or simply at the time of going to bed or during the night after in bed)	1 (Mild)
In the evening – 6 p.m. or later (Symptoms may start at any time between 6 p.m. and the usual bedtime)	2 (Moderate)
Afternoon – before 6 p.m. (Symptoms start in the afternoon and persist into the evening and night)	3 (Severe)

1.5. Discussion

As RLS is primarily a subjective condition, subjective scales are adequate screening tools. As opposed to objective measures of RLS, these questionnaires can be effectively and easily applied to all patients.

The IRLS is the most extensively used RLS tool in clinical practice. It has been used in multiple settings and groups, and it has also been translated into multiple languages. The results indicate that changes in the scale scores are likely to reflect real changes in the severity of underlying condition. It shows a reliable response to changes resulting from treatment and therefore constitutes a principal tool used in RLS treatment trials. The limitation of the IRLS is that it should be applied in the presence of the professional interviewer, due to the fact that it remains unclear whether the scale would give reliable results if administered without a direct supervision (Walters et al., 2003).

The RLSSQ has proven to be a useful tool for diagnosing or excluding RLS with high accuracy. However, to our knowledge, one study has assessed its utility.

The JHRLSS is an easy-to-use screening tool that can be used to quickly identify patients with RLS and assess the severity of the disease. It is highly reliable and highly correlates with objective assessment of sleep disturbances.

1.6. Conclusions

Compared to the RLSSQ and JHRLSS, the IRLS is the most widely-used and analyzed tool in the RLS and it should be the first-choice option in the evaluation of RLS severity, both in research and clinical practice.

2. Questionnaires used to assess circadian rhythm sleep disorders

2.1. Introduction

The Circadian rhythm is a natural, internal process regulated by the 24-hour internal clock located in the suprachiasmatic nucleus of the brain, which is responsible for the regulation of many physiological processes (Kalmbach et al., 2016; Reddy et al., 2021). This "master clock" is entrained to the external environmental cues (*zeitgebers*). In the mammalian circadian system, the prominent zeitgeber is light (Heyde and Oster, 2019).

A chronotype is defined as a behavioral manifestation of underlying circadian system that reflects the preferred timing of sleeping and waking (Kalmbach et al., 2016). Three major types of chronotype are distinguished: the morning type, evening type and intermediate type. The morning type refers to those who prefer to wake up early, feel the most active during earlier parts of the day and fall asleep early at night (colloquially named as *larks*). The evening type, that refers to people who prefer to wake up late in the day, typically feel most active in the late evening and therefore fall asleep late at night (colloquially named as *owls*). Individuals who remain between the two mentioned types are referred to as intermediate types (Haldar et al., 2020; Kalmbach et al., 2016).

Circadian rhythm sleep disorders (CRSD) are characterized by a discrepancy between the desired sleeping time and the capability to fall and remain asleep (Taylor and Hasler, 2018). The mismatch is typically a result of an endogenous clock system dysfunction (e.g. delayed sleep phase disorder) or a desynchronization between internal sleep-wake rhythms and the external environment (e.g. jet lag) (Luca and Van Den Broecke, 2020; Reid and Zee, 2009). The most common type of circadian rhythm sleep disorder (CRSD) is delayed sleep-wake phase disorder (DSWDP). Its prevalence is estimated to be 0.13%–3.1% in the general population (Schrader et al., 1993; Wyatt, 2004; Yazaki et al., 1999). It is manifested as a chronic dysregulation of a patient's circadian rhythm, characterized by abnormally late sleep and wake times (Mundey et al., 2005).

If left untreated, CRSD can lead to insomnia and excessive daytime sleepiness that considerably impair daytime functioning; therefore; as such it is of great importance to recognize potential CRSDs. Chronotype is frequently evaluated by self-assessment questionnaires (Table 6), of which the most commonly used is the Morningness-Eveningness Questionnaire (MEQ). Other tools used to assess the sleep-wake patterns are the Composite Morningness Scale (CSM) and the Munich Chronotype Questionnaire (MCTQ).

Table 6. Questionnaires used to assess individual chronotype.

Questionnaire	Evaluated aspects	Scoring	Cut-off value	Advantages	Disadvantages	Reference
Morningness-Eveningness Questionnaire (MEQ) [Table 7]	The degree of patient alertness and activity at certain times of the day	19 questions rated on a scale from 0 to 4 or 5 points The total score ranges from 16 to 86 points	Scores 41 points and below indicate "evening types" Scores 42-58 points indicate "intermediate types" Scores of 59 points and above indicate "morning types"	1. Good validity and reliability. 2. Availability of the short form, that can be used for limited time. 3. Satisfying correlation with various objective measures such as peak times of body temperature, dim light melatonin onset, actigraphy. 4. Satisfying correlation with subjective sleep measures such as sleep habits, and optimal time for performance and alertness. 5. Highly correlates with the CSM and MCTQ.	1. The initial cut-off values may be inappropriate in age groups different than young adults. 2. May be too lengthy.	Horne and Östberg, 1976
Composite Scale of Morningness (CSM) [Table 8]	Preferred times to sleep and wake up, peak cognitive performance, morning affect	13 questions rated on a scale from 0 to 4 or 5 points The total score ranges from 13 to 55 points	Two terms of classification: 1) two categories (morning and evening types) 2) three categories (morning, intermediate and evening types)	1. Good reliability. 2. Availability of the short form. 3. Highly correlates with the MEQ and rMEQ.	1. Moderate correlation with objective measures, such as actigraphy. 2. Moderate correlation with subjective measures, such as preferred times of wake and sleep. 3. Unclear classification of the chronotype groups.	Smith et al., 1989

Table 6 (cont.)

Questionnaire	Evaluated aspects	Scoring	Cut-off value	Advantages	Disadvantages	Reference
Munich Chronotype Questionnaire (MCTQ) [Table 9]	sleep latency, wake and sleep schedules, level of energy during the day, subjective assessment of chronotype	19 questions with the total score ranging between 16 and 86	The questionnaire does not provide a set of cut-off values	1. Relatively objective measure – assessment of the chronotype based on the mid-point between sleep onset and offset on work-free days (considered as a marker of melatonin onset). 2. MCTQ mid-point correlates with actigraphy measures. 3. Highly correlates with the MEQ scores.	1. Does not provide predefined cut-off values. 2. May be too lengthy.	Roenneberg et al., 2003

2.2. Morningness-Eveningness Questionnaire

The Morningness-Eveningness Questionnaire (MEQ) is a tool developed to assess individuals' chronotype (Horne and Östberg, 1976) and is the most widely-used measure in chronobiology and sleep research. It contains 19 questions rated from 0 to 4 or 5 points, with the overall score ranging from 16 to 86 points. Horne and Östberg (1976) originally predefined cut-off values as follows: scores of 41 points and below indicate the evening-type preference, scores between 42–58 points indicate intermediate types, and scores of 59 points and above indicate the morning-type preference. The items assess the degree of alertness and activity at certain times of the day (Table 7). The MEQ is also available as a short form containing only five questions (rMEQ). The maximum score ranges from 4 to 26 points and higher scores indicate morning types (Danielsson et al., 2019).

However, the authors did not report the reason for establishing the mentioned cut-off values, nor did they report the internal reliability of the questionnaire (Kim and Kim, 2020); in addition, the study only included a relatively small number of young adults (n=150) (Horne and Östberg, 1976). Considering that young adults are skewed towards eveningness (Adan and Natale, 2002; Chelminski et al., 1997), the original cut-off values should be used with caution, particularly for other age groups (Kim and Kim, 2020).

Nonetheless, the scale has been assessed in different age samples (Carciofo et al., 2012; Cavallera and Boari, 2015; Taillard et al., 2004). Some research conducted by Cavalerra and Boari (2015) suggests that the MEQ is an appropriate and relevant tool also for measuring morningness-eveningness among adolescents. In addition, a study on subjects aged 44-58 years by Taillard et al. (2004) demonstrated that the MEQ can be useful in identifying age-related changes in sleep. The authors also suggested a different cut-off values in the mentioned group: 16–52 (evening types), 53–64 (intermediate types) and 65–86 (morning types). Carciofo et al. (2012) identified a strong correlation (0.595) between age and MEQ score in a sample of people aged 18-87 years old. The authors also concluded that the scale is internally consistent. In contrast, some research by Paine et al. (2006) indicated that the original criteria of Horne and Östberg (1976) are not suitable for classifying chronotypes in a middle-aged population.

Several studies have confirmed that the MEQ has good validity and reliability, reflected by a Cronbach's alpha coefficient ranging from 0.785 to 0.870 (Adan and Natale, 2002; Inomata et al., 2014; Pündük et al., 2005; Zacharia et al., 2014). LI et al. (2010) note that the MEQ has good psychometric properties and its cut-off scores allow morning types to be effectively distinguished from evening types.

The validity of the MEQ was assessed using objective indicators (Bailey and Heitkemper, 2001; Burgess et al., 2018; Griefahn et al., 2001; Horne and Östberg, 1976; Ishihara et al., 1987; Kantermann et al., 2015; Matuzaki et al., 2014). Several studies report differences in peak times of body temperature between morning and evening types (Bailey and Heitkemper, 2001; Griefahn et al., 2001; Horne and Östberg, 1976; Ishihara et al., 1987), with evening types demonstrating a significantly later peak than morning types, and with intermediate type subjects peaking between the other two. A validation study by Horne and Östberg (1976) found that the subjective time of peak alertness is associated with the time of peak body temperature. Differences in cortisol (Bailey and Heitkemper, 2001; Griefahn et al., 2001) and melatonin (Bailey and Heitkemper, 2001) release were also reported.

Kantermann et al. (2015) assessed the correlation between MEQ score and dim light melatonin onset (DLMO), which is the most reliable measure of central circadian timing in humans. The authors

observe that DLMO significantly correlated with MEQ score. Although the MEQ score could be used to predict DLMO, a 4-hour range in DLMO was observed at a given MEQ score; therefore, the MEQ should not be used to time light or exogenous melatonin treatment with regard to the DLMO (Kantermann et al., 2015). On the other hand, Burgess et al. (2018) showed that the MEQ score also correlated with a phase advance in the DLMO, and most importantly, they indicated that the MEQ can reflect a change in circadian timing after light treatment, which can suggest underlying changes in circadian rhythm.

Moreover, the MEQ was also compared against the actigraphy-based circadian parameters among students by Roveda et al. (2017). The authors concluded that the acrophase, i.e. the time at which the peak of rhythm occurs, as determined by actigraphy, can be predicted using the MEQ score (Roveda et al., 2017). A previous study found the group defined by actigraphy as morning types demonstrated significantly higher scores than evening types (Matuzaki et al. 2014).

The relationship with subjective measures was also assessed. The researchers identified differences in sleep habits (Ishihara et al., 1987) and optimal times for alertness and performance between morning and evening types (Adan, 1991; Natale and Cicogna, 2002). However, the length of the MEQ remains a major criticism.

Table 7. Morningness-Eveningness Questionnaire (Horne and Östberg, 1976).

1. What time would you get up if you were entirely free to plan your day?					
5:00 – 6:30 am	6:30 – 7:45 am	7:45 – 9:45 am	9:45 – 11:00 am	11:00 – 12:00 am	12:00 – 5:00 am
2. What time would you go to bed if you were entirely free to plan your evening?					
8:00 – 9:00 pm	9:00 – 10:15 pm	10:15 – 12:30 am	12:30 – 1:45 am	1:45 – 3:00 am	3:00 – 8-00 am
3. If there is a specific time at which you have to get up in the morning, to what extent do you depend on being woken up by an alarm clock?					
Not at all dependent	Slightly dependent	Fairly dependent	Very dependent		
4. How easy do you find it to get up in the morning (when you are not woken up unexpectedly)?					
Not at all easy	Not very easy	Fairly easy	Very easy		
5. How alert do you feel during the first half hour after you wake up in the morning?					
Not at all alert	Slightly alert	Fairly alert	Very alert		
6. How hungry do you feel during the first half-hour after you wake up in the morning?					
Not at all hungry	Slightly hungry	Fairly hungry	Very hungry		

Table 7 (cont.)

7. During the first half-hour after you wake up in the morning, how tired do you feel?			
Very tired	Fairly tired	Fairly refreshed	Very refreshed
8. If you have no commitments the next day, what time would you go to bed compared to your usual bedtime?			
Seldom or never later	Less than one hour later	1-2 hours later	More than two hours later
9. You have decided to engage in some physical exercise. A friend suggests that you do this for one hour twice a week and the best time for him is between 7:00 – 8:00 am. Bearing in mind nothing but your own internal "clock", how do you think you would perform?			
Would be in good form	Would be in reasonable form	Would find it difficult	Would find it very difficult
11. You want to be at your peak performance for a test that you know is going to be mentally exhausting and will last for two hours. You are entirely free to plan your day. Considering only your own internal "clock", which one of the four testing times would you choose?			
8:00 am – 10:00 am	11:00 am – 1:00 pm	3:00 pm – 5:00 pm	7:00 pm – 9:00 pm
12. If you got into bed at 11:00 pm, how tired would you be?			
Not at all tired	A little tired	Fairly tired	Very tired
13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which one of the following are you most likely to do?			
Will wake up at usual time, but will NOT fall back asleep	Will wake up at usual time and will doze thereafter	Will wake up at usual time but will fall asleep again	Will NOT wake up until later than usual
14. One night you have to remain awake between 4:00 – 6:00 am in order to carry out a night watch. You have no commitments the next day. Which one of the alternatives will suite you best?			
Would NOT go to bed until watch was over	Would take a nap before and sleep after	Would take a good sleep before and nap after	Would sleep only before watch
15. You have to do two hours of hard physical work. You are entirely free to plan your day and considering only your own internal "clock" which one of the following times would you choose?			
8:00 am – 10:00 am	11:00 am – 1:00 pm	3:00 pm – 5:00 pm	7:00 pm – 9:00 pm

Table 7 (cont.)

16. You have decided to engage in hard physical exercise. A friend suggests that you do this for one hour twice a week and the best time for him is between 10:00 – 11:00 pm. Bearing in mind nothing else but your own internal "clock" how well do you think you would perform?			
Would be in good form	Would be in reasonable form	Would find it difficult	Would find it very difficult

17. Suppose that you can choose your own work hours. Assume that you worked a five-hour day (including breaks) and that your job was interesting and paid by results). Which five consecutive hours would you select?				
5 hours starting between 4:00 am and 8:00 am	5 hours starting between 8:00 am and 9:00 am	5 hours starting between 9:00 am and 2:00 pm	5 hours starting between 2:00 pm and 5:00 pm	5 hours starting between 5:00 pm and 4:00 am
18. At what time of the day do you think that you reach your "feeling best" peak?				
5:00 – 8:00 am	8:00 – 10:00 am	10:00 am – 5:00 pm	5:00 – 10:00 pm	10:00 pm – 5:00 am

19. One hears about "morning" and "evening" types of people. Which one of these types do you consider yourself to be?			
Definitely a "morning" type	Rather more a "morning" than an "evening" type	Rather more an "evening" than a "morning" type	Definitely an "evening" type

2.3. Composite Scale Of Morningness

The Composite Scale of Morningness (CSM) was developed from a number of different instruments to respond to the weaknesses of other scales (Kolomeichuk et al., 2015; Smith et al., 1989). It comprises 13 items: nine items from the MEQ and four from the DTS (7-item Diurnal Type Scale), each valued from 0 to 4 or 5 points with the total score ranging from 13 (extremely evening types) to 55 (extreme morning types). The items ask about morning affect, preferred times for going to bed, waking up and for the best possible cognitive performance (Table 8). As in the case of the MEQ, a reduced version of the CSM was developed (Randler, 2009).

Various studies have found the internal reliability of the CSM to typically be greater than 0.80 (Caci et al., 1999, 2005, 2009; Díaz-Morales, 2007; Gomez et al., 2011; Smith et al., 1989, Thun et al., 2012). It was only found to have lower reliability (0.65) in one study, which was performed in a Thai sample (Pornpitakpan, 1998); in this case, however, the worse performance can be explained by the difficulties experienced in translating some items into the Thai language and adapting the timing of activity to the local Thai rhythm. Data obtained by Randler et al. (2009) showed that the CSM is a valid tool to evaluate circadian preferences in its full and reduced version, both in adults and adolescents' samples.

The validity of the CSM has been assessed using both objective and subjective measures. Thun et al. (2012) report a moderate association between the CSM and sleep/wake times recorded during actigraphy. A number of studies revealed a relationship between the CSM score and self-reported preferred times for waking and bed times, both for weekdays and weekends (Bohle et al., 2001; Caci et al., 1999; Smith et al., 2002).

The classification of the subjects to different chronotypes remains unclear. Smith et al. (1989) proposed grouping individuals into three categories using 10th/90th percentiles. This resulted in various cut-off values in different countries (Adan et al., 2005; Caci et al., 2009; Greenwood, 1994; Randler, 2009; Smith et al., 1989). Bohle et al. (2001) suggested a two-category classification using quartiles. However, neither method may be appropriate to use in cross-cultural studies (Di Milia et al., 2013).

CSM, MEQ and rMEQ share common factors; therefore, they show a strong correlation (Caci et al., 2009; Greenwood, 1994). Both the MEQ and rMEQ demonstrated high sensitivity for categorizing subjects into the same chronotype (Caci et al., 2009). The authors of the scale, Smith et al. (1989), stated that the associations between the CSM and external criteria are comparable or even stronger than similar associations between previously published scales and external criteria.

Table 8. Composite Scale of Morningness (Smith et al., 1989).

1. Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your own day?				
5:00 – 6:30 am	6:30 – 7:45 am	7:45 – 9:45 am	9:45 – 11:00 am	11:00 – 12 am
2. Considering your only "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan your own evening?				
8:00 – 9:00 pm	9:00 – 10:15 pm	10:15 pm – 12:30 am	12:30 – 1:45 am	1:45 – 3:00 am
3. Assuming normal circumstance, how easy do you find getting up in the morning?				
Not easy at all	Slightly easy	Fairly easy	Very easy	
4. How alert do you feel during the first half hour after having awakened in the morning?				
Not at all alert	Slightly alert	Fairly alert	Very alert	
5. During the first half hour after having awakened in the morning, how tired do you feel?				
Very tired	Fairly tired	Fairly refreshed	Very refreshed	
6. You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is 7:00 – 8:00 am Bearing in mind nothing else but you own "feeling best" rhythm, how do you think you would perform?				
Would be in good form	Would be in reasonable form	Would find it difficult	Would find it very difficult	
7. At what time in the evening do you feel tired and, as a result, in need of sleep?				
8:00 – 9:00 pm	9:00 – 10:15 pm	10:15 pm – 12:30 am	12:30 – 1:45 am	1:45 – 3:00 am

Table 8 (cont.)

8. You wish to be at your peak performance for a test which you know is going to be mentally exhausting and lasting for two hours. You are entirely free to plan your day, and considering only your own "feeling best" rhythm, which one of the four testing times would you choose?			
8:00 – 10:00 am	11:00 am – 1:00 pm	3:00 – 5:00 pm	7:00 – 9:00 pm
9. One hears about "morning" and "evening" types of people. Which one of these types do you consider yourself to be?			
Definitely a morning type	More a morning than an evening type	More an evening than a morning type	Definitely an evening type
10. When would you prefer to rise (provided you have a full day's work – 8 hours) if you were totally free to arrange your time?			
Before 6:30 am	6:30 – 7:30 am	7:30 – 8:30 am	8:30 am or later
11. If you always had to rise at 6:00 am, what do you think it would be like?			
Very difficult and unpleasant	Rather difficult and unpleasant	A little unpleasant but no great problem	Easy and not unpleasant
12. How long a time does it usually take before you "recover your senses" in the morning after rising from a night's sleep?			
0 – 10 minutes	11 – 20 minutes	21 – 40 minutes	More than 40 minutes
13. Please indicate to what extent you are a morning or evening <u>active</u> individual.			
Pronounced morning active (morning alert and evening tired)	To some extent, morning active	To some extent, evening active	Pronounced evening active (morning tired and evening alert)

2.4. Munich Chronotype Questionnaire

The Munich Chronotype Questionnaire (MCTQ) is considered an objective measure of circadian timing. It refers to sleep latency and precise times of going to bed and waking up (Roenneberg et al., 2003). The MCTQ estimates chronotype based on the mid-point between sleep onset and offset on days free from work (midsleep on free days – MSF), which is corrected for "oversleep", being the result of the sleep debt accumulated over the working week (Roenneberg et al., 2003, 2015). The mid-point of sleep is believed to be a marker for melatonin onset (Terman et al., 2001), whereas the DLMO is the most reliable measure of central timing in humans (Kantermann et al., 2015). It consists of 19 questions, which assess sleep latency, exposure to daylight, wake and sleep schedules, and level of energy during the day (Table 9). There are also subjective items in which patients identify the chronotype that describes them best. The total score ranges from 16 to 86 points, with lower values corresponding to later types. Unlike previous chronotype assessment tools, the MCTQ does not use a set of predefined cut-off values, and individuals are categorized into one of seven categories when they complete the questionnaire online.

Various studies have demonstrated that the MCTQ is a valid tool for evaluating chronotype (Cheng and Hang, 2018; Fárková et al., 2020; Ryu et al., 2018; Suh et al., 2018). In a study on 5,055 subjects, Zavada et al. (2005) found that MEQ scores highly correlate with the MCTQ assessment of time of mid-sleep on free days and workdays, and that sleep schedule on free days constitutes a good predictor of chronotype. Fárková et al. (2020) also report mutual substitutability between the MEQ and MCTQ.

A strong correlation between the DLMO and chronotype, assessed with the MSF, was also observed in a physiological validation study by Cheng and Hang (2018). These outcomes were confirmed by Kantermann et al. (2015), who report a significant correlation between DLMO and MSC. Furthermore, the MSC was the strongest predictor of DLMO. However, as in the case of the MEQ, using the MSF in light periods or exogenous melatonin treatment could result in mistiming of these treatments relative to the DLMO (Kantermann et al., 2015).

Santisteban et al. (2018) report a strong correlation between the MCTQ-derived mid-point and an objective actigraphy measurement. In addition, Ryu et al. (2018) demonstrate the validity of the MCTQ in an older adult population, and Suh et al. (2018) indicate that the MCTQ is useful in young adults.

Table 9. Munich Chronotype Questionnaire (Roenneberg et al., 2003).

Please enter your age, gender, etc. This information is important for our evaluation.			
Age: ……..	Female/Male	Height: ……..	Weight: ……..
<u>On work days:</u>			
I have to get up at ……. o'clock.			
I need ……. minutes to wake up.			
I regularly wake up ……. before the alarm with the alarm.			
From ……. o'clock I am fully awake.			
At around ……. o'clock, I have an energy dip.			
On nights before workdays, I go to bed at ……. o'clock.			
…and it then takes me ……. minutes to fall asleep.			
If I get the chance, I like to take a siesta/nap…			
I then sleep for ……. minutes.		Correct	
I would feel terrible afterwards.		Not correct	
<u>On free days</u> (please only judge normal free days, i.e., without parties etc.):			
My dream would be to sleep until ……. o'clock.			
I normally wake up at ……. o'clock.			
If I wake up at around the normal (workday) alarm time, I try to get back to sleep…		Correct	
		Not correct	
If I get back to sleep, I sleep for another ……. minutes.			
I need ……. minutes to wake up.			
From ……. o'clock I am fully awake.			
At around ……. o'clock, I have an energy dip.			
On nights before workdays, I go to bed at ……. o'clock.			
…and it then takes me ……. minutes to fall asleep.			
If I get the chance, I like to take a siesta/nap…			

Table 9 (cont.)

I then sleep for …….. minutes.	Correct						
I would feel terrible afterwards.	Not correct						
Once I am in bed, I would like to read for …….. minutes.							
…but generally, fall asleep after no more than …….. minutes.							
I prefer to sleep in a completely dark room.	Correct						
	Not correct						
I wake up more easily when morning light shines into my room.	Correct						
	Not correct						
How long per day do you spend on average outside (really outside) exposed to daylight?							
On work days: …….. hours …….. minutes	On free days: …….. hours …….. minutes						
Self-assessment							
After you have answered the preceding questions, you should have a feeling to which chronotype (type-of-day-type) you belong to. If, for example, you (and manage) to sleep quite a bit longer on free days than on workdays, or if you cannot get out of bed on Monday morning, even without a Sunday-night-party, then you are more a late go to bed early than to an evening concert then you are an early type. In the following questions, you should categorize yourself and your family members. Please tick only one possibility!							
Description of categories: Extreme early type = 0 Moderate early type = 1 Slight early type = 2 Normal type = 3 Slight late type = 4 Moderate late type = 5 Extreme late type = 6							
I am…	0	1	2	3	4	5	6
As a child, I was…	0	1	2	3	4	5	6
As a teenager, I was…	0	1	2	3	4	5	6
In case you are older than 65: in the middle of my life, I was….	0	1	2	3	4	5	6
My parents are/were…	0	1	2	3	4	5	6
Mother…	0	1	2	3	4	5	6
Father…	0	1	2	3	4	5	6
My siblings are/were… (Please underline brother or sister)							
Brother/Sister	0	1	2	3	4	5	6
Brother/Sister	0	1	2	3	4	5	6
Brother/Sister	0	1	2	3	4	5	6
Brother/Sister	0	1	2	3	4	5	6
My partner (girl/boyfriend, spouse, significant other) is/was…	0	1	2	3	4	5	6

2.5. Discussion

Questionnaires are commonly applied in the assessment of chronotype. Two examples, the MEQ and CSM subjective measurements, both demonstrate excellent reliability and, sharing common items, correlate significantly with each other. Unfortunately it is not possible to assess the reliability of the more objective MCTQ, as it does not contain items answered using Likert response scales. In addition, the test-retest reliability of the sleep mid-point has not been stated in any available studies.

The primary criticism of subjective circadian rhythm measures concerns the lack of differentiation between behavior during free and work days; incompatibilities between the circadian timing and the daily schedule leads to sleep deprivation on working days in individuals with evening chronotypes. Roenneberg et al. (2003) suggest that the sleep debt requires rectification.

An important issue to resolve for future research is whether the circadian rhythm is best characterized by a psychological preference for behavior, or by physiological biomarkers such as sleep mid-point. In such cases, it would be advantageous to consider which marker of circadian rhythm best suits the main aim of a particular study. It is also more difficult to determine which questionnaire is appropriate in assessing circadian rhythm sleep disorders in outpatient care or sleep clinic.

2.6. Conclusions

The subjective measurements described in this review have very satisfactory levels of reliability; in contrast, the only objective measure is based on the mid-point of sleep, which is considered to be a marker for melatonin onset. The MEQ seems to be the best CRSD screening tool in clinical practice. It is not only the most commonly-used and analyzed tool, but it also provides a set of predefined cut-off values and strongly correlates with objective sleep measures.

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