Revista Médica del
Hospital General de México

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ORIGINAL ARTICLE

Development and validation of an instrument to measure sleep deprivation, sleepiness, and executive function in medical residents: cross-sectional study

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Abstract

Introduction: *Residents are constantly exposed to sleep deprivation. The daily recommendation is at least 7 h of sleep per night. Failure to do so leads to deterioration in neurocognitive function and executive functions, as well as a greater risk of errors and accidents.* **Objective:** *The objective of the study was to validate an instrument to measure sleep deprivation, planning, inhibitory control, cognitive flexibility, working memory, emotional control, and sleepiness in residents.* **Material and methods:** *An instrument was designed, and a validation study was conducted with a quantitative cross-sectional method. Validation is done by nine experts employing criteria of univocity and pertinency, along with a pilot study involving 52 residents and a reliability analysis using Cronbach's alpha.* **Results:** *According to an expert judgment, 48 items were retained in their original form and 4 were modified (item 2 Ui 0.77, Pi 0.81; item 6 Ui 0.74, Pi 0.70, item 8 Ui 0.62, Pi 0.74; item 30 Ui 0.77, Pi 0.85), with no items removed. By stratifying the items corresponding to each domain, a Cronbach's alpha of.956 was obtained for sleepiness; 0.909 for working memory; of 0.899 for inhibitory control; 0.890 for cognitive flexibility; of 0.903 for planning and 0.942 for emotional control.* **Conclusion:** *The instrument is valid and reliable for measuring sleep deprivation, planning, inhibitory control, cognitive flexibility, working memory, emotional control, and sleepiness in residents.*

Keywords: *Executive functions. Sleep deprivation. Residency. Validation study.*

Introduction

The American Academy of Sleep Medicine and the Sleep Research Society recommend that individuals obtain at least 7 h of sleep per night to promote optimal health[1]. It is well-established that failing to meet this recommendation can lead to a range of adverse health outcomes, including obesity, diabetes, hypertension, coronary heart disease, depression, and declines in neurocognitive function and attention[2]. Sleep disturbances are ubiquitous and not necessarily specific, but sleep manipulations have powerful effects on clinical state, and even precede a psychotic event[3].

However, achieving the recommended amount of sleep can be challenging for some individuals due to various factors, including medical conditions and professional responsibilities. This is particularly true for medical specialty residents -physicians who are training in specific areas of medicine – who often endure extended shifts exceeding 24 consecutive h multiple times a week[4]. In Mexico, the most recent regulation regarding the organization and functioning of medical residencies, NOM-001-SSA3-2023, mandates that schedules should not exceed 80 h/week on average annually, including regular work hours and on-call duties.

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Date of reception: 23-05-2025
Date of acceptance: 27-08-2025
DOI: 10.24875/HGMX.25000039

Available online: 24-04-2026
Rev Med Hosp Gen Mex. 2026;89(2):64-68
www.hospitalgeneral.mx

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An interesting Mexican study also examines the impact of the first 6 months of the residency program at the *Hospital General de México Dr. Eduardo Liceaga*, in Mexico City, on several physiological and emotional aspects, particularly concerning the personality traits of resident doctors from various specialties[5].

The validity of an instrument refers to its ability to accurately measure the variable it intends to assess[6]. Conversely, reliability pertains to the consistency of results produced by an assessment tool when used in the same environment with similar subjects. Reliability is a crucial component of an instrument's validity[7].

Cronbach's alpha, a measure developed by Lee Cronbach in 1951, assesses the internal consistency of a questionnaire or scale. It is expressed on a scale from 0 to 1, with values closer to 1 indicating greater internal consistency[8]. Internal consistency reflects the extent to which all items in a questionnaire measure the same construct and must be evaluated before an instrument can be employed for research purposes[8].

Expert judgment validation is also integral to the validation process. This can be performed using Carrera's method[9], which involves selecting from various levels of univocity and pertinency ranging from 0 (null) to 3 (optimal).

As noted, sleep deprivation is prevalent among resident physicians and can adversely affect their executive functions, leading to heightened levels of sleepiness[10]. García et al.[11] indicate that 24 h of sleep deprivation diminishes various components of cognitive processing essential for daily activities, thereby increasing the risk of errors and accidents. Massar et al.[12] found that sleep deprivation on 24-h shift schedules is associated with greater irregularity and poorer sleep quality, increased sleepiness, and impaired executive functions such as working memory and vigilance. Despite this knowledge, measuring these variables within this population remains uncommon due to a lack of validated instruments.

Consequently, there is a pressing need to develop an instrument that accurately measures these variables among resident physicians while ensuring its validity and reliability.

Materials and methods

A validation study was conducted using a quantitative cross-sectional methodology outlined by Hernández-Sampieri et al.[6]. The study followed a structured procedure comprising several phases, detailed below.

Phase 1: instrument integration

A thorough literature review was conducted to identify the BRIEF-A questionnaire[13] and the Epworth Sleepiness Scale[14]. These instruments served as foundational references for the development of the instrument to be validated in this study (Supplementary data, Annex 1).

Phase 2: validation by expert judgment

For content validation, the instrument was reformatted into a Google Forms template and subsequently distributed via email to 18 judges recognized as experts in the field, each holding at least a master's degree and possessing relevant research experience. The validation process employed Carrera's method[9], wherein each expert assessed the uniqueness and relevance of each item, selecting from various levels of univocity (Table 1) and pertinency (Table 2): optimal, high, low, and null.

Following this assessment, the univocity index (Ui) for each item was calculated based on the following criteria:

- If Ui ≥ 0.80: items remain in their original form
- If 0.79 ≥ Ui ≥ 0.60: items are modified in wording
- If Ui ≤ 0.59: items are excluded.

The pertinency index (Pi) was similarly calculated for each item with these thresholds:

- If Pi ≥ 0.80: items remain unchanged.
- If 0.79 ≥ Pi ≥ 0.60: items are revised in wording or placement.
- If Pi ≤ 0.59: items are removed.

Phase 3: reliability analysis

A pilot test was conducted involving resident physicians. The instrument was adapted into a Google Forms format and disseminated to resident physicians via email and instant messaging. The collected responses were analyzed using IBM Statistical Package for the Social Sciences (SPSS) Statistics version 29.0.1.0 software, with items stratified by domain and Cronbach's alpha calculated to assess reliability.

The procedures described adhere to the ethical standards of the Hospital's IRB (CEI-0189-2017) and the University's IRB (CI-006-21), following the 1964 Declaration of Helsinki and its subsequent revisions (including that of the 75th General Assembly in Helsinki, Finland, in October 2024). Both committees are registered with the National Bioethics Commission of the Ministry of Health. Finally, informed consent was

Table 1. Definition of the levels on the univocity scale

Level of univocity	Meaning	Assigned value
Optimal univocity	The item can be understood or interpreted unequivocally in one and only one way	3
High univocity	The item is open to interpretation, but can generally be understood in one way	2
Low univocity	The item can be understood in various ways and leans more toward ambiguity	1
Null univocity	The item is likely not to be understood or interpreted with widely differing meanings, falling within ambiguity.	0

Adapted from Carrera et al.[7].

Table 2. Definition of the levels on the pertinency scale

Level of pertinency	Meaning	Assigned value
Optimal pertinency	The item can unequivocally belong to the collective and age group it is directed towards	3
High pertinency	The item can mostly belong to the collective and age group it is directed towards	2
Low pertinency	The item can belong to different collectives and age groups or may be less relevant to the collective and age group	1
Null pertinency	The item may not belong to the collective and age group or may not be relevant to the collective or age group it is directed towards	0

Adapted from Carrera et al.[7].

obtained from the residents through the Google Forms format.

Results

Phase 1: instrument integration

An instrument was developed consisting of a total of 52 items, designed to collect socio-demographic data from participants and to measure the following variables: sleep deprivation (1 item), sleepiness (10 items), inhibitory control (8 items), cognitive flexibility (6 items), working memory (8 items), planning (9 items), and emotional control (10 items).

Phase 2: validation by expert judgment

A total of nine responses were received from the expert judges. The demographic profile of the respondents included three males and six females. On average, the experts possessed 9.4 years of research experience (standard deviation = 7.31). Among them, seven held doctoral degrees, two had master's degrees, and one of the latter also possessed a medical specialty.

Based on the assessments of univocity and pertinency, 48 items were retained in their original form, while four items were modified as follows: item 2 (Ui = 0.77, Pi = 0.81), item 6 (Ui = 0.74, Pi = 0.70), item 8 (Ui = 0.62, Pi = 0.74), and item 30 (Ui = 0.77, Pi = 0.85). No items were eliminated from the instrument (Table 3).

Phase 3: reliability analysis

The study included participation from 52 resident physicians, whose responses were analyzed using SPSS software. Items were stratified according to their respective domains. The following Cronbach's alpha values were obtained: 0.956 for sleepiness, 0.909 for working memory, 0.899 for inhibitory control, 0.890 for cognitive flexibility, 0.903 for planning, and 0.942 for emotional control (Table 4). The corrected item-total correlation ranged from 0.424 to 0.869; however, item number one exhibited a negative correlation. Despite this finding, it was decided to retain item one due to its necessity within the instrument; only its wording was modified.

Discussion

Sleep deprivation and its impact on executive functions in resident physicians is a worldwide-recognized problem, with direct implications for patients' security, medical staff well-being, and the quality of medical care[15,16]. However, the precise and contextualized measurement of these phenomena has been limited by the absence of validated instruments adapted to the reality of the residents.

In this sense, the generation and validation of the instrument presented in this study constitute a fundamental advance for both research and clinical practice.

Concerns regarding patient safety and the clinical resident's well-being led to the implementation of restrictions for residents' working hours by the US Accreditation Council for Graduate Medical Education[17]

Table 3. List of items modified due to lack of univocity and/or pertinency

Original item	Ui	Pi	Modified item
At this moment, how likely are you to tap your fingers or compulsively move your legs?	0.77	0.81	At this moment, how likely are you to compulsively move your legs or hands?
At this moment, how likely is it that others think I get easily distracted?	0.74	0.70	At this moment, how likely is it that I get easily distracted?
At this moment, how likely is it that I have trouble waiting my turn?	0.62	0.74	At this moment, how likely is it that I have difficulty in staying patient while waiting my turn in a line?
At this moment, how likely is it that I have a low ability to concentrate?	0.77	0.85	At this moment, how likely is it that I find hard to concentrate?

Ui: univocity index; Pi: pertinency index.

Table 4. List of domains, number of items, and Cronbach's alpha for each domain

Domain	Number of items	Cronbach's alpha
Sleepiness	10	0.956
Working memory	8	0.909
Inhibitory control	8	0.899
Cognitive flexibility	6	0.890
Planning	9	0.903
Emotional control	10	0.942

and the Mexican Health Department (NOM-001-SSA3-2023), and the European Working Time Directive[18], which limit a resident's number of continuous on-duty hours to 80 and 48 h, respectively.

The international literature, including the paper of Choshen-Hillel et al.[19], has shown that both acute and chronic sleep deprivation significantly impair executive function, attention, and emotional regulation in medical residents. However, most studies have used complex neuropsychological batteries or instruments not specifically designed for residents, limiting the applicability of the results in real-life medical training settings. The development of an instrument that comprehensively and specifically assesses sleep deprivation, sleepiness, and multiple domains of executive function addresses an unmet methodological and clinical need.

The instrument designed and validated here integrates key domains such as working memory, inhibitory control, cognitive flexibility, planning, and emotional control, as well as sleepiness and sleep deprivation, allowing for a holistic and contextualized assessment. This approach is especially relevant since residents face unique working conditions, with long hours and frequent sleep interruptions, which affect their performance and well-being in a complex and multifactorial way.

Validation by expert judgment using the Carrera method[9] ensures that the instrument's items are relevant and unambiguous, faithfully reflecting the constructs to be measured. Furthermore, the high internal consistency obtained in all domains (Cronbach's alpha ≥ 0.89) supports the reliability of the instrument for use in research and clinical practice.

This methodological rigor is essential, since, as Tavakol and Dennick[8] point out, the validity and reliability of measurement instruments are prerequisites for generating robust scientific knowledge and informed decision-making in the health field.

The availability of such a specific instrument will allow for more precise epidemiological and intervention studies, facilitating the identification of residents at risk of cognitive and emotional decline due to sleep deprivation. It can also be used as a monitoring tool in residency programs, supporting institutional decision-making to reduce fatigue and improve the well-being of medical staff.

Finally, the validation of this instrument also opens the door to international comparisons, as it is based on widely used benchmarks such as the BRIEF-A and the Epworth Sleepiness Scale, but adapted and contextualized for the Spanish-speaking medical residents.

The limitations of the study include the sample size for reliability analysis and the lack of direct comparison with objective neuropsychological tests or biomarkers, such as those used by Choshen-Hillel et al.[19].

Conclusion

The development and validation of this instrument represent a significant methodological and clinical contribution, providing a reliable and relevant tool for measuring sleep deprivation, sleepiness, and executive functions in medical residents. Its implementation will facilitate research, monitoring, and timely intervention, contributing to improved medical staff well-being and patient safety.

Funding

The authors declare that they have not received funding.

Conflicts of interest

The authors declare no conflicts of interest.

Ethical considerations

Protection of human subjects and animals. The authors declare that no experiments involving humans or animals were conducted for this research.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from all patients, and secured approval from the Ethics Committee. SAGER guidelines have been followed as applicable to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing or creation of the content of this manuscript.

Supplementary data

Supplementary data are available at *Revista Médica del Hospital General de México* online (DOI: 10.24875/HGMX.25000039). These data are provided by the corresponding author and published online for the benefit of the reader. The contents of supplementary data are the sole responsibility of the authors.

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