The Egyptian Journal of Hospital Medicine (October 2024) Vol. 97, Page 4220-4225

Validation of an Excel-Based Tool for Automated Calculation of the Pittsburgh Sleep Quality Index: Accuracy and Efficiency Assessment

Ahmed Hamdy
Neurology Department, Faculty of Medicine, Mansoura University, Egypt
E-mail: ahmedhamdy@mans.edu.eg, **Mobile**: +201063654245, **Orcid**: 0000-0002-3646-9594

ABSTRACT
Background: The Pittsburgh Sleep Quality Index is a widely used tool for evaluating sleep quality, but manual scoring can be time-consuming and error prone. **Objectives**: To develop and validate an Excel-based automated tool for calculating Pittsburgh Sleep Quality Index scores, assessing its accuracy and quantifying time savings compared to manual calculations.
Subjects and Methods: A cross-sectional study was conducted with 100 participants recruited from patients attending the Neurology Department's Sleep Clinic of Mansoura University Hospital and healthy volunteers from the hospital staff. Pittsburgh Sleep Quality Index scores were calculated both manually and using the automated Excel tool. Accuracy was assessed by comparing component and global Pittsburgh Sleep Quality Index scores between methods. Time efficiency was evaluated by comparing calculation times.
Results: Perfect agreement was found between manual and automated calculations for all Pittsburgh Sleep Quality Index components and global scores (intraclass correlation coefficient = 1.0). The automated method significantly reduced calculation time by 45% (manual: 9.19 ± 1.50 minutes; automated: 5.02 ± 0.68 minutes; $p < 0.0001$).
Conclusion: The Excel-based automated Pittsburgh Sleep Quality Index calculation tool showed perfect accuracy and significantly improved efficiency compared to manual scoring. This tool has the potential to enhance both clinical practice and sleep research by streamlining Pittsburgh Sleep Quality Index assessments.
Keywords: questionnaire, Pittsburgh Sleep Quality Index, Sleep assessment, Automated scoring, Validation study.

INTRODUCTION

Sleep quality is a critical component of overall health and well-being, affecting various aspects of mental and physical health [1,2]. The Pittsburgh Sleep Quality Index (PSQI) is one of the most widely used instruments for evaluating sleep quality and disruptions over a one-month period, developed in 1989 by **Buysse *et al.*** [3]. The PSQI has since been validated in various populations and translated into multiple languages, making it the gold standard for clinical use and research.

PSQI's strength lies in its comprehensive approach. It consists of 19 distinct items, that are grouped into seven component scores, each evaluating a certain aspect of sleep. These components include: (1) subjective sleep quality, (2) sleep latency, (3) sleep duration, (4) habitual sleep efficiency, (5) sleep disturbances, (6) use of sleep medications, and (7) daytime dysfunction [4].

Multiple processes are involved in the manual calculation of the PSQI. The first step is to translate each of the 19 items' responses into numerical values using predetermined standards. Seven component scores, each ranging from 0 to 3, are then obtained by adding these numbers. The global PSQI score, which goes from 0 to 21, is finally calculated by adding the scores of these seven component parts; greater scores indicate lower sleep quality [3]. Even though this procedure seems simple, processing huge amounts of data in clinical and research settings makes it difficult.

Manual scoring is prone to errors because each response must be carefully interpreted and converted into its respective component score, with any mistakes potentially leading to inaccurate global scores. This problem is further compounded when handling large datasets or performing longitudinal assessments, where manual scoring of the PSQI becomes both time-consuming and inefficient. Research staff or clinicians must spend a considerable amount of time scoring each questionnaire, which increases the likelihood of delays in data processing and decision-making. Additionally, human error in manual scoring can result in inconsistent results, which can affect the reliability of the PSQI as an assessment tool.

In an era where digital tools are increasingly integrated into clinical and research workflows [5], there is a clear need for automated solutions that can promote the accuracy and efficiency of PSQI scoring. The development of automated tools, such as the Excel-based solution proposed in this study, addresses these challenges by streamlining the scoring process, reducing the risk of errors, and improving the overall efficiency of PSQI assessment. Automation in data processing not only minimizes the potential for human error but also enables quick data analysis, which speeds up research procedures and enables prompt clinical decision-making [6]. Despite the availability of numerous scoring instruments and software for different psychometric assessments, there is a lack of validated automated tools specifically designed for PSQI. Addressing this gap could greatly increase workflow efficiency in both research and clinical contexts, enabling more accurate and quick processing of data on sleep quality data.

The primary objective of this study is to develop an Excel-based tool that automates the calculation of the PSQI score. Excel was chosen because it is widely available and familiar among clinicians and researchers,

Received: 26/06/2024
Accepted: 27/08/2024

making the tool accessible without the need for specialized software. This tool is designed to automatically calculate both the component scores and the global PSQI score upon data entry, thus decreasing the need for manual calculation. To guarantee the tool's accuracy and efficiency, its output is checked against manually calculated PSQI scores in a sample population. Additionally, the study aimed to quantify the time savings achieved by using the automated tool over manual scoring. This study will share to the growing body of literature on the digitization of healthcare instruments and the continuous attempts to incorporate technology into clinical practice to improve patient outcomes.

PATIENTS AND METHODS

This study employed a cross-sectional design to evaluate accuracy and efficiency of an Excel-based tool for automating the calculation of the Pittsburgh Sleep Quality Index (PSQI). 100 participants were recruited during the year 2024 from patients attending the Neurology Department's Sleep Clinic of Mansoura University Hospital and healthy volunteers from the hospital staff. Sample size was estimated based on that the primary outcome for accuracy was the Intraclass Correlation Coefficient (ICC) between manual and automated methods. Based on previous literature on similar tools [7], an ICC of at least 0.90 was anticipated, with a lower bound of the 95% confidence interval no less than 0.85. Using a two-tailed test with a power of 80% (β = 0.20) and a significance level of 5% (α = 0.05), a minimum of 84 participants was needed. To account for potential incomplete or invalid data (15% dropout rate), the final sample size was set at 100 participants.

The inclusion criteria were adults aged 18 years and older, either from patients attending sleep outpatient clinic or from healthy volunteers from the hospital staff. Individuals who were unable to complete the PSQI questionnaire due to cognitive impairments or language barriers were excluded.

Manual Calculation:

Each participant completed the PSQI questionnaire, which included 19 self-rated questions assessing various aspects of sleep quality over the past month. Responses were collected through face-to-face interviews by a well-trained staff, familiar with using the questionnaire, ensuring that all sections of the PSQI were completed.

Excel Tool Development: The Excel tool was designed to mirror the structure of the PSQI questionnaire, automating the calculation of the seven component scores and the global PSQI score**.** Formulas were implemented to replicate the scoring algorithm of the PSQI, including conversion of raw responses to component scores and calculation of the global PSQI score**.** The interface is user-friendly and allows for quick data entry.

Automated Calculation: The same data obtained for each participant's questionnaire was entered into the Excel tool by the same interviewing staff to automatically calculate the PSQI scores and to compare the accuracy of its results with the manual method.

Efficiency Assessment:

Time was recorded for the manual calculation process and the automated calculation process (including data entry time). Time measurement was conducted using a digital stopwatch with recording precision to the nearest second. Time recording was begun at the start of data entry/calculation and end when the final PSQI score was obtained. Both start and end times were documented for each method.

Ethical Approval:

The study was approved by the Institutional Review Board (IRB) of Mansoura University (IRB code: R.24.09.2811.R2). All participants signed informed consent before enrollment in the study. The Helsinki Declaration was followed throughout the study's conduct.

Statistical Analysis: IBM SPSS Statistics for Windows, version 25 was used for the statistical analysis (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated, including means and standard deviations for participant demographics and PSQI component and global scores for both manual and automated methods. Agreement between manual and automated scoring methods were assessed using a consistent set of analyses: Intraclass Correlation Coefficients (ICC) with 95% confidence intervals (with ICC values $\geq$0.90 indicating excellent agreement [8]), paired t-tests, and percentage of perfect matches. Bland-Altman plot was generated to visualize the level of agreement between scoring methods [9]. Time efficiency analysis compared the duration of manual versus automated calculations by computing mean differences and standard deviations, with statistical significance assessed via paired t-test. The magnitude of time savings was quantified using Cohen's d effect size, and the percentage of time saved through automation was calculated. A p-value of $\leq$ 0.05 was considered statistically significant.

RESULTS

Participant Characteristics:

The study included 100 participants with a mean age of 29.63 years (SD = 7.95). Gender distribution was nearly balanced with 57% male and 43% female participants (Table 1).

Table (1): Age and Gender Statistics:

Parameter	**Sub-Parameter**	**Value**
Age	Mean	29.63
	Standard deviation	7.95
Gender	Male Count	57
	Male Percentage	57.0%
	Female Count	43
	Female Percentage	43.0%

48% of the participants reported sleep complaints. The most common complaints were insomnia (19%), snoring (12%), and daytime sleepiness (8%). 52% of the participants were healthy volunteers (Table 2).

Table (2): Sleep Complaints among Participants:

Sleep Complaint	Count	Percentage
No Complaints	52	52.0%
Insomnia	19	19.0%
Snoring	12	12.0%
Daytime Sleepiness	8	8.0%
Bad Dreams	6	6.0%
Sleep Apnea	3	3.0%

Accuracy assessment:

Perfect agreement was observed between manual and automated PSQI calculations across all seven components and the global PSQI score. Both methods yielded identical means and standard deviations for each component and the global score. Intraclass Correlation Coefficients (ICC) of 1.0 for all components and the global score confirmed perfect agreement between manual and automated methods (Table 3). The Bland-Altman plot also showed perfect agreement between manual and automated methods for the global PSQI score, with all points falling on the zero-difference line. This visual representation further confirmed the accuracy of the automated calculation method (Figure 1).

Table (3): Manual vs. Automated PSQI Calculation:

Component	Manual Mean (SD) n=100	Automated Mean (SD) n=100	p-value	Perfect Match (%)	ICC Value
Component 1	0.92 (1.03)	0.92 (1.03)	1	100%	1.0
Component 2	0.91 (0.84)	0.91 (0.84)	1	100%	1.0
Component 3	1.00 (0.92)	1.00 (0.92)	1	100%	1.0
Component 4	0.86 (0.80)	0.86 (0.80)	1	100%	1.0
Component 5	1.55 (0.61)	1.55 (0.61)	1	100%	1.0
Component 6	0.41 (0.64)	0.41 (0.64)	1	100%	1.0
Component 7	0.78 (1.01)	0.78 (1.01)	1	100%	1.0
Global PSQI	6.43 (3.96)	6.43 (3.96)	1	100%	1.0
Time (min.)	9.19 (1.50)	5.02 (0.68)	<0.0001	-	-

PSQI: Pittsburg Sleep Quality Index, ICC: Intraclass Correlation Coefficient

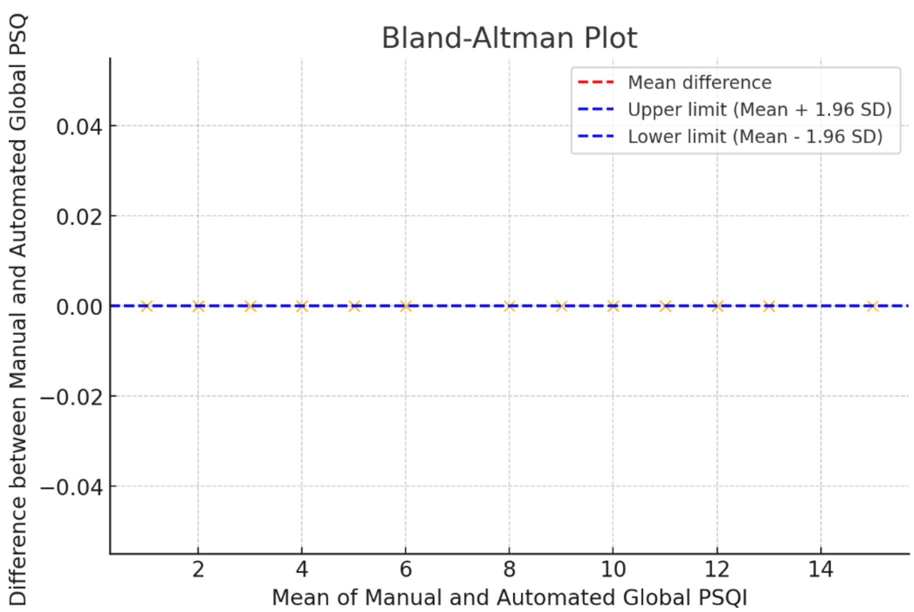

Figure (1): Bland-Altman plot for the difference between manual and automated global PSQI.

Time Efficiency:

The automated method demonstrated significant time savings compared to the manual method. On average, manual calculation took 9.19 minutes (SD = 1.50), while the automated method required only 5.02 minutes (SD = 0.68). This difference was statistically significant (t (99) = 25.63, p < 0.0001) with a large effect size (Cohen's d = 3.67). The automated method reduced calculation time by 45%, representing a substantial improvement in efficiency (Table 4 and figure 2).

Table (4): Time efficiency analysis in manual versus automated calculation:

Metric	Value
Mean Manual Time (min)	9.19 ± 1.50
Mean Automated Time (min)	5.02 ± 0.68
Paired t-test	25.63
Degrees of freedom (Df)	99
P-value	<0.0001
Effect Size (Cohen's d)	3.67
Percentage of Time Saved	45%

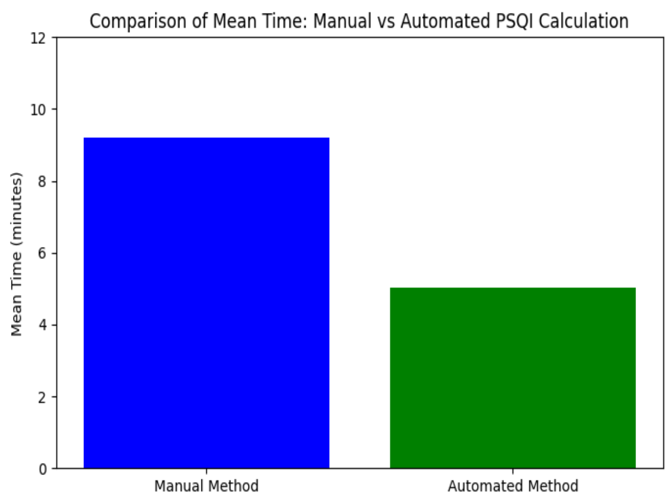

Figure (2): A bar graph comparing the mean time in the manual vs automated PSQI calculation.

These results demonstrate that the developed automated PSQI calculation tool provided perfectly accurate results across a diverse sample of participants, with significant reduction of the time required for score calculation. This automated tool has been made available for clinical and research use at https://doi.org/10.6084/m9.figshare.27868671.v2 [10].

DISCUSSION

This study presents the first validated Excel-based automated calculation tool for the Pittsburgh Sleep Quality Index (PSQI). Our findings demonstrate perfect agreement between the automated and manual calculation methods, coupled with a significant reduction in calculation time. These results have important implications for both clinical practice and sleep research.

Novelty and Comparison with Manual Scoring

Our Excel-based tool represents a novel approach to PSQI scoring. Since its introduction by **Buysse *et al.*** [3], the PSQI has been widely used in sleep research and clinical practice. However, manual scoring of the PSQI can be time-consuming and prone to human error, particularly when dealing with large datasets. Our automated tool addresses these challenges directly.

The perfect agreement observed between manual and automated calculations for all PSQI components, and the global score is a key finding of this study. This level of accuracy ensures that the automated method can be used with confidence in various settings, from individual patient assessments to large-scale research studies. Moreover, the significant reduction in calculation time (45% decrease) represents a substantial improvement in efficiency. With the manual method taking an average of 9.19 minutes and the automated method only 5.02 minutes, the time savings could be considerable, especially in settings where multiple PSQI assessments are performed regularly.

Implications for Clinical Practice

The development of this automated PSQI scoring tool has several important implications for clinical practice. As **Hartmann *et al.*** [11] emphasized, efficient and accurate assessment of subjective sleep quality is crucial in clinical settings, our tool could significantly streamline the process of sleep quality assessment in busy clinical environments.

The time saved through automation could be redirected to other aspects of patient care, potentially allowing for more comprehensive sleep evaluations. Furthermore, the reduced time and effort required might encourage more widespread and frequent use of the PSQI in clinical practice, leading to improved monitoring of sleep quality over time.

The Excel-based format of our tool also enhances its accessibility, as Microsoft Excel is commonly available in most clinical settings. This wide availability, combined with the tool's ease of use, could reduce barriers to implementing standardized sleep quality assessments in various healthcare contexts. Also, the automated nature of the tool could reduce the need for extensive training in PSQI scoring, making it more feasible to implement in various healthcare settings.

Comparison with Other Automated Health Assessment Tools

While our study focuses specifically on PSQI automation, it is worth considering our approach in the context of other automated health assessment tools. For instance **Torous *et al.*** [7] developed a smartphone application for automated assessment of depressive symptoms using the Patient Health Questionnaire-9 (PHQ-9). Although their focus was on depression rather than sleep, their work demonstrates the growing trend towards automation in mental health assessments.

Similar to **Torous *et al.*** 's [7] findings, our results show that automation can significantly improve the efficiency of health assessments without compromising accuracy. However, our Excel-based approach offers unique advantages in terms of accessibility and ease of integration into existing clinical and research workflows, as it does not require the development and distribution of a specialized application.

Potential for Research Applications

The efficiency gains provided by our automated PSQI tool could have substantial implications for sleep research. As demonstrated by **Pilz *et al.*** [12], accurate analyses of PSQI data can yield important insights into sleep quality patterns, such as differences between workdays and free days. Our tool could make these complex analyses easier by enabling researchers to process larger datasets more quickly and with a lower chance of calculation errors.

Moreover, the tool's accuracy and efficiency could allow for more frequent longitudinal assessments of sleep quality in research settings. This could result in more detailed tracking of sleep patterns over time, potentially revealing subtle changes that might be missed with less frequent assessments.

Limitations and Future Directions

Despite the strong results, some considerations remain. While our sample included participants with a variety of sleep complaints, more research could evaluate the tool's usability in a variety of clinical and research settings to make sure it satisfies the practical needs of a wide range of users. Additionally, while the single-center design had no effect on the fixed scoring algorithm, future studies could investigate the tool's integration within different workflow systems to improve its generalizability and potential for wider implementation.

Future research directions could include

1. Incorporating the automated tool with electronic medical records to further streamline sleep quality assessments in clinical settings.
2. Creating a web or mobile version of the tool to increase accessibility and enable remote sleep quality assessments.
3. Examining how the increased efficiency from automation could influence clinical decision-making and research results in the field of sleep medicine.
4. Investigation of the tool's potential role in facilitating the development and validation of shorter sleep quality measures, as suggested by **Yu *et al.*** [13] in their work on short-form sleep disturbance measures.

Broader Implications for Sleep Medicine

The development and validation of this automated PSQI scoring tool align with broader initiatives to enhance sleep health evaluation and management. As **Buysse** [14] argued, the concept of sleep health goes beyond the absence of sleep disorders and encompasses positive sleep attributes linked to physical, mental, and neurobehavioral well-being.

Our tool, by enabling more efficient and precise assessment of sleep quality, could contribute to these broader efforts in several ways:

1. Allowing for more routine evaluation of sleep quality in primary healthcare settings, potentially leading to earlier identification and intervention for sleep issues.
2. Facilitating larger-scale epidemiological studies on sleep quality, which could improve our understanding of population-level sleep health.
3. Promoting the incorporation of standardized sleep quality assessments into research on various health conditions, given the increasing recognition of sleep's impact on overall health.

CONCLUSION

This automated Excel-based tool for PSQI calculation marks a significant step forward in sleep quality assessment. By combining flawless accuracy with enhanced efficiency, it has the potential to improve both clinical practice and sleep research. As we continue to recognize sleep's crucial role in overall health, tools that enable accurate and efficient sleep quality evaluation will become increasingly important. Future studies should explore its potential integration with other health assessment and management systems.

Conflict of interest: Author declares no conflict of interest.

Sources of funding: No fund was received.

REFERENCES

1- **Medic G, Wille M, Hemels M (2017):** Short-and long-term health consequences of sleep disruption. Nature and Science of Sleep, 9:151-61.
2- **Grandner M (2022):** Sleep, health, and society. Sleep Medicine Clinics, 17(2):117-39.
3- **Buysse D, Reynolds C, Monk T *et al.* (1989):** The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry research, 28(2):193-213.
4- **Mollayeva T, Thurairajah P, Burton K *et al.* (2016):** The Pittsburgh sleep quality index as a screening tool for sleep dysfunction in clinical and non-clinical samples: A systematic review and meta-analysis. Sleep Medicine Reviews, 25:52-73.
5- **Bates D, Wright A (2009):** Evaluating eHealth: undertaking robust international cross-cultural eHealth research. PLoS Medicine, 6(9): e1000105.
6- **Davenport T, Kalakota R (2019):** The potential for artificial intelligence in healthcare. Future Healthcare Journal, 6(2):94-8.
7- **Torous J, Staples P, Shanahan M *et al.* (2015):** Utilizing a personal smartphone custom app to assess the patient health questionnaire-9 (PHQ-9) depressive symptoms in patients with major depressive disorder. JMIR Mental Health, 2(1): e3889.
8- **Shrout P, Fleiss J (1979):** Intraclass correlations: uses in assessing rater reliability. Psychological Bulletin, 86(2):420.
9- **Bland J, Altman D (2010):** Statistical methods for assessing agreement between two methods of clinical measurement. International Journal of Nursing Studies, 47(8):931-6.
10- **Hamdy A (2024):** Excel-based PSQI scoring tool. Figshare. https://doi.org/10.6084/m9.figshare.27868671.v2.
11- **Hartmann J, Carney C, Lachowski A *et al.* (2015):** Exploring the construct of subjective sleep quality in patients with insomnia. The journal of Clinical Psychiatry, 76(6):6984.
12- **Pilz L, Keller L, Lenssen D *et al.* (2018):** Time to rethink sleep quality: PSQI scores reflect sleep quality on workdays. Sleep, 41(5): zsy029.
13- **Yu L, Buysse D, Germain A *et al.* (2012):** Development of short forms from the PROMIS™ sleep disturbance and sleep-related impairment item banks. Behavioral Sleep Medicine, 10(1):6-24.
14- **Buysse D (2014):** Sleep health: can we define it? Does it matter? Sleep, 37(1):9-17.