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The factor structure of the Pittsburgh Sleep Quality Index in persons with traumatic brain injury. A NIDRR TBI model systems module study

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Abstract.
BACKGROUND: Sleep disturbances are common following traumatic brain injury (TBI). The Pittsburgh Sleep Quality Index (PSQI) is a widely used measure of sleep quality that has been used in numerous populations. Although this measure has been used in TBI research, there are few studies examining the psychometric properties in this population.
OBJECTIVE: The current study examined the factor structure of the PSQI in a sample of persons with TBI and tested the one, two, and three factor models derived from previous studies in other populations.
METHODS: A telephone interview was conducted with 243 individuals who had sustained a TBI. All participants were approximately one year post-injury. Factor analyses were conducted (exploratory and confirmatory) to examine the factor structure of the PSQI.
RESULTS: Results confirm the fit of models previously tested in the literature but also reveal an alternative conceptualization of sleep containing both qualitative and quantitative factors.
CONCLUSIONS: While the 3-factor model best fits the data in this TBI sample, the use of a 2-factor model is acceptable and may be more clinically relevant due to the grouping of time-related variables that could provide important information with regard to circadian rhythm disorders.

Keywords: Brain injury, sleep, measurement

1. Introduction

Sleep-wake disturbances are common sequelae of traumatic brain injury (TBI) (Baumann, 2012; Makley et al., 2008; Mathias & Alvaro, 2012; Orff, Ayalon, & Drummond, 2009). Nakase-Richardson and colleagues (2013) found that 84% of their sample of 152 individuals with TBI reported mild to severe sleep disturbance upon admission to rehabilitation, with 63% in the moderate to severe range (Nakase-Richardson et al., 2013). Insomnia and daytime sleepiness are widely reported by a significant proportion of individuals recovering from TBI. Fichtenberg and colleagues (2002) found that 30%

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of individuals with TBI met DSM-IV criteria for insomnia with an additional 12% experiencing considerably poor sleep quality as measured through a self-report questionnaire (Fichtenberg, Zafonte, Putnam, Mann, & Millard, 2002). For this group, delayed sleep onset occurred almost twice as often as reduced sleep duration. Similarly, Beetar and colleagues (1996) found that nearly twice as many individuals with TBI reported significant difficulty with insomnia as compared to individuals without TBI (56% vs 31%) (Beetar, Guilmette, & Sparadeo, 1996). Additionally, they (Beetar et al., 1996) and others (Baumann, Werth, Stocker, Ludwig, & Bassetti, 2007; Castriotta & Lai, 2001; Guilleminault, Faull, Miles, & van den Hoed, 1983; Kempf, Werth, Kaiser, Bassetti, & Baumann, 2010; Parcell, Ponsford, Rajaratnam, & Redman, 2006) have found that excessive daytime sleepiness impacts between 17% and 90% of study participants. However, some studies suggest these findings are not different than reports of excessive sleepiness in the general population (Parcell et al., 2006), which may be in part due to lack of sensitivity and specificity of the measurement tools used.

A number of different methods have been used to measure sleep problems in this population. One of these, the Pittsburgh Sleep Quality Index (PSQI) is a widely used self-report measure of sleep quality (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The PSQI has been shown to have good psychometric properties and has been used in numerous clinical populations including people with stroke (Cavalcanti, Campos, & Araujo, 2013), Guillain-Barre Syndrome (Karkare, Sinha, Taly, & Rao, 2013), hypertension (Afsar, 2013b), migraine (Engstrom et al., 2013) chronic pulmonary disease (Soler, Diaz-Piedra, & Ries, 2013), renal disease (Afsar, 2013a), and a variety of psychiatric disorders (Afonso, Figueira, & Paiva, 2011).

1.1. Psychometric properties of the Pittsburgh Sleep Quality Index (PSQI)

The Pittsburgh Sleep Quality Index (PSQI) is a measure of sleep quality in which the respondent is asked to respond to questions about their sleep over the past month. The PSQI contains 9 items. Some of the items use multiple choice responses that indicate quality or severity (i.e., “During the past month, how would you rate your sleep quality overall?” with choices “very good, fairly good, fairly bad, [and] very bad”). Others represent frequency (i.e., “During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?” with choices “Not during the past month, less than once a week, once or twice a week, [and] three or more times a week”). Higher item ratings signify poorer sleep-related functioning. The items are divided into seven clinically derived domains, including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction due to sleepiness. Scoring is based on a scale from 0 to 3 for each of the domains, and a global sum greater than 5 suggests “poor” sleep (Buysse et al., 1989). An example of all of the items on the PSQI and scoring instructions to derive the 7 domain scores can be found at the following website: http://www.sleep.pitt.edu/content.asp?id=1484&subid=2316.

The PSQI has acceptable to good internal consistency (Cronbach alphas of.77 to.85) when used with healthy controls and participants dealing with depression, insomnia and sleep issues, cancer, and transplant patients (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002; Beck, Schwartz, Towsley, Dudley, & Barsevick, 2004; Carpenter & Andrykowski, 1998; Grandner, Kripke, Yoon, & Youngstedt, 2006). There have been reports of low component-to-total correlations for component 6 (use of sleeping medication) for cancer patients (Beck et al., 2004) and healthy individuals (Grandner et al., 2006). Buysse et al (1989) also reported that component 6 had low item-to-total correlations in normal individuals, but that these items were significantly correlated for individuals with sleep issues or depression (Buysse et al., 1989).

In terms of test-retest reliability, the PSQI has been shown to be very stable over time for periods of up to one month in insomnia patients (Backhaus et al., 2002), healthy individuals, patients with depression or sleep disorders (Buysse et al., 1989), and nursing home residents (Gentili, Weiner, Kuchibhatil, & Edinger, 1997). Stability of the measure over longer periods of time up to one year has been established in early middle aged adults (Knutson, Rathouz, Yan, Liu, & Lauderdale, 2006).

Convergent and discriminant validity was examined in transplant and cancer patients by comparing the PSQI global scores with other measures thought to be related or unrelated to sleep (Carpenter & Andrykowski, 1998). The PSQI was moderately to highly correlated with constructs related to sleep quality or problems (Symptom Experience Report item on sleep problems and CES-D item on sleep restlessness) and had low or non-significant correlations with unrelated constructs like nausea, vomiting or change in taste. In TBI, validity studies have shown high correlations between the PSQI and sleep logs or diaries (Backhaus et al., 2002; Fictenberg, Putnam, Mann, Zafonte, & Millard, 2001; Grandner et al., 2006) but much lower or non-significant correlations with polysomnographic (Buysse et al., 1989; Grandner et al., 2006) measures of sleep. Fichtenberg et al. (2001) found that individual PSQI items correlated highly with certain items from the Beck Depression Inventory, Epworth Sleepiness Scale, and Multidimensional Pain Inventory scales in a sample of individuals with TBI (Fictenberg et al., 2001).

Much of the other PSQI validation work has been conducted using known group detection. A PSQI global score >5 resulted in a sensitivity of 99 and specificity of 84 as a marker for sleep disturbances in insomnia patients versus controls (Backhaus et al., 2002). Carpenter and Andrykowski (1998) using information on previously reported sleep issues, sleep quality, or sleep restlessness, found that Global PSQI scores were under 5 for all patients with no sleep issues (Carpenter & Andrykowski, 1998). Mean Global PSQI scores were greater than 8 for groups that had sleep issues, prompting them to argue that a cutoff of 8 may be more appropriate for certain populations. Similarly, a Global PSQI score of 8 correctly classified 100% and 94%, respectively, of insomniacs and non-insomniacs following TBI (Fictenberg et al., 2001).

1.2. Factor structure of the PSQI

The factor structure of the PSQI has been examined in other populations. Cole et al. (2006) questioned whether the single-factor model best captures the multidimensional nature of sleep disturbances as indexed by the PSQI (Cole et al., 2006). Using a combination of exploratory and confirmatory factor analyses (EFA and CFA, respectively), the authors noted a three-factor model to show a significantly better fit to their data than the original single-factor model or a two-factor model, in a sample of community-dwelling depressed and non-depressed adults over 60 years of age. The resultant factors were referred to as sleep efficiency, perceived sleep quality, and daily disturbances.

The fit of the three-factor model was confirmed in subsequent studies on samples of Australian adults aged 18 to 59 years (Magee, Caputi, Iverson, & Huang, 2008), renal transplant recipients (Burkhalter et al., 2011), and patients with chronic fatigue syndrome (Mariman, Vogelaers, Hanoulle, Delesie, & Pevernagie, 2012). Although Magee et al. (2008) found the three-factor model to have a superior fit compared with the one-factor model, they favored a two-factor model. This decision was based on findings of redundancy and overlap in the three factor model. Cole et al. (2005) also found the two factor model to be better than the single factor model.

Previous factor analytic studies of the PSQI have been criticized for various reasons. For example, the loading of sleep efficiency and sleep duration on the same factor in the Cole and Magee models may be a product of the inclusion of sleep duration in the sleep efficiency score. The overlap of sleep duration on these two items has been seen as redundant (Beck et al., 2004). Another problematic issue in the Cole and Magee models can be seen in the Sleep Quality factor. With the PSQI having been established as a measure of sleep quality, giving a factor the same name raises questions about whether the five items loading on this factor are sufficient to constitute a measure of sleep quality. The additional two components pose a potential problem with regard to the unidimensionality of the PSQI as a measure of sleep quality.

To date, no study has examined the factor structure of the PSQI in a sample of individuals with TBI even though the PSQI has been more frequently utilized in this population as awareness of the prevalence of sleep-wake disturbances following TBI has grown over the past decade. It is thus important to examine the factor structure of the PSQI in persons with TBI, in order to identify the most appropriate way to analyze the data provided by the measure in this population. Understanding the underlying factors can provide additional information about the nature of subjective sleep quality in persons with TBI and allow researchers to pinpoint more specific relationships when investigating how the factors correlate with other patient characteristics. The current study aims to determine whether the PSQI is unidimensional or multidimensional among individuals with TBI, and to determine which factor model, if any, offers the best fit to the data.

2. Methods

2.1. Participants

Participants were a subset of individuals with TBI enrolled in the National Institute of Disability and Rehabilitation Research TBI Model Systems program (TBIMS) National Data Base (NDB). The TBIMS NDB is a prospective, longitudinal multi-center study which collects data about individuals with TBI, their injury, and their outcomes. The NDB eligibility criteria include: 1) Presence of TBI of at least sufficient severity to necessitate inpatient rehabilitation (post-traumatic amnesia [PTA] at least 24 hours, or the presence of trauma-related intracranial neuroimaging abnormalities, or loss of consciousness [LOC] with duration of more than 30 minutes); 2) Glasgow Coma Scale (GCS) score of less than 13 upon admission to the emergency department; 3) Age 16 or older at the time of injury; 4) Admission to an acute care hospital of the TBIMS within 72 hours following injury; 5) Participation in inpatient rehabilitation for brain injury at a designated TBIMS rehabilitation center (hospital, hospital-based skilled nursing facility, or long-term acute care hospital); 6) Informed consent.

2.2. Procedures

The TBIMS NDB collects information during the rehabilitation hospital stay (through interview and chart abstraction) and at post-injury follow up intervals (1, 2, 5, and 10 post-injury and every 5 years there-after) through telephone interview. The present study was based on a subset of the TBIMS NDB participants who were enrolled at one of five TBIMS centers: Mount Sinai Medical Center in New York, NY; Santa Clara Valley Medical Center in San Jose, CA; Kessler Foundation in West Orange, NJ; Carolinas Rehabilitation in Charlotte, NC; and JFK Johnson Rehabilitation Institute in Edison, NJ. For this subset of NDB participants, at the one year follow up contact, the participants were asked to participate in additional data collection to provide information about sleep and insomnia through a structured telephone interview. For this additional data collection interview, only those individuals with TBI who could provide their own responses were included (that is, information from a proxy was not allowed). In total, 243 individuals with TBI provided complete PSQI data allowing their inclusion in the present study. Table 1 Summarizes key demographic and injury characteristics of the study sample.

2.3. Measures

Posttraumatic amnesia: Injury severity was quantified by duration of PTA in days. The end of the period of inability to form new memories was determined using either the Orientation Log (O-Log) (Jackson, Novack, & Dowler, 1998) or the Galveston Orientation Amnesia Test (GOAT) (Levin, O'Donnell, & Grossman, 1979).

Table 1
Sample characteristics

Demographics and Injury Characteristics	Frequencies (%)
Sex	
Male	157 (64.6)
Female	80 (32.9)
Age*	43.5 (20.1)
Education	
11th grade or less	27 (11.1)
High School/GED	71 (29.2)
Some college/Associates degree	93 (38.3)
Bachelor's degree or Graduate school	52 (21.5)
Marital Status	
Single (never married)	111 (45.7)
Married	82 (33.7)
Divorced/Separated/Widowed/Other	50 (20.6)
Cause of Injury	
Vehicular collision	132 (54.3)
Assault	19 (7.8)
Fall	74 (30.5)
Sports/Other	8 (3.3)
Length of PTA*	20.7 (19.1)

*Values represent means and (standard deviations). Note: PTA = post traumatic amnesia in days.

Emergence from PTA was defined by the occurrence of two consecutive scores within a 72-hour period of 25 or above on the O-LOG or 76 or above on the GOAT.

2.4. Data analysis

The sample of 243 participants was split randomly into two groups. The first group consisted of 121 participants (Sample 1) who showed no significant differences from the remaining 122 participants (Sample 2) on any of the key variables or demographics. For Sample 1, the seven components of the PSQI were entered into an exploratory factor analysis (EFA) using maximum likelihood estimation with Promax rotation using IBM SPSS Statistics 21. The number of factors was determined by the lowest eigenvalue greater than 1. The resulting factor structure was then examined in Sample 2 through a confirmatory factor analysis (CFA) performed using AMOS statistical software to construct the models and generate fit indices. To determine goodness of fit, the chi-square value generated by the model was examined in addition to criteria discussed by Hu and Bentler (1999)(Hu & Bentler, 1999):

1. A non-significant chi-square value ($p \geq .05$)
2. Comparative fit index (CFI): ≥ 0.95)
3. Non-normed fit index (NNFI): ≥ 0.95)
4. Root mean squared approximation of error (RMSEA): <0.06

3. Results

The results of the EFA and CFA are summarized in Table 2. The EFA on Sample 1 yielded two factors in 6 iterations. The Promax rotation converged in 3 iterations. Factor 1 accounted for 47.9% of the variance and had item loadings ranging from 0.51 (latency) to 0.93 (duration). Factor 2 accounted for 14.5% of the variance and had item loadings ranging from 0.47 (daytime dysfunction) to 0.67 (sleep disturbance). Factor 1 contains time-related items whereas Factor 2 contains items associated with sleep quality, sleep disturbance, and daytime dysfunction. This model highlights two major aspects of sleep, namely quantity and quality.

The CFA then examined the fit of this factor structure to the second half of the sample. Loadings ranged from 0.63 (latency) to 0.82 (duration) for Factor 1 and 0.31 (medication) to 0.79 (quality) for Factor 2. This structure did not satisfy any of the criteria for a good fitting model (See Table 2). Because the quality item came very close to loading on two factors in the EFA (0.37 on the first factor and 0.51 on the second), an additional model was tested with this quality item removed. This resulted in two distinct factors correlated at 0.85. As can be seen in Table 2, this model satisfied all goodness-of-fit criteria. Internal consistency reliability was acceptable for the first factor (Cronbach's alpha (α) = 0.74) but less than desirable for the second (Cronbach's $\alpha = 0.59$). If sleep quality were included on both scales, there would be a slight improvement in their internal consistency (Cronbach's $\alpha = 0.80$ and 0.67, respectively).

Using the entire sample of 243 participants, three additional models from the literature were tested using CFA. The single factor model illustrates the use of a single Global PSQI score, a linear combination of the seven PSQI components as described by Buysse (1989). The factor loadings in this model ranged from 0.41 (medication) to 0.78 (quality). This model did not meet any of the criteria for goodness of fit (See Table 3).

The two factor model selected for Australian adults (Magee et al., 2008) fit the data as indicated by all the fit indices examined (See Table 3). The three-factor model selected as best for community-dwelling depressed and non-depressed elderly individuals (Cole et al., 2006) also fit the data well according to all fit indices examined.

Internal consistency reliability was examined for the items in the factors for each of the three models. The single factor model had a satisfactory internal consistency (Cronbach's Alpha = 0.80). The factor of Sleep Efficiency from the two factor model (Magee et al., 2008) and three factor model (Cole et al., 2006) showed a satisfactory internal consistency as well (Cronbach's Alpha = 0.75). Factor two for the Magee model also showed a satisfactory internal consistency (Cronbach's Alpha = 0.70). The second and third factor in Cole's model, however, had less than satisfactory internal consistency.

Table 2
Exploratory (EFA) and confirmatory (CFA) factor analysis results

	EFA		CFA 1		CFA 2	
PSQI Components	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2
1. Duration	0.93		0.82		0.68	
2. Efficiency	0.72		0.68		0.51	
3. Latency	0.51		0.63		0.68	
4. Quality		0.51		0.79	[removed]	
5. Medication		0.53		0.31		0.40
6. Disturbance		0.67		0.67		0.73
7. Dysfunction		0.47		0.58		0.66
Cronbach's alpha	0.791	0.691	0.744	0.672	0.744	0.591
Model Properties						
Chi-square	12.86		29.66		7.09	
Degrees of Freedom	$df = 8$		$df = 13$		$df = 7$	
p - value	$p = 0.117$		$p = 0.005$		$p = 0.419$	
CFI			0.932		0.999	
NNFI			0.854		0.998	
RMSEA			0.103		0.010	
RMSEA 90% CI			0.054–0.152		0.000 – 0.113	
Factor Correlations	0.70		0.87		0.85	

Note: CFI = Comparative fit index, NNFI = Non-normed fit index, RMSEA = Root mean squared approximation of error, CI = Confidence interval.

Table 3
A comparison of three different factor models

	Buysse (year)	Magee et al. (year)		Cole et al. (year)		
PSQI Components	Factor 1	Factor 1	Factor 2	Factor 1	Factor 2	Factor 3
1. Duration	0.74	0.92		0.85		
2. Efficiency	0.65	0.68		0.71		
3. Latency	0.61		0.67		0.62	
4. Quality	0.78		0.79		0.81	
5. Medication	0.41		0.32		0.43	
6. Disturbance	0.52		0.67			0.61
7. Dysfunction	0.58		0.59			0.69
Cronbach's alpha	0.80	0.75	0.70	0.75	0.64	0.59
Model Properties						
Chi-square	48.2	16.1		17.2		
Degrees of freedom	$df = 14$	$df = 13$		$df = 11$		
p - value	$p < 0.001$	$p = 0.246$		$p = 0.103$		
CFI	0.926	0.987		0.987		
NNFI	0.852	0.973		0.966		
RMSEA	0.1	0.044		0.048		
RMSEA 90% CI	0.070 – 0.132	0.000 – 0.105		0.000 – 0.090		

Note: CFI = Comparative fit index, NNFI = Non-normed fit index, RMSEA = Root mean squared approximation of error, CI = Confidence interval.

4. Discussion

Consistent with previous research, the current study found that the single-factor model is not the optimal factor structure for the PSQI in persons with TBI.

The two-factor model found in the present study using EFA is not radically different from the multi-factorial models described in the literature. However, the loading of the sleep latency component on the first factor in the present analysis makes a very clear delineation between time-related, quantitative variables and the more subjective components of the PSQI, which has not been found in previous studies where sleep latency tends to cluster with components measuring subjective impression of sleep and daytime performance. The sleep quality item loading on both factors is not surprising, given that both sleep quantity and quality components contribute to one's overall experience of sleeping well.

Recognizing that one's sleep experience has both qualitative and quantitative aspects is important because the two aspects are dissociable. In other words, one may sleep for very long periods of time yet feel that the quality of sleep was poor, and vice versa. There is also clinical utility in this conceptualization because it can be useful in the diagnosis of circadian rhythm disorders with time-related patterns.

One criticism of the two- and three-factor solutions found in previous studies is that they both involve factors with less than three indicators. Interpretation of factors containing only two indicators has been described as "hazardous" (Tabachnick & Fidell, 1996). This is partially due to the tendency of scales to have better internal consistency with a larger number of appropriate parallel items. One criticism of the two-factor model found here is that the internal consistency of the Qualitative factor was less than desirable (Cronbach's alpha below 0.70). Additional research on this factor structure among individuals with TBI is needed, as this is the first time this particular factor structure has been found.

While it may be useful to conceptualize the PSQI as having qualitative and quantitative factors, it is important to keep in mind that the PSQI summary score has an established cut-off that has been used for decades to screen for sleep dysfunction. Additional research is needed to determine the sensitivity and specificity of cut-off scores on the PSQI for individuals with TBI.

Future research can also establish cut-off scores for the qualitative and quantitative factors to examine whether there is any difference in sensitivity, specificity, and overall validity compared with the global score among individuals with TBI. The measure could then be used to better understand sleep after TBI in terms of the predictors, consequences, and other correlates of sleep dysfunction. There is also utility in examining each of the seven components separately. For example, someone who gets into bed for 3 hours per night can have a sleep efficiency score, time asleep divided by time in bed, close to 100% if they are asleep for that entire time. However, examining sleep duration separately could raise concerns about insufficient amount of sleep that might go unnoticed if one is only attuned to global or composite scores.

One trend that was noted in these analyses is that the Medication item showed consistently lower loadings than the other items. In the scale analyses conducted here to determine internal consistency, the medication item yielded the lowest item-total correlation and its removal resulted in improved internal consistency values for the overall scale. Further analysis revealed that this item had a bi-modal distribution with peaks at the extremes 0 (none) and 3 (three or more times in the last month), indicating that individuals used medication either not at all, or very frequently. Future research should examine this item closely to determine its contribution to the overall global PSQI score in terms of how much information it adds to the measurement of sleep quality.

Improved measurement and characterization of sleep and fatigue complaints are essential for appropriate management of somnolence problems in those with TBI. Patients may be inappropriately medicated or otherwise treated when sleep complaints are not well delineated. It is not feasible or reasonable to obtain costly overnight polysomnographic studies for all patients with these complaints. Self-report measures such as the PSQI can be invaluable in "sorting" multiple factors that might contribute to sleep disorders or fatigue. Being able to distinguish between qualitative and quantitative aspects of sleep more reliably will ultimately improve patient care and allow for better subjective evaluation of therapeutic interventions.

There are a number of limitations to this study. As the TBIMS NDB sample is drawn from those individuals with TBI who are admitted to inpatient rehabilitation facilities, the majority have moderate to severe injuries. This study may not represent those with mild injuries not requiring inpatient rehabilitation. Those on the severe end of the TBI severity spectrum were also not fully represented as we only studied those who were admitted to inpatient rehabilitation and were able to independently provide information during the telephone follow-ups. The subjects included in this study tend to reflect the typical preponderance of males in any TBI population; gender differences may be present that are not accounted for in this study. Additionally, the population is skewed towards younger individuals (Corrigan et al., 2012) and those with somewhat higher educational levels than might be expected. Given these limitations, the findings require replication in other TBI populations, particularly those persons with mild to moderate injuries who do not require inpatient rehabilitation and older adults who do. In addition, future studies can examine the clinical utility of the 2-factor model in identifying and managing circadian rhythm disorders.

Conflict of interest

None of the authors have any conflict of interest to disclose.

References

Afonso, P., Figueira, M. L., & Paiva, T. (2011). Sleep-promoting action of the endogenous melatonin in schizophrenia compared to healthy controls. *Int J Psychiatry Clin Pract*, *15*(4), 311-315. doi: 10.3109/13651501.2011.605954

Afsar, B. (2013a). The relation between Internet and social media use and the demographic and clinical parameters, quality of life, depression, cognitive function and sleep quality in hemodialysis patients: Social media and hemodialysis. *Gen Hosp Psychiatry*, *35*(6), 625-630. doi: 10.1016/j.genhosppsych.2013.05.001

Afsar, B. (2013b). The relationship between cognitive function, depressive behaviour and sleep quality with 24-h urinary sodium excretion in patients with essential hypertension. *High Blood Press Cardiovasc Prev*, *20*(1), 19-24. Doi: 10.1007/s40292-013-0002-7

Backhaus, J., Junghanns, K., Broocks, A., Riemann, D., & Hohagen, F. (2002). Test-retest reliability and validity of the Pittsburgh Sleep Quality Index in primary insomnia. *J Psychosom Res*, *53*(3), 737-740. doi: S0022399902003306 [pii]

Baumann, C. R. (2012). Traumatic brain injury and disturbed sleep and wakefulness. *Neuromolecular Med*, 14(3), 205-212. doi: 10.1007/s12017-012-8178-x

Baumann, C. R., Werth, E., Stocker, R., Ludwig, S., & Bassetti, C. L. (2007). Sleep-wake disturbances 6 months after traumatic brain injury: A prospective study. *Brain*, *130*(Pt 7), 1873-1883. doi: 130/7/1873 [pii] 10.1093/brain/awm109

Beck, S. L., Schwartz, A. L., Towsley, G., Dudley, W., & Barsevick, A. (2004). Psychometric evaluation of the Pittsburgh Sleep Quality Index in cancer patients. *J Pain Symptom Manage*, *27*(2), 140-148. doi: 10.1016/j.jpainsymman.2003.12.002

Beetar, J. T., Guilmette, T. J., & Sparadeo, F. R. (1996). Sleep and pain complaints in symptomatic traumatic brain injury and neurologic populations. *Arch Phys Med Rehabil*, *77*(12), 1298-1302. doi: S0003-9993(96)90196-3 [pii]

Burkhalter, H., Sereika, S. M., Engberg, S., Wirz-Justice, A., Steiger, J., & De Geest, S. (2011). Validity of 2 sleep quality items to be used in a large cohort study of kidney transplant recipients. *Prog Transplant*, *21*(1), 27-35.

Buysse, D. J., Reynolds, C. F., 3rd, Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Res*, *28*(2), 193-213. doi: 0165-1781(89)90047-4 [pii]

Carpenter, J. S., & Andrykowski, M. A. (1998). Psychometric evaluation of the Pittsburgh Sleep Quality Index. *J Psychosom Res*, *45*(1), 5-13.

Castriotta, R. J., & Lai, J. M. (2001). Sleep disorders associated with traumatic brain injury. *Arch Phys Med Rehabil*, *82*(10), 1403-1406. doi: S0003-9993(01)45573-0 [pii] 10.1053/apmr.2001.26081

Cavalcanti, P. R., Campos, T. F., & Araujo, J. F. (2013). Circadian and homeostatic changes of sleep-wake and quality of life in stroke: Implications for neurorehabilitation. *NeuroRehabilitation*, *32*(2), 337-343. doi: 10.3233/NRE-130853.

Cole, J. C., Motivala, S. J., Buysse, D. J., Oxman, M. N., Levin, M. J., & Irwin, M. R. (2006). Validation of a 3-factor scoring model for the Pittsburgh sleep quality index in older adults. *Sleep*, *29*(1), 112-116.

Corrigan, J. D., Cuthbert, J. P., Whiteneck, G. G., Dijkers, M. P., Coronado, V., Heinemann, A. W., Graham, J. E., et al. (2012). Representativeness of the Traumatic Brain Injury Model Systems National Database. *J Head Trauma Rehabil*, *27*(6), 391-403. doi: 10.1097/HTR.0b013e3182238cdd

Engstrom, M., Hagen, K., Bjork, M. H., Stovner, L. J., Gravdahl, G. B., Stjern, M., & Sand, T. (2013). Sleep quality, arousal and pain thresholds in migraineurs: A blinded controlled polysomnographic study. *J Headache Pain*, *14*(1), 12. doi: 10.1186/1129-2377-14-12.

Fichtenberg, N. L., Zafonte, R. D., Putnam, S., Mann, N. R., & Millard, A. E. (2002). Insomnia in a post-acute brain injury sample. *Brain Inj*, *16*(3), 197-206. doi: 10.1080/02699050110103940

Fictenberg, N. L., Putnam, S. H., Mann, N. R., Zafonte, R. D., & Millard, A. E. (2001). Insomnia screening in postacute traumatic brain injury: Utility and validity of the Pittsburgh Sleep Quality Index. *Am J Phys Med Rehabil*, *80*(5), 339-345.

Gentili, A., Weiner, D. K., Kuchibhatil, M., & Edinger, J. D. (1997). Factors that disturb sleep in nursing home residents. *Aging (Milano)*, *9*(3), 207-213.

Grandner, M. A., Kripke, D. F., Yoon, I. Y., & Youngstedt, S. D. (2006). Criterion validity of the Pittsburgh Sleep Quality Index: Investigation in a non-clinical sample. *Sleep Biol Rhythms*, *4*(2), 129-139. doi: 10.1111/j.1479-8425.2006.00207.x

Guilleminault, C., Faull, K. F., Miles, L., & van den Hoed, J. (1983). Posttraumatic excessive daytime sleepiness: A review of 20 patients. *Neurology*, *33*(12), 1584-1589.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1-55.

Jackson, W. T., Novack, T. A., & Dowler, R. N. (1998). Effective serial measurement of cognitive orientation in rehabilitation: The Orientation Log. *Arch Phys Med Rehabil*, *79*(6), 718-720.

Karkare, K., Sinha, S., Taly, A. B., & Rao, S. (2013). Prevalence and profile of sleep disturbances in Guillain-Barre Syndrome: A prospective questionnaire-based study during 10 days of hospitalization. *Acta Neurol Scand*, *127*(2), 116-123. doi: 10.1111/j.1600-0404.2012.01688.x

Kempf, J., Werth, E., Kaiser, P. R., Bassetti, C. L., & Baumann, C. R. (2010). Sleep-wake disturbances 3 years after traumatic brain injury. *J Neurol Neurosurg Psychiatry*, *81*(12), 1402-1405. doi: jnnp.2009.201913 [pii] 10.1136/jnnp.2009.201913

Knutson, K. L., Rathouz, P. J., Yan, L. L., Liu, K., & Lauderdale, D. S. (2006). Stability of the Pittsburgh Sleep Quality Index and the Epworth Sleepiness Questionnaires over 1 year in early middle-aged adults: The CARDIA study. *Sleep*, *29*(11), 1503-1506.

Levin, H. S., O'Donnell, V. M., & Grossman, R. G. (1979). The Galveston Orientation and Amnesia Test. A practical scale to assess cognition after head injury. *J Nerv Ment Dis*, *167*(11), 675-684.

Magee, C. A., Caputi, P., Iverson, D. C., & Huang, X. (2008). An Investigation of the dimensionality of the Pittsburgh Sleep Quality Index in Australian adults. *Sleep and Biological Rhythms*, *6*(4), 222-227.

Makley, M. J., English, J. B., Drubach, D. A., Kreuz, A. J., Celnik, P. A., & Tarwater, P. M. (2008). Prevalence of sleep disturbance in closed head injury patients in a rehabilitation unit. *Neurorehabil Neural Repair*, *22*(4), 341-347. doi: 10.1177/1545968308315598

Mariman, A., Vogelaers, D., Hanoulle, I., Delesie, L., & Pevernagie, D. (2012). Subjective sleep quality and daytime sleepiness in a large sample of patients with chronic fatigue syndrome (CFS). *Acta Clin Belg*, *67*(1), 19-24.

Mathias, J. L., & Alvaro, P. K. (2012). Prevalence of sleep disturbances, disorders, and problems following traumatic brain injury: A meta-analysis. *Sleep Med*, *13*(7), 898-905. doi: 10.1016/j.sleep.2012.04.006

Nakase-Richardson, R., Sherer, M., Barnett, S. D., Yablon, S. A., Evans, C. C., Kretzmer, T., Modarres, M., et al. (2013). Prospective evaluation of the nature, course, and impact of acute sleep abnormality after traumatic brain injury. *Arch Phys Med Rehabil*, *94*(5), 875-882. doi: 10.1016/j.apmr.2013.01.001

Orff, H. J., Ayalon, L., & Drummond, S. P. (2009). Traumatic brain injury and sleep disturbance: A review of current research. *J Head Trauma Rehabil*, *24*(3), 155-165. doi: 10.1097/HTR.0b013e3181a0b281

Parcell, D. L., Ponsford, J. L., Rajaratnam, S. M., & Redman, J. R. (2006). Self-reported changes to nighttime sleep after traumatic brain injury. *Arch Phys Med Rehabil*, *87*(2), 278-285. doi: S0003-9993(05)01360-2 [pii] 10.1016/j.apmr.2005.10.024

Soler, X., Diaz-Piedra, C., & Ries, A. L. (2013). Pulmonary rehabilitation improves sleep quality in chronic lung disease. *COPD*, *10*(2), 156-163. doi: 10.3109/15412555.2012.729622

Tabachnick, B. G., & Fidell, L. S. (1996). Using Multivariate Statistics. New York: Harper Collins.