DOCTORAL DISSERTATION

SLEEP QUALITY AND SUBSTANCE USE IN ADOLESCENTS

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La presente Tesis Doctoral, titulada "SLEEP QUALITY AND SUBSTANCE USE IN ADOLESCENTS" se presenta bajo la modalidad de **tesis por compendio** de las siguientes **publicaciones**:

LIST OF STUDIES

Four scientific articles were developed as a result of achieving the objectives of this doctoral thesis.

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Studies under review

Two more studies were developed to address objectives 3, 4, and 5 of this doctoral thesis. These studies are currently under review and therefore are included as complementary studies of the compilation of this dissertation.

STUDY III. Sancho-Domingo, C., & Carballo, J. L. (2024). Identification of sleep patterns in adolescents and the association with substance use. *Under review*

STUDY IV. Sancho-Domingo, C., & Carballo, J. L. (2024). Examining the impact of sleep changes on adolescents' alcohol use: A two-wave prospective study. *Under review*

El **Dr. *José Luis Carballo***, director de la tesis doctoral titulada "**SLEEP QUALITY AND SUBSTANCE USE IN ADOLESCENTS"**

INFORMA:

Que Dña. ***Clara Sancho Domingo*** ha realizado bajo mi supervisión el trabajo titulado **"SLEEP QUALITY AND SUBSTANCE USE IN ADOLESCENTS"** conforme a los términos y condiciones definidos en su Plan de Investigación y de acuerdo al Código de Buenas Prácticas de la Universidad Miguel Hernández de Elche, cumpliendo los objetivos previstos de forma satisfactoria para su defensa pública como tesis doctoral.

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ABSTRACT

During adolescence, various biological, contextual, and psychosocial changes occur that can disrupt sleep patterns, thereby increasing the likelihood of experiencing poor sleep quality. Although these patterns are not yet well-defined, scientific literature indicates that experiencing poor sleep quality is a risk factor for the development of various physical and mental health problems. However, more than 50% of adolescents report having sleep problems, and only 20% sleep the recommended hours. These issues seem to maintain a bidirectional relationship with substance use, where drug use alters sleep structure, and poor sleep quality promotes substance use in adolescence. However, further studies are needed to thoroughly analyze this relationship and the role sleep could play in preventing drug use.

Although sleep represents a key health indicator in adolescence, the measurement tools currently available to assess sleep quality and its components are limited or require revision and adaptation for this population. Having these instruments could allow for the evaluation of adolescents' latent sleep patterns and analyze how these relate to drug use. Therefore, the objectives of this doctoral thesis were, on the one hand, to develop a brief measure of sleep and adapt it to the adolescent population, and on the other hand, to identify adolescents' latent sleep patterns and their relationship with drug consumption, as well as to study sleep as a potential protective factor in reducing alcohol use.

To achieve these objectives, four correlational studies were conducted, three of them cross-sectional and one longitudinal, evaluating different aspects related to sleep and alcohol and other drug use. Through these studies, the Brief Pittsburgh Sleep Quality Index (B-PSQI) was developed, reducing its length to six items, resulting in a concise and reliable measure of sleep quality and its dimensions. Additionally, psychometric analyses confirmed the validity and reliability of the B-PSQI adaptation for adolescents. Furthermore, using the B-PSQI allowed for the identification of four distinct sleep patterns among adolescents, including "Good Quality" (43.3%), "Night Awakenings" (31.8%), "Poor Efficiency and Sleep Onset" (9.4%), and "Poor Quality" (15.5%). Poor sleep quality patterns showed a higher association with binge alcohol consumption, tobacco, cannabis, and other illicit drugs. Additionally, longitudinal analyses revealed that improving sleep over time is associated with a higher likelihood of reducing alcohol consumption.

The results of this doctoral thesis significantly contribute to advancing knowledge about the relationship between sleep quality and drug use in adolescents. The B-PSQI is currently allowing for the assessment of sleep quality in research and clinical settings, improving the adaptability of the scoring method in adolescents. Likewise, the results have revealed sleep patterns in adolescents, which are of interest for adapting health programs aimed at minimizing risks associated with poor sleep habits during adolescence. The findings of this thesis also address an existing gap in the literature by exploring links between sleep patterns and drug use in adolescents, including frequency, occurrence, and quantity of consumption. This also includes the potential impact of improving sleep quality on the reduction of alcohol use among regular-drinking adolescents. In this regard, transdiagnostic sleep interventions could represent a key component for substance use prevention, addressing both sleep problems and substance consumption among adolescents. This thesis provides a solid foundation for future research examining the effectiveness of sleep interventions as preventive strategies for drug consumption in adolescents.

RESUMEN

Durante la adolescencia, se producen diversos cambios biológicos, contextuales y psicosociales que puede alterar el patrón de sueño, aumentando así la probabilidad de experimentar una pobre calidad del mismo. Aunque estos patrones aún no están bien definidos, la literatura científica indica que experimentar una pobre calidad de sueño es un factor de riesgo para el desarrollo de diversos problemas de salud física y mental. A pesar de ello, más del 50% de los adolescentes refiere tener problemas de sueño, y sólo un 20% duerme las horas recomendadas. Estos problemas parecen mantener una relación bidireccional con el uso de sustancias, donde el consumo de drogas altera la estructura del sueño, y la mala calidad de sueño favorece el consumo en la adolescencia. Sin embargo, aún son necesarios estudios que analicen en profundidad esta relación, y papel que el sueño podría desempeñar en la prevención del consumo de drogas.

Aunque al sueño representa un indicador de salud clave en la adolescencia, los instrumentos que hay disponibles actualmente para evaluar la calidad de sueño y sus componentes, son limitados o requieren ser revisados y adaptados a esta población. Disponer de estos instrumentos podría permitir evaluar los patrones latentes de sueño de los adolescentes y analizar cómo estos se relacionan con el consumo de drogas. Por ello, los objetivos de esta tesis doctoral fueron, por un lado, desarrollar una medida breve de sueño y adaptarla a población adolescente, y por otro, identificar los patrones latentes de sueño de los adolescentes y su relación con el consumo de drogas, así como estudiar el sueño como potencial factor de protección en la reducción del consumo de alcohol.

Para lograr estos objetivos, se llevaron a cabo cuatro estudios correlacionales, tres de ellos transversales y uno longitudinal, evaluando diferentes aspectos relacionados con el sueño y el uso de alcohol y otras drogas. A través de estos estudios, se desarrolló la versión Breve del Índice de Calidad de Sueño de Pittsburgh (B-PSQI), que redujo su longitud a seis ítems, lo que dio lugar a una medida concisa y fiable de la calidad del sueño y sus dimensiones. Además, los análisis psicométricos confirmaron la validez y fiabilidad de la adaptación del B-PSQI para adolescentes. Por otro lado, el uso del B-PSQI permitió identificar cuatro patrones distintos de sueño entre los adolescentes, que incluyen "Buena Calidad" (43.3%), "Despertares Nocturnos" (31.8%), "Pobre Eficiencia y Latencia de Sueño" (9.4%) y "Pobre Calidad" (15.5%). Los patrones de pobre calidad de sueño mostraron una

mayor asociación con el consumo en atracón de alcohol, tabaco, cannabis y otras drogas ilícitas. Además, los análisis longitudinales revelaron que mejorar el sueño con el tiempo, se asocia con una mayor probabilidad de reducir el consumo de alcohol.

Los resultados de esta tesis doctoral contribuyen significativamente al avance del conocimiento sobre la relación entre la calidad del sueño y el consumo de drogas en adolescentes. El B-PSQI está permitiendo la evaluación de la calidad de sueño en entornos de investigación y clínicos, mejorando la adaptabilidad del método de puntuación en adolescentes. Asimismo, los resultados han revelado los patrones de sueño en los adolescentes, lo cual resulta de interés para adaptar programas de salud destinados a minimizar los riesgos asociados con hábitos de sueño deficientes durante la adolescencia. Los hallazgos de esta tesis también abordan una brecha existente en la literatura al explorar vínculos entre los patrones de sueño y el consumo de drogas, incluyendo la frecuencia, ocurrencia y cantidad de consumo. Esto también incluye el potencial impacto que tiene mejorar la calidad del sueño en la reducción del consumo de alcohol entre adolescentes que beben de forma regular. En este sentido, las intervenciones transdiagnósticas de sueño podrían representar un componente clave para la prevención del consumo de sustancias, abordando tanto los problemas para dormir, como el consumo de sustancias entre los adolescentes. Esta tesis proporciona una base sólida para futuras investigaciones que examinen la eficacia de intervenciones de sueño como estrategias preventivas del consumo de drogas en adolescentes.

Part 1.

INTRODUCTION

1.1. SLEEP QUALITY IN ADOLESCENCE

1.1.1. Definition and sleep components

Sleep is a vital and complex process that serves several essential functions for maintaining health. According to the National Institute of Mental Health (NIMH), sleep and wakefulness are recurring behavioral states that reflect changes in the functional organization of the brain to optimize physiology, behavior, and health (NIMH, 2023). The process of sleep is intrinsically linked with the concept of sleep quality, which is commonly defined as the subjective degree of "excellence" in the sleep experience that can impact wakefulness function (Buysse, 2014).

This definition of sleep quality comprises a set of dimensions that include quantity, continuity, and timing of sleep (Matricciani et al., 2019). Among these dimensions, individual subjective perception of experiencing poor or good quality sleep is particularly noteworthy, determined by the sensation of restorative sleep (American Psychiatric Association, 2013; Drake et al., 2014; Roth et al., 2010). In addition to subjective perception, various quantitative parameters form part of the definition and measurement of sleep quality, including sleep duration, sleep latency, sleep efficiency, night awakenings or continuity of sleep at night, and sleep schedule (Buysse, 2014; Ramlee, Sanborn, & Tang, 2017).

Sleep duration represents the component that has received the most attention when evaluating sleep quality. The amount of sleep hours is a central component mainly due to the negative impact insufficient hours of sleep can have on physical health, emotional well-being, and cognitive functioning (Amin & Sankari, 2023). However, other aspects of sleep are important for defining its quality, such as *sleep latency*. This term refers to the amount of time it takes a person to fall asleep. A longer sleep latency indicates greater difficulty in sleeping and acts as a key indicator for diagnosing sleep disorders, such as insomnia (de Entrambasaguas et al., 2023). The average sleep latency in healthy individuals corresponds to 11.7 minutes (de Entrambasaguas et al., 2023; Iskander et al., 2023), whereas taking more than half an hour to fall asleep is associated with reducing the number of sleep cycles during the night, shorter sleep duration, greater daytime dysfunction, and health issues (Roth et al., 2010; Siddiquee et al., 2023; Yuen, 2017).

Also, the quality of sleep is characterized by *sleep efficiency*, which refers to the percentage of the total time spent asleep while lying in bed. A low sleep efficiency indicates that a person spends most of their time awake in bed, which is linked to longer periods awake before falling asleep, interrupted sleep during the night, or engaging in activities lying in bed that disrupt sleep, like using the mobile phone (Silva-Caballero et al., 2023). A low sleep efficiency reduces the association between environmental stimuli (e.g., the bed) and sleep, which can also contribute to experiencing night awakenings. In this regard, the maintenance of sleep during the night also plays a role in overall sleep health, as nighttime awakenings can disrupt the architecture and natural pattern of restorative sleep (Matricciani et al., 2019). Fragmentation of sleep architecture can impact its overall quality and lead to daytime drowsiness or impaired functioning (Medic et al., 2017).

Likewise, another important dimension of sleep quality is the alignment of *sleep schedules* with biological and social rhythms as a key aspect of sleep quality. This involves synchronizing one's sleep-wake cycle with the body's internal clock and social activities (Chaput et al., 2022; Haynie et al., 2017; Raman & Coogan, 2020). Greater delayed bedtimes can lead to misalignment which has been prospectively associated with more fatigue and daytime sleepiness (Hrozanova et al., 2023; Raman & Coogan, 2020).

The quality of sleep and its dimensions exhibit variation across the lifespan. For instance, young individuals or infants may necessitate a greater number of sleep hours, while with advancing age, this requirement may diminish. Consequently, sleep patterns change throughout the lifetime, with specific age periods being more susceptible to experiencing sleep-related issues, such as adolescence (Kocevska et al., 2021).

1.1.2. Changes during adolescence and sleep

During adolescence, biological and psychological changes can negatively affect the quality of sleep, which in turn can impact cognitive, physical, and emotional processes. Therefore, it is of great importance to address and study sleep quality during this stage of life due to its potential impact on the health of adolescents.

Those changes are likely to occur between the ages of 13 and 18 that affect various dimensions of sleep, and increase the probability of negatively impacting memory consolidation, mood regulation, and physical development in adolescents (Carskadon, 2011). Both biological and psychosocial alterations contribute to the fact that a large percentage of adolescents experience sleep problems, including difficulty falling asleep, fewer hours of sleep, and increased daytime sleepiness (Carskadon, 2011; Saxvig et al., 2021).

This change in sleep patterns can be explained by the biopsychosocial model for sleep, where biological, contextual, and psychosocial factors come together and interact to contribute to delayed bedtimes, a preference for an evening sleep chronotype, and maladjustment of sleep schedules (Becker et al., 2015). These occur throughout the entire period of adolescent development rather than at specific moments. As shown in Figure 1, some of these changes encompass alterations in the circadian rhythm, increased independence from parental norms, more interest in social activities leading to later bedtimes, changes in school schedules, and an increase in screen time before bedtime (Becker et al., 2015). The elements comprising the biopsychosocial model are described in the following sections.

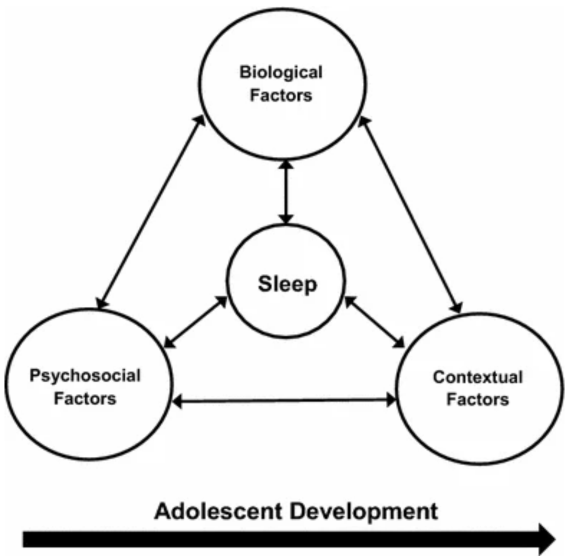

Fig. 1. Sleep biopsychosocial and contextual model in adolescence. *Reproduced with permission from Springer Nature*

Biological changes

Two biological processes regulate sleep, known as the circadian process and the homeostatic process (Borbély, 2022), which operate independently but interact, affecting the daily regulation of sleep (Carskadon, 2011). The circadian rhythm refers to the biological rhythm and follows an approximate 24-hour cycle. The circadian clock is influenced by various factors, with exposure to light being particularly significant. Situated in the hypothalamus, the suprachiasmatic nucleus acts as the body's internal clock, sensitive to environmental cues such as light. It controls the secretion of melatonin and helps regulate body temperature, both of which are associated with wakefulness and sleep regulation (Borbély, 2022). In adolescents, the onset of melatonin production in response to decreased light occurs approximately one hour later than in preadolescents, suggesting a hormonal regulation of sleep during puberty (Carpenter et al., 2015; Taylor et al., 2005).

On the other hand, the homeostatic process of sleep is associated with the accumulated need for rest and recovery from daily fatigue (Borbély, 2022; Carskadon, 2011). As wakefulness continues, the need for rest increases, prompting the homeostatic system to adjust and regulate the duration and quality of sleep accordingly. Conversely, as the duration of sleep increases, the homeostatic pressure for rest diminishes, leading to increased levels of wakefulness. This homeostatic pressure gradually accumulates in adolescents compared to children, resulting in maintaining alertness until later hours (Borbély, 2022; Carskadon, 2011). Thus, along with changes in the circadian rhythm, adolescents develop a preference for an evening chronotype, feeling more awake and active during the afternoon.

Contextual changes

During adolescence, one of the key contextual changes is the increase of academic and school demands. The timing of high school schedules plays a central role in determining the sleep quality of adolescents. Starting classes earlier than in preadolescence (between 9 and 12 years old) contributes to fewer hours of sleep, poor sleep efficiency, worse satisfaction with sleep, and increased fatigue and school absenteeism (Dutil et al., 2022; Minges & Redeker, 2016). In fact, studies analyzing the effects of delaying school start times have shown that it can benefit adolescent sleep by aligning sleep schedules between school days and weekends, increasing sleep duration by up to one hour, and reducing daytime sleepiness and fatigue (Barlaan et al., 2022; Minges & Redeker, 2016). Schools' influence on adolescents' sleep further emphasizes the importance and necessity of addressing mental health within educational settings (Fonseca Pedrero et al., 2023).

Furthermore, after the age of 13, there is also increased demand, and consequently, more time is dedicated to school and academic tasks. This increased demand is inversely proportional to sleep duration, especially when considering participation in extracurricular activities or part-time employment (Davidson-Urbain et al., 2023; Yeo et al., 2020). These contextual changes contribute to misaligned weekday and weekend schedules due to academic demands and social activities, which can often conflict with individuals' natural circadian rhythms, leading to what is known as social jetlag. This phenomenon seems to be predominant in men and exacerbated by psychosocial changes as well (Minges & Redeker, 2016). It affects both schooled adolescents and those who do not continue post-compulsory secondary education. Although there are not many studies on this subgroup of the adolescent population, non-institutionalized individuals sleep fewer hours and are likely to exhibit misaligned sleep schedules (e.g., Chehal et al., 2022).

Furthermore, the type of leisure activities that adolescents engage in also changes, increasing the likelihood of having poorer sleep quality. Some of these activities include starting to use mobile phones to access social media or engaging in gambling activities, for example. Research has shown that these behaviors are associated with fewer hours of sleep, longer sleep onset latency, and evening chronotype (Almeida et al., 2023; Fabbri et al., 2024; Hena & Garmy, 2020; Scott et al., 2019). On the other hand, a range of other nighttime activities for adolescents related to greater independence emerges, which can negatively impact sleep, such as going out clubbing (Becker et al., 2015).

Psychosocial changes

As mentioned above, adolescents undergo significant psychosocial changes characterized by greater autonomy and more social interactions. These changes manifest in various aspects of adolescent life, including shifts in family dynamics, peer relationships, mental health, and behavioral patterns. Among these, substance use emerges as one of the most notable factors to consider in this context (Becker et al., 2015; Troxel et al., 2022).

In the family environment, the establishment of rules concerning sleep hours and family routines seems to be associated with the quality of sleep. Research by Bartel et al. (2015) suggests that some specific bedtime behaviors, such as avoiding screen time at night, are associated with extended sleep duration. Moreover, flexible family functioning in changes and needs, are also associated with better sleep patterns of adolescents (Sasser & Oshri, 2023). In this regard, previous studies indicate that those adolescents with more autonomy and less parental control maintain a prospective relationship with a preference for evening hours, which can lead to a disruption in sleep schedules (Diaz-Morales et al. 2014).

As part of this autonomy, peer interactions play a significant role, not only in emotional well-being but also in the influence exerted by the social network on the individual. During adolescence, emotional bonds among peers increase, facilitating the dissemination of both maladaptive sleep habits and related addictive behaviors (Haynie et al., 2017; Mednick et al., 2010; Scott et al., 2019). For example, among adolescents, there's a prevailing social norm or expectation to remain accessible on social media platforms throughout the night (Almeida et al., 2023; Scott et al., 2019). This appears to be driven by the fear of missing out on social events or connections, leading to delayed sleep schedules and contributing to a worse quality of sleep (Armstrong-Carter et al., 2023; Hena & Garmy, 2020).

In addition to online availability, in-person interactions are likely to occur particularly during evening hours. This is linked to the initiation of substance use during adolescence which may also be influenced by peer pressure (Ajilore et al., 2016; Mednick et al., 2010; Pedersen et al., 2017). In addition, the use of substances during adolescence can lead to the emergence of sleep problems, as evidenced in longitudinal studies (Haynie et al., 2017; Kwon et al., 2019), which, in turn, may contribute to more severe sleep problems and substance use during the transition to adulthood (Troxel et al., 2021).

The increased likelihood of drug use is also linked to behavioral and mood changes in adolescents. This is particularly evident during the transition from childhood to adolescence, with an increase in depressive mood and anxiety between the ages of 13 and 18. (Lunetti et al., 2022; Maciejewski et al., 2017). Longitudinal data has suggested that experiencing internalizing symptoms during early adolescence appears to significantly act as a risk factor for developing sleep problems later in this period (Kortesoja et al., 2020).

These mood changes during adolescence, combined with other psychosocial, contextual, and biological factors, contribute to the high prevalence of sleep problems in adolescents, posing a potential threat to their health in both adolescence and adulthood (Medic et al., 2017).

1.1.3. Prevalence data on adolescents' sleep quality

Over the past decade, there has been a noticeable decrease in the amount of sleep that adolescents get (Otsuka et al., 2021), with their sleep duration being lower compared to other age groups (Kocevska et al., 2021). From early adolescence to late adolescence, young people transition from an average of 8.1 hours of sleep to 7.4 hours (Saelee et al., 2023). This is evidenced by the fact that up to 80% of adolescents fail to meet the recommended sleep duration of 8 to 10 hours, and approximately 50% sleep less than 7 hours each night (Kocevska et al., 2021; Saxvig et al., 2021).

Alongside the reduction in sleep duration, there has been an increased prevalence of other sleep problems, such as difficulties in falling asleep, delaying bedtime, and experiencing daytime sleepiness, which are predominant (Ghekiere et al., 2019; Otsuka et al., 2021). According to previous studies, adolescents take an average of 21 to 47 minutes to fall asleep on most nights, with approximately 65% reporting that it takes them more than 30 minutes to fall asleep (Bauducco et al., 2016; Hysing et al., 2013; Saxvig et al., 2021; Sivertsen et al., 2013). These data align with symptoms related to insomnia and are associated with experiencing fear or worry during bedtime, as well as increased physical and cognitive arousal (Arnison et al., 2022; Jansson-Fröjmark & Norell-Clarke, 2012).

On the other hand, the average of adolescents' bedtimes during weekdays ranges from 9:42 PM to 11:18 PM, and during weekends from 11:14 PM to 12:54 AM. (Gariepy et al., 2020), with a preference for a delayed bedtime reflected in more than 20% going to sleep after 1:00 AM (Otsuka et al., 2021). Delayed bedtimes are associated with increased daytime sleepiness and greater misalignment in sleep schedules (Saxvig et al., 2021). These rates are consistent with the prevalence of insomnia among adolescents, which slightly exceeds 20% (Bauducco et al., 2016; Otsuka et al., 2021).

Besides prevalence data on sleep quality indicators, recent research suggests that there are between 3 and 4 distinct sleep patterns in adolescents. The two most prevalent patterns consist of experiencing good quality of sleep across different components (up to 50%), and presenting good overall quality but insufficient sleep duration (up to 65%) (Cooper et al., 2023; Saelee et al., 2023; Yue et al., 2022). Less prevalent patterns are also worth noting, in which various subgroups of adolescents experience more severe sleep problems (e.g., insomnia) or a preference for an evening chronotype (Bauducco et al., 2022; Cooper et al., 2023; Saelee et al., 2023; Yue et al., 2022). Likewise, while sleep patterns in children under 13 years old seem to be similar regardless of gender (Cooper et al., 2023), sleep patterns may vary between male and female adolescents, given the extensive literature demonstrating sex differences. However, there are currently no studies that have analyzed these potential discrepancies. Future studies are still needed to explore the various dimensions of sleep to understand the sleep health status of adolescents (Meltzer et al., 2021).

Regarding Spanish adolescents, sleep problems appear to be more prevalent compared to other European countries. In Spain, recent studies on sleep indicate that adolescents sleep an average of 7.3 hours per night, with only 19% reporting sleeping 8 or more hours (Galan-Lopez et al., 2021; Martinez-Gomez et al., 2022). Regarding other sleep problems, up to 59% of Spanish adolescents experience difficulties with falling or staying asleep at night (Gaya et al., 2023) and exhibit the highest delayed bedtimes among European adolescents (Gariepy et al., 2020). Compared to other age groups, the Spanish youth are more prone to experiencing night and daytime symptoms of insomnia (de Entrambasaguas et al., 2023). Despite the significant changes that adolescents experience in their sleep patterns, there are still very few studies that identify the specific sleep patterns corresponding to this period, and further research is needed.

Differences in sleep between male and female adolescents

As previously mentioned, the scientific literature has demonstrated that there exists significant differences between males and females in sleep quality (Baker et al., 2023). Generally, both objective and subjective data indicate that young females report poorer sleep quality. Given that females start puberty at an earlier chronological age, they prefer an evening schedule at an earlier age than male adolescents (Meers et al., 2019; Tonetti et al., 2008). Additionally, female adolescents tend to exhibit extreme sleep duration, sleeping either significantly shorter (<6 hours) or longer (>10 hours) than average (Meers et al., 2019). These sleep differences appear to be related to the presence of emotional problems more likely in females, such as depressive symptoms (Lemke et al., 2023), as well as a higher likelihood of being diagnosed with insomnia (Meers et al., 2019; Zhang et al., 2016).

Despite females seeming to experience a worse quality of sleep, evidence indicates that these differences do not apply to all dimensions of sleep and that sleep patterns could vary between males and females and across adolescence. Research suggests that during the weekdays, young females tend to sleep for a shorter duration (with 53% sleeping <8 hours) compared to males (38%), while on weekends their sleep durations appear to be similar (Lemke et al., 2023). However, longitudinal data suggest that, during the transition to adulthood, females are less likely to sleep poorly, while males increase their likelihood of having progressively shorter sleep patterns (Saelee et al., 2023).

On the other hand, sleep schedules have also shown differences in terms of sex. At puberty, bedtime appears to be later in males, with a greater discrepancy in sleep schedules between weekdays and weekends, hence experiencing more social jetlag (Hrozanova et al., 2023; Hysing et al., 2013; Lemke et al., 2023). Although males typically spend more time in bed before falling asleep compared to females (Saxvig et al., 2021), female adolescents tend to report a longer sleep onset latency linked to experiencing insomnia (Hrozanova et al., 2023; Hysing et al., 2013). While these studies reveal certain differences between males and females, more research is needed to provide more accurate results on sleep patterns in adolescence.

1.1.4. Assessment of sleep quality in adolescents

The assessment of sleep in adolescents involves conducting a comprehensive evaluation of the different components of sleep, including but not limited to quantity, architecture, quality, and sleep-related behaviors such as sleep hygiene (Erwin & Bashore, 2017; Hall & Nethery, 2019). Additionally, it is important to assess the impact of sleep on daily functioning and consider other related variables like mood or dysfunctional beliefs about sleep (Bartel et al., 2015; Díaz-Morales et al., 2012; Eidelman et al., 2016). Through this assessment process, the goal is to gain a holistic understanding of an adolescent's overall sleeping patterns and habits.

Evaluating different aspects of sleep helps to gain a more comprehensive and precise understanding of the affected areas and the severity of the sleep problems, if present. This, in turn, allows for identifying specific issues with sleep and devising effective therapeutic strategies to address them. To achieve this, researchers and healthcare professionals require access to assessment tools that can validly and reliably measure and quantify sleep across various age groups (Ji & Liu, 2016; Short et al., 2017; Williams et al., 2020). These tools correspond to both objective measures and subjective measures of sleep.

Objective sleep measures

Objective measures to assess sleep quality in adolescents, as well as in adults, are based on devices that directly and quantitatively record physiological characteristics of the sleep cycle (e.g., brain wave activity). These measures provide more precise data compared to self-reports assessing quantitative parameters (e.g., sleep duration), yet they have certain limitations, particularly the complexity and specialized equipment required. Actigraphy and polysomnography (PSG) are frequently recognized as the standard tools for objective sleep measurement.

The PSG is considered the gold standard measure of sleep (Rundo & Downey, 2019). It simultaneously records various physiological variables such as brain activity, eye movements, muscle activity, airflow, heart rate, and oxygen saturation. Although it is a valid and reliable measure, PSG is typically used only in clinical settings due to its high cost and the need for specialized equipment (Rundo & Downey, 2019).

In contrast, actigraphs are portable devices worn on the wrist that record physical activity and exposure to light (Walia & Mehra, 2019). They assess sleep-wake patterns through motor activity. They can be a reliable and valid alternative that provides similar results to PSG (Williams et al., 2020) when assessing circadian rhythms, sleep efficiency, and total sleep duration in natural settings; however, they come with high costs and complex data processing and analysis (Walia & Mehra, 2019).

Currently, there are new sleep assessment devices alternative to conventional PSG and actigraphy methods. Emerging technologies such as contactless sleep monitoring systems have the potential to provide accurate and comprehensive sleep data (Zhai et al., 2023). Likewise, although *smartwatches* still need to improve their accuracy in sleep evaluation (Haghayegh et al., 2019), may contribute to providing an alternative to access sleep-related information for adolescents.

Self-reported measures of sleep quality

Sleep self-reports are tools where adolescents provide data to assess the quality of their sleep. While not as precise as objective measures, these reports have been demonstrated to be valid and reliable in evaluating sleep quality (Erwin & Bashore, 2017; Ji & Liu, 2016). Unlike objective tools, self-administered sleep assessments represent a cost-effective and user-friendly approach to evaluating adolescents' sleep quality, providing comprehensive data on subjective experiences, and facilitating the follow-up of sleep patterns and behaviors. These sleep self-reports mainly encompass questionnaires, scales, and sleep diaries that are also used as self-monitoring.

When objective measures are not feasible, using a sleep diary to record multiple nights throughout the week can provide a more accurate assessment of adolescents' sleep patterns and quality (Campanini et al., 2017; Kearns et al., 2023). The inclusion of a sleep diary in research and clinical practice has been recommended by international guidelines, such as the European Sleep Research Society (Riemann et al., 2017). Recording various sleep parameters for at least one week provides a more comprehensive insight into one's health, hygiene, and sleep patterns (Short et al., 2017).

Since sleep diaries are often designed by researchers and healthcare professionals, a consensus was reached to establish standardized criteria for evaluating insomnia and sleep quality, to make it easier to compare results across studies (Carney et al., 2012). This consensus instrument is known as the Consensus Sleep Diary and is notable among validated sleep diaries for collecting data on sleep duration, latency, schedule, number of awakenings during the night, etc. However, one drawback of using sleep diaries is that adolescents often struggle to consistently complete them over multiple days (Kearns et al., 2023). Hence, it is recommended to use other self-report measures concurrently that can provide information about sleep.

Some of the most commonly used self-report measures include the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989), the Insomnia Severity Index (ISI; Bastien et al., 2001), the Epworth Sleepiness Scale (ESS; Johns, 1991), the Adolescent Sleep-Wake Scale (ASWS; LeBourgeois et al., 2005), as well as some measures to assess domains related to sleep quality, such as sleep hygiene and physical and cognitive activation before sleep.

The PSQI is one of the most widely used instruments for assessing sleep quality in both adults and adolescents. The questionnaire was developed to assess the quality of sleep and its dimensions by combining quantitative aspects similar to those found in a sleep diary or objective measures (e.g., time taken to fall asleep) with more qualitative dimensions such as daytime fatigue perception or reasons for waking up during the night. Through these measures, the PSQI assesses sleep quality over the last month through seven sleep dimensions: sleep duration, latency, efficiency, frequency of awakenings during the night, daytime dysfunction, use of sleep medication, and subjective sleep quality. The sum of the scores obtained in each of the dimensions provides an overall sleep quality score ranging from 0 to 21. Higher scores suggest poorer sleep quality, with a cutoff point above five indicating that the individual experiences poor sleep quality. The tool of the PSQI has also been adapted and validated in adolescent populations, proving to be a valid and reliable instrument for assessing sleep quality in this population (de la Vega et al., 2015; Mollayeva et al., 2016)

Although the PSQI is one of the most widely used instruments for evaluating various dimensions of sleep, including identifying sleep disturbances, other instruments have been developed as screening and diagnostic tools for specific sleep disorders. In this regard, the ISI is another self-reported tool that has been used in numerous studies to assess the severity of insomnia in adolescents (Chehri et al., 2021; Chung et al., 2011). The questionnaire consists of seven items providing information about insomnia symptoms, satisfaction with sleep, and its impact on quality of life. Scores above 8 suggest the presence of insomnia in the adolescent population (Chung et al., 2011).

On the other hand, and as an important aspect in assessing sleep quality, the ESS scale was developed to measure the level of daytime sleepiness in eight different situations, such as reading or being in class. There is a version suitable for adolescents where the situations in which a person may fall asleep are adapted, such as replacing the situation of driving with riding on a bus. This adaptation has demonstrated adequate reliability and validity according to previous research (Janssen et al., 2017; Wang et al., 2022).

In addition to identifying sleep disorders, related fatigue, or overall sleep quality, other instruments have been developed to evaluate behavioral patterns, particularly among adolescents, associated with sleep rather than sleep itself. The ASWS scale is a self-report measure that gathers information about sleep and wake patterns in adolescents. The ASWS comprises five subscales of sleep behavior: difficulties going to bed, falling asleep, maintaining sleep, reinitiating sleep, and returning to wakefulness. The ASWS evaluates the frequency of experiencing different situations rather than accounting for quantitative parameters. The ASWS scale has shown good internal consistency, and a shorter version with ten items has been developed (Essner et al., 2015).

Another dimension of sleep quality recommended to assess in adolescents is pre-sleep arousal. For this purpose, the Pre-Sleep Arousal Scale (PSAS; Nicassio et al., 1985) was created to evaluate two dimensions of pre-sleep arousal: cognitive arousal and physical arousal. The PSAS measures to what extent a person experiences arousal when attempting to sleep, and has demonstrated adequate reliability and concurrent validity with other sleep measures in both adult and adolescent populations (Jansson-Fröjmark & Norell-Clarke, 2012; Okajima et al., 2020; Ruivo Marques et al., 2018).

Assessment of risk factors associated with sleep problems

As mentioned in the biopsychosocial model, some changes during adolescence can represent a risk factor for experiencing sleep problems (Becker et al., 2015). Several clinical guidelines recommend that in addition to assessing sleep quality and patterns, behaviors and situations that may foster and perpetuate sleep problems should also be evaluated (George & Davis, 2013).

In this regard, sleep hygiene encompasses a variety of factors that can impact sleep, including the sleeping environment (e.g., temperature and noise levels), dietary choices before bedtime (e.g., alcohol consumption), and behaviors related to arousal (e.g., rumination at bedtime) (Erwin & Bashore, 2017; Hall & Nethery, 2019). One commonly used instrument to assess sleep hygiene in the adolescent population is the Adolescent Sleep Hygiene Scale (ASHS; LeBourgeois et al., 2005). This scale provides a structured way to evaluate behaviors and environmental factors that may interfere with sleep.

Likewise, some researchers have also included substance use as part of sleep hygiene behaviors among adolescents (Hall & Nethery, 2019). This is highly relevant due to the impact that drug use can have on adolescents' sleep, encompassing the use of coffee or energy drinks to the use of illegal substances in adolescents like tobacco, alcohol, and/or cannabis. There are numerous methods available to assess substance use in adolescents. Notable examples include the TimeLine Follow-Back (TLFB; Sobell & Sobell, 1992) to retrospectively register substance use using a calendar, the Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993), or the Drug Use History Questionnaire (DUHQ; Sobell et al., 1995), among others (Fernández-Artamendi & Weidberg, 2016).

In addition to sleep hygiene, evaluating adolescents' mood is also relevant. Anxiety and depression are known to be strong risk factors for sleep problems in this age group (Kortesoja et al., 2020). Therefore, the assessment of the emotional state is central for a comprehensive and more holistic approach to addressing sleep issues, as mood disturbances can both influence and be influenced by sleep patterns. A common brief and valid measure to evaluate both dimensions is the Depression, Anxiety and Stress Scales (DASS-21; Antony et al., 1998; Fonseca et al., 2010).

Therefore, it is essential to evaluate various dimensions of sleep and related behaviors using the mentioned measurement instruments in combination as part of a comprehensive evaluation of sleep quality. It is also important to continually update and improve measurement instruments over time, as they may become outdated, as recommended by national and international Test Commissions (Hernández et al., 2022).

1.1.5. Sleep as a health indicator in adolescents

The American Academy of Sleep Medicine asserts that sleep is fundamental to the health of adolescents and that inadequate sleep or untreated sleep disorders are detrimental to health, productivity, and safety (Ramar et al., 2021). The importance of sleep quality and duration as a health indicator is supported by evidence from longitudinal data indicating that experiencing sleep problems increases the risk of negatively affecting domains that include cognitive functioning, mood, mental health, and overall physical health (Bacaro et al., 2024; Chaput et al., 2016; Matricciani et al., 2019; Medic et al., 2017).

In particular, adolescents need sufficient sleep for adequate brain development, learning and memory consolidation, and maintaining immune functions (Agostini & Centofanti, 2021; Bruce et al., 2017). In this regard, poor sleep quality during adolescence can have significant effects on neuronal and brain development contributing to hindering the maturation of the prefrontal cortex, which is responsible for higher-order cognitive processes such as decision-making, reward processing, social interactions, and emotion regulation (Agostini & Centofanti, 2021). This may lead to an increased risk of developing physical and mental health problems (Anastasiades et al., 2022).

Experiencing sleep problems (e.g., sleep disruption, fragmented sleep, prolonged sleep latency, etc.) has been linked to obesity, diabetes, pain, and cardiovascular problems (Medic et al., 2017). Likewise, sleep problems may contribute to impaired cognitive performance and emotional regulation, increased risk of psychiatric disorders and higher likelihood of risk-taking behaviors (Bacaro et al., 2024; Matricciani et al., 2019). Specifically, going to bed later is linked with worse emotional control, lower brain function, less physical activity, and poor academic performance in adolescents (Dutil et al., 2022).

Consistently, longer sleep durations are associated with fewer anxiety and depression symptoms over time while sleep disruptions can negatively impact emotional processing and cognitive functions leading to psychopathology (Bacaro et al., 2024; Medic et al., 2017). This tendency for emotional problems often involves worry and rumination –engaging repeatedly in unproductive thoughts about personal issues, which hinders emotional processing (de Jong-Meyer et al., 2009). Such cognitive processes have been identified as aggravating factors for internalizing symptoms in adolescents (Bacaro et al., 2024). Furthermore, inadequate sleep among adolescents, including irregular sleep habits, pre-sleep arousal, and short sleep duration, has also been bidirectionally correlated with externalizing behaviors like impulsiveness, addictions, and antisocial behaviors (Bacaro et al., 2024; Kortesoja et al., 2020). Table 1 presents a summary of the short- and long-term associated risks of sleep disturbances on adolescents' health.

Despite the importance of sleep, a significant proportion of adolescents do not achieve the recommended amount of sleep and experience sleep problems (Hysing et al., 2013; Saxvig et al., 2021). In response to these issues, several organizations have introduced initiatives and guidelines to promote healthier sleep patterns among adolescents. The Office of Disease Prevention and Health Promotion (ODPHP) and the Canadian 24-Hour Movement Guidelines for Children and Youth outline objectives explicitly focused on improving sleep health to enhance the quality of life and reduce health disparities (ODPHP, 2021; Tremblay et al., 2016). This includes improving sleep quality, increasing sleep duration, and advocating for later school start times (CDC, 2023). Likewise, various health organizations, such as the National Sleep Foundation, highlight the importance of sleep duration and quality and offer consensus recommendations for an appropriate quantity (8-10 hours) (Hirshkowitz et al., 2015).

Table 1. Summary of the short- and long-term consequences of sleep disruption in adolescents, based on findings from Medic et al. (2017)

SHORT-TERM	LONG-TERM
Stress Response Activation: - Sleep disruption leads to increased activity of the sympathetic nervous system and hypothalamic–pituitary–adrenal axis. - The hormonal stress response affects mood and cognitive functionality.	**Cardiovascular and Metabolic Health:** - Chronic sleep disruption in adolescents can lead to hypertension and cardiovascular disease. - Related to weight-related issues and can contribute to metabolic syndrome and type 2 diabetes mellitus.
Somatic Symptoms: - Adolescents may experience somatic pain, such as headaches and abdominal pain. - This is related to personality factors and life events.	**Mental Health:** - Persistent sleep disruption is a risk factor for mood disorders, including depression and anxiety, which could result in a diminished quality of life.
Psychosocial Issues: - Impaired sleep negatively affects emotional well-being, and lead to psychiatric symptoms and substance use. - Adolescents may experience emotional distress, irritability, psychosocial difficulties, and school performance.	**Cognitive and Performance Impairment:** - Over time, sleep disruption can lead to deficits in cognitive functioning, negatively affecting attention, memory, and performance. - Increase the likelihood of risk-taking behaviors.

1.2. SUBSTANCE USE IN ADOLESCENCE

1.2.1. Consequences of substance use during adolescence

As occurs with sleep issues, adolescence is a period where the probability of using alcohol and other drugs significantly increases (EMCDDA, 2020; OEDA, 2023a) and the preservation of physical and mental health is at risk (Ammerman, 2019; Blakemore, 2019). The initiation of drug use at an early age not only increases the probability of health issues but also contributes to developing substance use problems and substance use disorder, highlighting adolescence as a critical timeframe for dependency development (Jordan & Andersen, 2017).

Different terminology has been used to talk about substance use in adolescents that needs differentiation. According to the American Psychiatric Association (APA), the term *Substance Use Disorder* (SUD), or *addiction,* denotes a condition where recurrent use of alcohol and/or drugs among adolescents results in clinically and functionally significant impairment, including health problems, disability, and difficulties meeting major responsibilities in various aspects of life, such as work, school, or family (APA, 2013). Besides substance use disorder, *substance misuse or problematic substance use* has been applied when adolescents encounter psycho-social, medical, or legal issues as a result of their drug use, often involving high doses (Ammerman, 2019; McLellan, 2017). For example, binge drinking is a common form of substance misuse, which refers to consuming 4 or more Standard Drinking Units (SDUs) on a single occasion for females and 5 or more SDUs for males (NIAAA, 2023). This behavior has been associated with several health and social problems (Keyes et al., 2020). Ammerman (2019) also proposes another subcategory of problems related to substance use in adolescents, the term *risky substance use.* The term refers to the use of drugs that leads adolescents to engage in behaviors they would not otherwise participate in, posing risks to their well-being (e.g., unsafe sex), but it does not necessarily imply that the problems have been established at a specific time.

In this sense, both sporadic and continuous use of drugs is associated with health risks in adolescents that can manifest as both short-term and long-term effects in adulthood. Concerning short-term associated effects, the use of alcohol and other drugs among high school students can often lead to risky behaviors. This includes driving under the influence of substances, putting at risk their health and safety (Osilla et al., 2019). Also, engaging in risky sexual behaviors increases the likelihood of contracting sexually transmitted diseases (Ritchwood et al., 2015). Similarly, studies have indicated a higher prevalence of certain medical conditions among adolescents who use substances, including breathing difficulties and pain-related diagnoses, among others (Ammerman, 2019). Regarding mental health, the development of mood disorders, such as depression, has been partly attributed to substance use (Gobbi et al., 2019). In this regard, the co-occurrence of mental health disorders and substance use can further contribute to the risk of suicidal thoughts and behaviors in adolescents (Berny & Tanner-Smith, 2022; Gobbi et al., 2019). In fact, studies have shown that adolescents with substance use disorders are about five times more likely to attempt suicide compared to non-drug-using adolescents (Jones et al., 2023).

Regarding long-term effects, it should be highlighted the risk posed by substance use for brain development during adolescence. Alcohol, cannabis, and nicotine exposure lead to a higher probability of negative effects on brain development and behavior (Steinfeld & Torregrossa, 2023). Alcohol use could result in cognitive impairments and increased vulnerability to stress-related mental health disorders. The use of cannabis may contribute to disrupting brain maturation processes, leading to psychiatric disorders, cognitive deficits, and changes in brain structure associated with schizophrenia and reward processing (Matheson et al., 2023). On the other hand, nicotine exposure can disrupt neurotransmitter systems, leading to mood and anxiety disorders, as well as an increased susceptibility to substance use. This alters brain pathways involved in reinforcement, making adolescents more vulnerable to nicotine addiction (Steinfeld & Torregrossa, 2023).

Despite these health issues, the prevalence of substance use and misuse among adolescents is currently a major global health concern, attributed to the rising rates of cannabis and nicotine consumption, particularly in Anglo-Saxon countries, as well as the persistently high prevalence of alcohol use worldwide (SAMHSA, 2022). Although in some countries such as Spain, a reduction in substance use among adolescents has been observed over the last ten years (Brime & Villalbí, 2023), SUDs remain one of the most prevalent mental disorders in childhood and adolescence (Bitsko et al., 2022; SAMHSA, 2022).

1.2.2. Prevalence data on adolescents' substance use

The initiation of drug use among adolescents is a significant public health concern, with alcohol, tobacco, and cannabis being the substances most used during early adolescence (EMCDDA, 2020; OEDA, 2023a). Despite these drugs being illegal for adolescents in most countries, adolescents typically begin experimenting with these substances between the ages of 12 and 15, marking the early onset of a potentially risky trajectory (Jordan & Andersen, 2017; OEDA, 2023a). Previous research indicates that while experimentation may start by the beginning of adolescence, the prevalence of drug use tends to escalate throughout this developmental period and peaks during late adolescence and early adulthood (Halladay et al., 2020; OEDA, 2023b; Pielech et al., 2023).

The prevalence of this increase in drug use has fluctuated in recent years and varies depending on the type of substance and the country. While alcohol use has decreased since the last decade (OEDA, 2023a), cannabis and nicotine consumption appear to have increased in the United States (Keyes et al., 2022), alongside other illicit drugs such as opioids (SAMHSA, 2022) or non-prescribed hypnotic sedatives in European countries (OEDA, 2023a).

Alcohol

Alcohol remains the most used substance among adolescents with more than a third of teenagers starting drinking before the age of 13, and approximately 79% prevalence of lifetime use of alcohol use (EMCDDA, 2020; OEDA, 2023a). The data from the European School Survey Project on Alcohol and Other Drugs indicates that about 47% of European adolescents reported drinking alcohol in the past month and 34% engaged in binge drinking (EMCDDA, 2020). These rates are similar among Spanish adolescents according to the Spanish Survey on Drug Use in Secondary Education (ESTUDES). The prevalence of intoxication and binge drinking in the past month is 20.8% and 28.2%, respectively, with boys showing higher rates than girls (OEDA, 2023a). Although the prevalence of alcohol use has decreased over the last decade among Spanish adolescents, there is still a considerable percentage of problematic use, and rates of Alcohol Use Disorder (AUD) identification can reach up to 27.2% (Fernández-Artamendi et al., 2021; Isorna et al., 2022). During adolescence, the prevalence of alcohol use also increases with age; older adolescents double the prevalence of alcohol use in the past month and are more likely to report episodic binge drinking (Keyes et al., 2022; Rodríguez-Ruiz et al., 2021; Scoppetta et al., 2022; Troxel et al., 2021).

Tobacco

Nicotine ranks as the second most commonly used substance following alcohol (EMCDDA, 2020; OEDA, 2023a). In recent years, there has been a notable rise in the prevalence of nicotine use in adolescents, especially in the context of electronic cigarette consumption (OEDA, 2023a; SAMHSA, 2022). The use of e-cigarettes, or vaping, is used to deliver flavorings and psychoactive substances such as nicotine, which is often delivered at higher doses than combustible cigarettes increasing the risk of addiction (CDC, 2016, 2020b; Jankowski et al., 2019). According to the U.S. National Survey on Drug Use and Health, among adolescents aged 12 to 17 who used nicotine products in the past month (7.3%), more than 70% vape nicotine against other tobacco products (SAMHSA, 2022). In Spain, smoking tobacco has decreased in the last years, with a current prevalence of 21% for the past month of use; however, the use of electronic cigarettes has increased to 26.3% in 2019 (OEDA, 2023a). According to the ESTUDES survey, tobacco and electronic cigarette use is more prevalent in women than in men, although the number of cigarettes and the age of onset remain similar (OEDA, 2023a).

Cannabis and other drugs

Cannabis stands as the third most-used drug among adolescents, and one of the most accessible illegal substances (EMCDDA, 2020; OEDA, 2023a). The prevalence of past-year cannabis use is 11.5% for European adolescents and has doubled in the past 10 years (Keyes et al., 2022). In Spain, recent data from the ESTUDES survey reveal a higher prevalence of cannabis use among adolescents, with about 22% reporting past-year cannabis use and 15.6% past month use, exceeding the European prevalence average (EMCDDA, 2020; OEDA, 2023a). Initiating drug use trajectories with marijuana is common, with two-thirds of adolescent illegal drug users beginning with cannabis (Zhang et al., 2021). While the exact prevalence of Cannabis Use Disorder (CUD) among adolescents is uncertain, recent studies indicate a prevalence rate between 7% and 10% of adolescents diagnosed with CUD (Fernández-Artamendi et al., 2021; Oladunjoye et al., 2023).

The use of other illicit drugs is considerably less common among adolescents with a prevalence rate of less than 3% in 12–17-year-olds teenagers (EMCDDA, 2020; OEDA, 2023a). In Europe, the lifetime prevalence is highest for the use of ecstasy (2.3%), cocaine (1.9%), and amphetamine (1.7%). In Spain, the rates are slightly higher than those of other European countries. There has been an increase in the non-prescribed use of hypnotic drugs over the last 10 years, with a current lifetime usage rate of 9.7% (OEDA, 2023a). The 12-month prevalence for non-prescribed hypnotic drugs is at 7.4%, while it is at 2.3% for cocaine and 2.2% for ecstasy—numbers that exceed the average lifetime usage in European countries (OEDA, 2023a).

During adolescence, the use of multiple substances is common, a phenomenon commonly referred to as polydrug use. Polydrug use occurs when individuals consume two or more substances either simultaneously or concurrently (Keyes et al., 2022). Simultaneous polydrug use involves the use of different substances at the same time, such as mixing alcohol with cocaine. This practice is often driven by the desire to enhance or alter the effects of one substance with another. Concurrent polydrug use, on the other hand, involves the use of different substances at different occasions or times. For example, adolescents may drink alcohol on one occasion and then experiment with cannabis on another occasion.

Both simultaneous and concurrent substance use behaviors lead to potentially dangerous interactions and increased risks of adverse outcomes, contributing to a pattern of polydrug use among adolescents that extends beyond single substance use.

1.2.3. Substance use patterns during adolescence

During adolescence, the use of multiple substances often overlaps, implying different patterns of drug use alongside specific risk factors (Halladay et al., 2020). In this regard, a recent systematic review of the literature indicates that adolescents exhibit an average of four profiles of drug use, with a range from two to six classes (Halladay et al., 2020). The predominant group consists of non-users or those with a low probability of only using alcohol, which jointly represents over 50% of adolescents. Other subgroups identified represent approximately one-third of adolescents with concurrent use of different types of drugs (Halladay et al., 2020). Among these cases, the most common polysubstance pattern includes drinking alcohol and using tobacco and/or cannabis (Banks et al., 2017; Halladay et al., 2020; Roberts et al., 2023; Tomczyk et al., 2015). However, other specific and less prevalent groups also include high multiple use of substances, such as high-risk alcohol use, cannabis, tobacco, misuse of medication, and or other illicit drugs (Halladay et al., 2020). In this case, initiating marijuana and inhalant use during adolescence poses significant risks for subsequent drug involvement, leading to greater health risks and continued drug use in the following years (Zhang et al., 2021).

Regarding this, research has also shown that a large percentage of adolescents have reported simultaneous use of substances (Keyes et al., 2022; Patrick et al., 2018). Rates of simultaneous use vary by substance and specific populations, with an average prevalence of 33% for lifetime use (Salmon et al., 2023). Alcohol and nicotine are simultaneously used by 8% of adolescents, including both cigarettes and vaping (Salmon et al., 2023). For alcohol and cannabis, the past-year prevalence of simultaneous use has decreased among adolescents over the past twenty years, dropping from 24.4% to 18.7%, which highlights shifting prevalence trends over time (Keyes et al., 2022). However, the rates of poly-use increase with the combination of tobacco and cannabis, with over 40% of young individuals engaging in trajectories involving different tobacco and cannabis products (Dugas et al., 2022; Lanza et al., 2021). The combination of alcohol with other illicit drugs is highly prevalent, especially the mixture of alcohol and cocaine (van Amsterdam & van den Brink, 2023).

Previous studies suggest that polydrug use increases the likelihood of developing potential SUD, overdose (Lyons et al., 2019; Rodríguez-Ruiz et al., 2021), and other harms including unhealthier lifestyle, psychosocial problems, and mental health disorders (Brook et al., 2016; Carbonneau et al., 2023; Rodríguez-Cano et al., 2023; Vergunst et al., 2022). Likewise, polysubstance abuse patterns have been linked to early onset age of drug use as well as factors such as belonging to racial/ethnic minorities, parental drug utilization history, and lower socioeconomic status (Banks et al., 2017; Coulter et al., 2019; Halladay et al., 2020; Tomczyk et al., 2015).

Regarding sex, findings remain inconclusive. While some studies suggest that male adolescents are more likely to engage in polydrug use and drinking more frequently than females (Halladay et al., 2020; Leung et al., 2019; McHugh et al., 2018; Zuckermann et al., 2019), other studies suggest that female adolescents tend to develop substance use problems earlier (McHugh et al., 2018), and are involved in more risky substance use behaviors (Gilreath et al., 2014; Halladay et al., 2020).

Although there is a broad field of study on substance use patterns, which continues to expand, substance use can vary depending on a variety of different risk or protective factors emerging in adolescence, including but not limited to environmental and socioeconomic factors, psychosocial influences, and individual differences.

1.2.4. Predominant biopsychosocial risk/protective factors

Considering the importance of risk and protective factors for substance use, this section will describe the predominant biopsychosocial factors related to the occurrence of substance use in adolescence.

As mentioned in previous sections, changes experienced during adolescence such as increased autonomy, more social interactions, and engagement in new evening activities may contribute to raising the risk of using substances. These changes interact with other environmental, psychosocial, and biological factors, providing a better understanding of the initiation of substance use among adolescents (Becoña, 2023). The biopsychosocial model and the ecological theory take this comprehensive approach over a narrow focus of other models and theories to understand addictive behavior (Becoña, 2023; Robertson et al., 2015; Skewes & Gonzalez, 2013). In accordance with the biopsychosocial model, Jessor's Risk Behavior Theory (Jessor, 1992) outlines five clusters of risk and protective factors. These factors establish a comprehensive conceptual framework for understanding adolescent drug use, encompassing biological aspects, social environment, perceived context, personality traits, and behavior. This framework posits that substance use and addiction among adolescents result from an interplay and reciprocal causation of these risk/protective factors (Jessor, 1992). Protective factors refer to assets and resources that enhance adolescents' ability to cope with and resist substance use or other risk-related factors. Conversely, risk factors represent vulnerabilities that increase the likelihood of drug use. In this regard, the prevention of substance use is oriented towards mitigating risk factors while promoting protective factors during adolescence (Becoña, 2023).

Biological factors

In adolescence, the heightened reactivity of reward, habit, and stress systems increases the risk of alcohol use (Jordan & Andersen, 2017; Volkow & Blanco, 2023; Volkow & Boyle, 2018). Neuroscience has shown that adolescents are more vulnerable to addiction than adults due to their developing brains and greater neuroplasticity. During adolescence, neuronal circuits associated with reward and motivation develop faster than those in the prefrontal cortex, leading to increased emotional reactivity and thrill-seeking behaviors (Jordan & Andersen, 2017; Volkow & Boyle, 2018).

The later development of the prefrontal cortex means that adolescents do not have the same ability as fully developed adults to self-regulate their behavior. This greater neuroplasticity explains why addiction develops faster among adolescents and makes this population more susceptible to environmental and psychosocial factors (Hasler & Clark, 2013; Volkow & Boyle, 2018). In this regard, delaying the onset of alcohol and other drug use can prevent or reduce problematic use or SUDs in adolescents and adults (Gallegos et al., 2021; Millar et al., 2021).

Additionally, other risk factors, such as male sex, genetics, or individuals with certain physical health conditions may increase the vulnerability for substance misuse (Becoña, 2023; Volkow & Blanco, 2023). For instance, head trauma or neurodevelopmental disorders may contribute to issues in the prefrontal cortex and therefore increase the risk of SUD in adolescents. Similarly, male sex has been associated with a higher risk for early initiation of substances as well as SUD (Volkow & Blanco, 2023). These biological factors can manifest early in life and undergo changes at different life stages influenced by social, environmental, and psychological factors.

Environmental factors

While biological factors play a central role in determining substance use in adolescents, the environment and contextual factors also influence this behavior. Numerous studies suggest that schools, neighborhoods, and communities play a significant role in influencing the likelihood of drug use among adolescents (Trucco, 2020). The environmental context of disadvantaged neighborhoods can often act as a facilitator for substance use. This is due in part to more accessible and lower-priced substances, for example alcohol and tobacco products in these areas, making it easier for adolescents to obtain them (Ajilore et al., 2016; Milam et al., 2016; Trucco, 2020). Likewise, previous studies have shown that there can be differences in substance access between rural and urban areas. Adolescents living in rural areas tend to report higher levels of access to legal substances, while adolescents from urban areas tend to report higher levels of access to illicit substances (Warren et al., 2015). However, it is important to note that these differences can vary depending on the culture, country, and the type of substances (Monnat & Rigg, 2016).

Besides environmental features, the absence of anti-drug policies in schools and a lack of resources dedicated to supporting at-risk teenagers within the community significantly contribute to increasing substance use among youths (Trucco, 2020; Vincent & Petch, 2017). In this regard, neighborhood disadvantage, crime, and policies limiting opportunities for economically disadvantaged families are also linked to the use of drugs (Amaro et al., 2021). By contrast, several schools' protective factors can contribute to preventing and reducing the likelihood of substance use. A prosocial school environment and feeling connected to the school/teacher can help protect from starting to smoke, drink alcohol, or use cannabis over time (Weatherson et al., 2018). Thus, research highlights the importance of social norms, substance-free environments, and legal measures in addressing the prevention of drug use as part of our ongoing efforts to tackle this issue affecting adolescents' health.

Interpersonal factors

Regarding social influences, families and peers also play a significant role in the use of substances representing one of the strongest effects contributing to adolescents' substance use behaviors (Solmi et al., 2021; Trucco, 2020). Modeling learning is one of the mechanisms through which adolescents initiate substance use, as proposed by Bandura's Social Learning Theory (Bandura, 1977, 1989). Adolescents who observe substance use in their parents are more likely to engage in substance use themselves compared to those who grow up in a drug-free environment (Homel & Warren, 2019). Furthermore, parental attitudes toward substance use can influence adolescents and either promote or discourage substance abuse, despite the parents' educational intent. For example, some parents provide alcohol to their children believing it could prevent excessive drinking with friends when unsupervised (van der Kruk et al., 2023; Wadolowski et al., 2016). However, studies indicate that this parental strategy leads teenagers to normalize their perception of drinking alcohol and increases the likelihood of subsequent binge drinking and alcohol-related problems (Mattick et al., 2018). Conversely, adequate parental reward in adolescents' prosocial behavior as well as increased parental monitoring of adolescent activities has been related to a lower frequency of alcohol use, a lower likelihood of illicit substance use, and delayed onset age of substance use (Muchiri & Raniti, 2018).

On the other hand, peer influence emerges as a potent determinant in substance use, particularly in the presence of socially deviant attitudes among peers (Hinnant et al., 2022). Engagement in drug use within a peer group can foster a sense of belonging and promote normative levels that endorse substance use. In fact, a predominant motive for alcohol use among adolescents lies in the desire to socialize and to be integrated within the social group (Nawi et al., 2021). This also relates to new activities associated with substance consumption by adolescents, or the permissive attitudes peers hold towards drugs (Becoña, 2023). Moreover, the association with friends who smoke or use cannabis stands out as the most robust predictor of engaging in similar drug-related behaviors (e.g., Wellman et al., 2023).

Psychological factors

Various psychological aspects, encompassing both internalizing and externalizing problems, as well as attitudes and beliefs regarding substance use are bidirectionally linked with the onset and regular use of drugs among adolescents (Brook et al., 2016; Gerdner & Håkansson, 2022; Köck et al., 2022; Solmi et al., 2021).

Personality-related variables have been consistently linked to a higher likelihood of substance use during adolescence and adulthood. These variables encompass attributes such as impulsivity, a preference for sensation-seeking behaviors, negative affectivity, and instability of mood (Solmi et al., 2021; Wellman et al., 2023). For instance, impulsivity may lead to risky decision-making regarding substance use, and sensation-seeking behavior may drive to experimentation with drugs. In addition, negative affectivity may prompt substance use as a coping mechanism, while mood instability may exacerbate susceptibility to substance abuse as a means of self-medication or mood regulation. Additionally, antisocial personality and deviant behaviors act as robust predictors of drug use, exhibiting high levels of comorbidity with SUD in adulthood (Brook et al., 2016; Köck et al., 2022). Similarly, the perception of the harmless use of substances contributes to increased drug experimentation among adolescents and greater tolerance attitudes (Nawi et al., 2021). These beliefs, formed by societal norms, peer influences, and the media, play a main role in shaping adolescents' behaviors toward substance use (Becoña, 2023). Therefore, several psychological factors contribute to the prevention of use, such as self-confidence or self-efficacy to adhere to anti-consumption norms, increased resilience skills to confront consumption-triggering situations, enhanced social competence and problem-solving skills, as well as improved social skills (e.g., Heradstveit et al., 2023; Lardier et al., 2020).

In addition to the mentioned factors, other potential risk/protective factors related to adolescent drug use should also be acknowledged and studied. One such factor is the quality of sleep, which can have a significant impact on the likelihood of substance use. Research has shown that experiencing sleep problems or disorders is prospectively associated with a higher risk of using drugs and alcohol in adolescents (Bacaro et al., 2024; Haynie et al., 2017; Troxel et al., 2021, 2022). In this regard, sleep quality has been identified as a potential transdiagnostic criterion and risk factor according to the Research Domain Criteria (RDoC) initiative by the National Institute of Mental Health. This initiative encourages research into uncovering biological and psychosocial mechanisms characterizing multiple mental health disorders, including the development and exacerbation of SUD (Feld & Feige, 2021).

In this way, just as with mental disorders, high comorbidity exists between sleep disorders and the presence of SUD in adolescents.

1.2.5. Comorbidity of SUDs with mental and sleep disorders

Psychiatric disorders are common among people who use substances or are diagnosed with a SUD, to the extent that it is debated whether it is a comorbidity inherent to SUDs or mental disorders (Fernández-Artamendi et al., 2024). Comorbidity is notably prevalent during adolescence, corresponding to about a third of adolescents with SUD also diagnosed with other disorders, with significantly larger comorbidity rates among girls (Fernández-Artamendi et al., 2021; Köck et al., 2022; Korsgaard et al., 2016; Schulte & Hser, 2014). Commonly associated psychiatric disorders include attention-deficit/hyperactivity disorder (ADHD), affective disorders, conduct disorders, and first-episode psychosis (Fahrendorff et al., 2023; Köck et al., 2022). In this regard, diagnosis of depression, anxiety, and obsessive-compulsive disorder is significantly linked with CUD and AUD, and with 21.4% of adolescents with problematic alcohol use (Chhoa et al., 2019). Furthermore, the prevalence of comorbid depressive disorder and illicit drug use among adolescents aged 12 to 17 is estimated at 26.1% (SAMHSA, 2022) while comorbid SUD is reported between approximately 13% and 27% of adolescents with pediatric bipolar disorder (Fahrendorff et al., 2023; Karlsson et al., 2006).

Regarding sleep, the prevalence of sleep disorders (e.g., hypersomnolence) is more prevalent among adolescents reporting substance use (Phiri et al., 2023; Zhabenko et al., 2016). The overall prevalence of sleep disturbances is 29%, but it fluctuates depending on the substance and the specific sleep problem (Phiri et al., 2023). For example, the prevalence rates of insomnia disorder vary across different groups. Among drinking adolescents, the rate is 31%, while among tobacco and cannabis users the rates are 28% and 26%, respectively. In terms of hypersomnolence, one-third of drinking adolescents experience this sleep disorder, with the percentage rising to 46% in adolescents who smoke tobacco (Phiri et al., 2023). The rates of exhibiting clinically sleep problems seemed also to be associated with substance use, particularly with non-prescribed stimulants, sedatives, and opioids (Zhabenko et al., 2016).. In clinical samples, adolescents experiencing poor sleep are 1.2 times more likely to report non-prescribed medication use and tobacco use, than those without sleep problems (Zhabenko et al., 2016).

Besides sleep disorders, sleep disturbances are commonly associated with SUDs, and as previously mentioned, can serve as a transdiagnostic indicator (Feld & Feige, 2021). This poses sleep quality and its relationship with SUDs as an important area of focus in understanding and addressing adolescent drug use.

1.3. SLEEP QUALITY AND DRUG USE: A BIDIRECTIONAL ASSOCIATION

As previously stated in this dissertation, sleep and substance use issues represent significant global health concerns, especially during the period of adolescence (Bacaro et al., 2024; Carbonneau et al., 2023; Medic et al., 2017; Rodríguez-Cano et al., 2023; Tuvel et al., 2023; Vergunst et al., 2022). Extensive research has focused on studying the relationship that exists between sleep and substance use, revealing a complex interplay where both factors influence each other (Haynie et al., 2017; Kwon et al., 2019; Pasch et al., 2012; Roehrs et al., 2021). Several longitudinal studies have underscored this dynamic interaction, indicating that adolescent substance use may significantly contribute to altering sleep patterns and contribute to disrupted sleep quality, while sleep problems and specific sleep patterns may play a significant role in both the initiation and maintenance of substance use (Hasler et al., 2022; Troxel et al., 2022; Wallis et al., 2022). This creates a vicious cycle where each factor maintains or aggravates the other, leading to escalating dose and increasing the risk for SUD (Conroy, 2017; Conroy & Arnedt, 2014).

1.3.1. Impact of substance use on sleep

The use of substances during adolescence can significantly impact various dimensions of sleep, encompassing the quantity and quality of deep sleep, Rapid Eye Movement (REM) sleep, sleep schedule, and sleep onset latency (Kwon et al., 2019). Studies have revealed that certain substances, such as alcohol and cannabis, can initially promote sleep by reducing the time needed to fall asleep and extending the periods of deep sleep stages (Jacobus et al., 2009; Vitiello, 1997). However, while these substances may offer immediate seeming advantages in helping to fall asleep and improving specific sleep phases, prolonged and excessive use can result in opposing outcomes. Research suggests that the use of sedative effects of certain substances like alcohol and cannabis can disrupt overall sleep architecture, resulting in fragmented sleep and frequent awakenings during the night (Colrain et al., 2014).

As an example of this effect, Figure 2 illustrates four hypnograms representing the stages of sleep during the night. These images demonstrate the impact of substance use on sleep architecture, with each hypnogram showing variations in sleep stages and disruptions caused by the short- and long-term effects of using cannabis (Kaul et al., 2021). As observed in hypnograms c and d, regular use might contribute to developing tolerance towards these drugs' sedative effects, leading to trouble initiating sleep cycles (Kaul et al., 2021; Martin-Willett et al., 2022). The use of alcohol or cannabis in adolescents can contribute to disruptive sleep patterns. This includes irregularities in adolescents' natural circadian rhythms with a preference for staying up late, reduced overall night sleep duration, and an increased tendency toward prolonged periods of deep sleep. Additionally, substance use can lead to difficulties falling asleep and maintaining quality rest during the night (Haynie et al., 2017; Kwon et al., 2019).

This association becomes more evident with an early onset age in substance use, higher frequency, and engaging in heavy episodic drinking, which has also been linked to difficulties in initiating and maintaining sleep in adolescents (Kwon et al., 2019; Ogeil et al., 2019; Winiger et al., 2019). Adolescents who drink alcohol regularly often experience a decreased duration of non-REM sleep, increased nocturnal awakenings, prolonged sleep latency, and reduced total sleep (Colrain et al., 2014; Kiss et al., 2023) –this effect is represented in the hypnogram c of Figure 2. Among individuals who engage in binge drinking or exhibit problematic alcohol use, sleep problems become particularly noticeable. Over time, these individuals frequently report a significant decrease in their amount of sleep, difficulty falling asleep and staying asleep, particularly during a period of abstinence (see hypnogram d), and contributing to an elevated risk of developing sleep disorders (Haynie et al., 2018; Lee et al., 2019; Patte et al., 2018).

The effects of regular or prolonged alcohol use on adolescents' sleep quality are also observed in those adolescents who frequently use cannabis. Besides alterations in the sleep architecture (Figure 2), cannabis use has been associated with higher rates of insomnia, short sleep duration during weekdays, later bedtimes, clinically significant sleep problems, and daytime dysfunction (Phiri et al., 2023; Troxel et al., 2021, 2022;

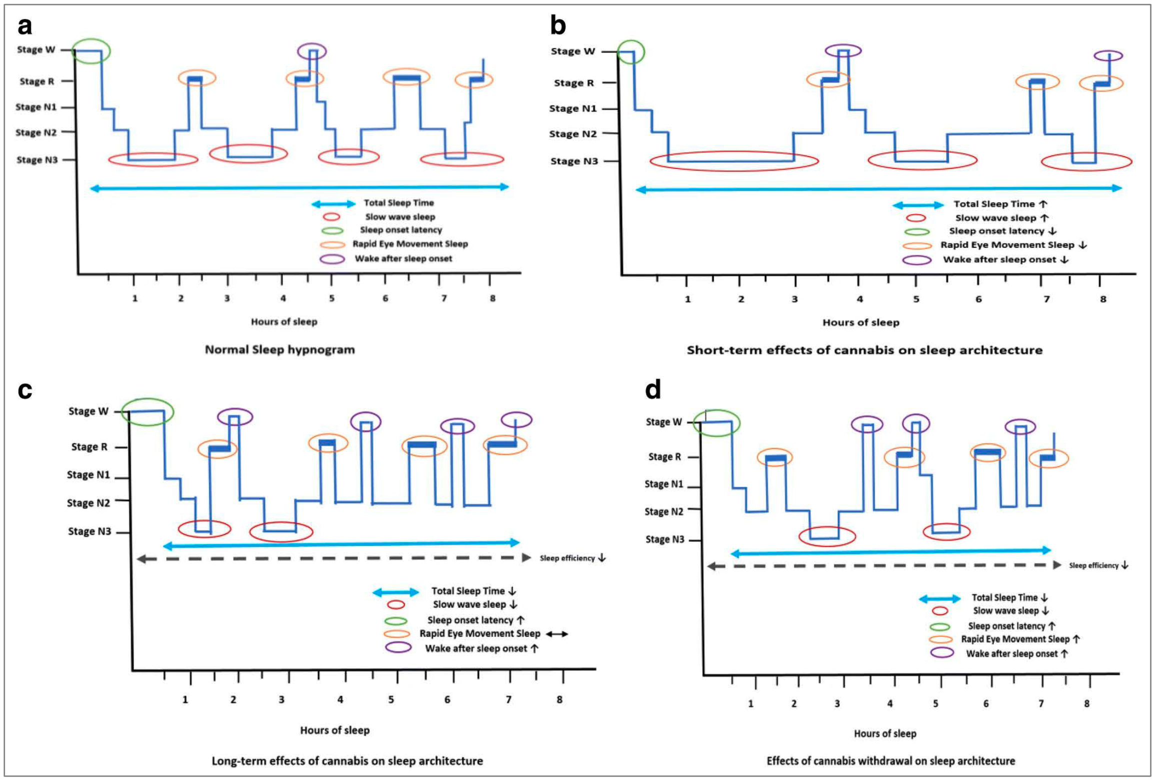

Fig. 2. Summary of effect of cannabis on sleep architecture (short term b, long term, and effects of withdrawal of cannabis). *Reproduced with permission from Springer Nature*

Winiger et al., 2022; Zhabenko et al., 2016). These findings are particularly relevant, given the widespread misinformation regarding the beneficial effects of cannabis on sleep improvement among adolescents (Hashemi & Gray, 2023; Isorna et al., 2023). Perceiving cannabis as less harmful and utilizing it for medical purposes have been associated not only with a greater risk for cannabis dependence but also with poor sleep (Goodhines et al., 2022; Wardell et al., 2021).

Regarding tobacco use, few longitudinal studies have been conducted in adolescents. Existing literature suggests that the stimulating effect of nicotine may contribute to altering the structure of sleep phases and impairing sleep onset. Several empirical data have revealed that an increased number of smoking occasions is linked to various sleep issues. These include more subsequent experiences of recent and chronic difficulty initiation sleep, reduced total weekly sleep hours, later bed and wake-up times of sleep, as well as poor alertness during daytime (Kwon et al., 2019). This effect seems to extend to the use of electronic cigarettes and vaping, with adolescents who used these products showing insufficient sleep than non-tobacco users, with dual users of smoking and non-smoking nicotine products more likely to report short sleep (Baiden et al., 2023; Dunbar et al., 2017; Merianos et al., 2021).

Regarding the use of other substances, studies have primarily focused on adult populations, and there is limited data on the impact that illicit drugs have on adolescent sleep. The literature suggests that stimulant substances such as cocaine or ecstasy are associated with wakefulness and sleep disturbances, particularly during acute intoxication (Bjorness & Greene, 2021; Ryan, 2019; Schierenbeck et al., 2008). Likewise, the use of opioids or misuse of medication is prospectively associated with non-restorative sleep, and insomnia among adolescents (Groenewald et al., 2021; Short et al., 2023).

In this regard, sleep is likely to vary according to different aspects of substance use behaviors (e.g., type of substance, time using, withdrawal, etc.) as well as a function of other health comorbidities (e.g., internalizing symptoms) experienced by people who use drugs. This negative impact on sleep can also have a reverse effect, meaning that reducing or quitting drugs can contribute to improving sleep quality (Huhn et al., 2022). Effective treatments for SUDs in adult clinical samples have demonstrated not only a reduction in consumption but also improvements in sleep as a secondary outcome (e.g., Coffin et al., 2020). This suggests that sleep could play a key role in the remission of the SUDs (Berro & Roehrs, 2022; Huhn et al., 2022).

1.3.2. Impact of poor sleep on substance use

In the preceding section, the impact of drug use on sleep quality has been described, since this relationship is bidirectional, this section addresses the impact of sleep quality on substance use.

Regarding the influence of inadequate sleep on the onset and persistence of drug use during adolescence, longitudinal studies remain scarce. The available evidence suggests that experiencing sleep problems increases the risk of using alcohol, cannabis, tobacco, and misuse of medication (Hasler et al., 2024; Kwon et al., 2019; Miller et al., 2017; Pielech et al., 2023; Short et al., 2023; Troxel et al., 2022). According to the study conducted by Nguyen-Louie et al. (2018), maladaptive sleep practices and increased daytime sleepiness in preadolescence can predict a greater lifetime use of substance use in adolescence. In particular, adolescents with an evening chronotype, characterized by a preference for staying active and sleeping later, appear to exhibit higher rates of alcohol and cannabis use. Additionally, erratic sleep behaviors (e.g., staying up all night) during adolescence may mediate the effect of inhibitory control on subsequent substance use. These findings suggest that sleep problems in early adolescence may be an important risk factor for substance use later in life (Hasler et al., 2024; Nguyen-Louie et al., 2018).

Similarly, previous research indicates that adolescents with poor sleep show a higher frequency of alcohol use over time compared to good sleepers (Kwon et al., 2019; Miller et al., 2017; Pielech et al., 2023; Troxel et al., 2022). This is characterized by delayed bed and wake-up times, greater misalignment of sleep schedules, and increasing difficulty sleeping, which has been linked to a higher likelihood of alcohol use in the transition to adulthood (Hasler et al., 2024; Nguyen-Louie et al., 2018; Troxel et al., 2021). This association appears to be supported by a preference for immediate rewards among those adolescents experiencing poor sleep, such as drinking and using alcohol as a sleep aid to induce sleep (Graupensperger et al., 2023; Hasler et al., 2017, 2022; Hasler & Pedersen, 2020). Data from longitudinal studies also suggest that shorter sleep duration and daytime sleepiness during preadolescence are associated with a higher likelihood of engaging in heavy episodic drinking and problems related to alcohol use in adolescence (Miller et al., 2017).

In line with this, associations have been observed for preadolescents reporting short sleep duration and an increased probability of using cannabis in adolescence (Miller et al., 2017). Recent findings indicate that both short sleep and alterations in sleep schedules correlate with changes in the likelihood of cannabis use over time. Specifically, declines in total time in bed on weekends, increases in weekday time in bed, as well as later bedtimes were associated with an increased likelihood of cannabis use (Nguyen-Louie et al., 2018; Troxel et al., 2021). As with alcohol, sleep problems may provide a pathway for using cannabis as a self-medication behavior. Although this association has been mostly investigated in the adult population, recent studies point to the same trend among adolescents (Goodhines et al., 2022; Graupensperger et al., 2023; Wallis et al., 2022).

Likewise, the short and long-term effects of sleep on nicotine initiation and consumption, particularly via electronic nicotine devices, are increasing among adolescents. Research indicates that experiencing sleep problems, such as trouble falling asleep, significantly raises the risk of subsequent smoking or the onset of electronic nicotine devices in the following year (Bellatorre et al., 2017; Holtz et al., 2022). Additionally, adolescent sleep deprivation, characterized by less than six hours of sleep per night, is associated with a heightened susceptibility to using electronic nicotine devices within the next 30 days (Holtz et al., 2022). Insufficient sleep hours have also been prospectively associated with the misuse of opioids among adolescents. In this case, insufficient hours of sleep, non-restorative sleep, and experiencing insomnia have been linked to an increased likelihood of opioid misuse (Groenewald et al., 2021; Short et al., 2023). Although there are not yet many studies on this topic, and some results are still inconsistent, sleep problems may play a significant role in the initiation and maintenance of substance use during adolescence and emerging adulthood.

The growing recognition of the significant role that sleep problems play in both the initiation and perpetuation of substance use supports the bidirectionality of this association. Although sleep problems can occur before adolescence, and thus typically before drug use, both factors appear to contribute to the onset of the other; however, the debate over whether sleep disturbances lead to drug use or vice versa resembles the chicken-and-egg paradox. In this regard, it remains unclear how strongly one factor can affect the other, necessitating further empirical studies to confirm theoretical models. These efforts would help clarify the dynamic between these two factors and how interact over time.

1.3.3. Integrative hypothetical models of sleep and substance use

The lack of studies explaining the initial establishment and maintenance of the relationship between sleep and drug use has led to the development of various theoretical models aimed at providing an explanation. These models are based on perspectives grounded in neuroscience, as well as psychosocial approaches that include contextual and mood factors. Based on previous empirical studies, Hairston (2015) proposed a hypothetical model postulating that sleep disturbances are not only a symptom of addiction but can also contribute to vulnerability to addictive behaviors.

The Hairston's model highlights the overlap of regulatory mechanisms in sleep with the neural systems involved in addiction development. The model proposes that disturbed sleep could affect dopamine function, altering reinforcing behaviors such as drug-seeking behavior (see Figure 3). As a result, poor sleepers may be more vulnerable to the effects of drugs and addiction development, also influenced by the impact on mood and affect regulation (Hairston, 2015). This seems to be supported by empirical data in which adolescents with a preference for an evening chronotype or delayed bedtimes are more likely to look for immediate rewards, like drinking alcohol, even when controlling for internalizing and externalizing symptoms (Hasler et al., 2017; Hasler & Clark, 2013; Hasler & Pedersen, 2020).

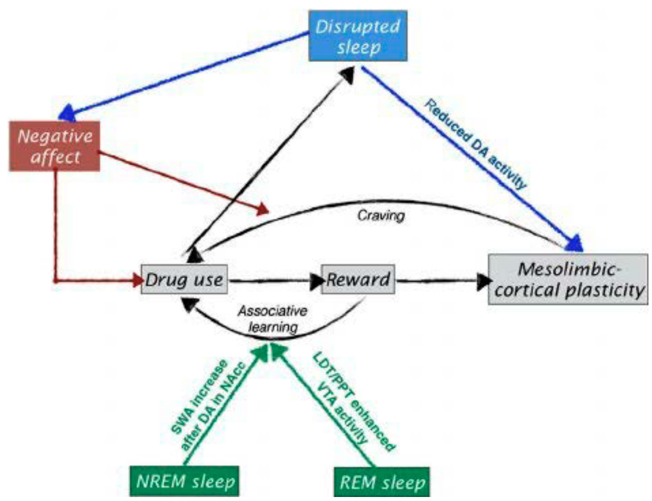

Fig. 3. Model proposed by Hairston (2015). *Reproduced with permission from Elsevier*

Hairston's model includes how emotional states affect the sleep-drug relationship. However, other models place greater emphasis on psychosocial aspects and their influence (Edwards et al., 2015; Nguyen-Louie et al., 2018). One such model is the one proposed by Edwards et al. (2015), which presents a hypothetical framework in which there is a bidirectional relationship established between the psychosocial aspects, pubertal developmental factors, sleep, and substance use (see Figure 4). This model considers the complex interplay of these factors under contextual stressors and suggests that sleep problems may lead to self-medication behaviors with substances through emotional dysregulation and cognitive deficits. Self-medication also applies to alleviating negative affect, contributing to a vicious cycle in which each of the models' factors mutually enhances one another.

This model acknowledges the reciprocal relationship between sleep and substance use that can be applied during adolescence. Yet, other models have focused on earlier ages previous to adolescence, positioning sleep as the trigger for drug use during adolescence (Hasler et al., 2016, 2024; Nguyen-Louie et al., 2018). Nguyen-Louie et al. (2018), tested a hypothetical model where personality traits and contextual factors during early adolescence influence sleep patterns, which in turn heightens the probability of drug use in late adolescence. According to their study, lower inhibition control, and internalizing and externalizing traits may contribute to increasing the likelihood of lifetime use of alcohol, tobacco, and cannabis through erratic sleep and maladaptive behaviors (Nguyen-Louie et al., 2018). Although empirical evidence corroborates associations of theoretical frameworks, demonstrating the bidirectional relationship between sleep and substance use, the strength of this association remains unexplored. As previously mentioned, sleep problems at an early age may contribute to the onset of substance use. However, the use of drugs during early adolescence could be a more significant trigger for the development or persistence of sleep disturbances, as has been similarly observed with emotional difficulties in adolescents (Kortesoja et al., 2020).

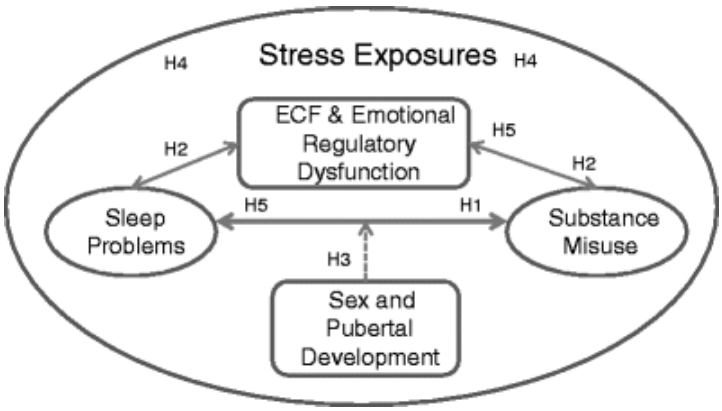

Fig. 4. Edwards et al. (2015) integrative model of the relationship between sleep problems and substance use in youth. *Reproduced with permission from Springer Nature*

Theoretical models also suggest that the link between substance use and sleep is influenced by psychological and environmental risk factors, as well as sleep patterns like a preference for an evening chronotype that can forecast the level of substance involvement in adolescents (Goodhines et al., 2017, 2022; Hasler et al., 2016; Miller et al., 2017; Nguyen-Louie et al., 2018). Some of these empirical studies test theoretical models, while others demonstrate that the relationship is influenced by variables such as depression, anxiety, inhibition control, family SUD history, etc. In this regard, the aforementioned models propose an explanation from both a neurobiological and psychosocial perspective with greater attention to internalizing/eternalizing symptoms.

However, other theories contribute to elucidating these models, offering explanations of underlying mechanisms beyond impairment in the reward system or self-medication behaviors. One such theory is behavioral economics, which integrates aspects of economics into operant learning approaches (Bickel et al., 2014; Herrnstein, 1961). The fact that cannabis or alcohol use shows sleep-inducing effects, increases the likelihood of re-using through negative reinforcement by alleviating sleep difficulties. In turn, the use of drugs worsens sleep quality, leading to impaired decision-making with a preference for immediate rewards (Bedi et al., 2015; MacKillop et al., 2014). Additionally, according to the behavioral economics approach, substance use is explained by an overvaluation of the reinforcing consequences provided by substances, generally immediate reinforcements (e.g., disinhibition). This is associated with a cost opportunity, meaning a deprivation of engaging in other behaviors, or activities that are inaccessible when drugs are consumed. In the case of sleep and substance use, engaging in nighttime activities (such as going out clubbing) not only increases the demand and access to substances but also deprives individuals of good sleep and prevents them from engaging in other valuable next-day activities due to inadequate rest (e.g., sports) (Finan & Lipperman-Kreda, 2020; Haynie et al., 2018).

Therefore, beyond the impact on the reward system, internalizing symptoms, or self-medication behavior, it seems that the relationship between sleep and drugs is also influenced directly by social and contextual factors, such as engaging in activities during the night. This suggests that it is relevant to analyze the relationship between sleep and drug use considering multiple factors that will intervene in this relationship.

1.3.4. Sleep as a potential preventive strategy for addictive behaviors

Both theoretical models and empirical evidence provide an explanation for the bidirectional relationship between sleep and substance use in adolescents. This relationship appears to persist concerning changes in both consumption and sleep quality. That is, improvement in one factor tends to contribute to changes in the other factor (e.g., sleep changes may contribute to changes in alcohol use). Some studies examining the efficacy of substance use treatment in adolescents found that a reduction in consumption also contributes to the remission of sleep problems (Huhn et al., 2022). It is important to note that when there is an issue associated with substance use or addiction, sleep problems may initially worsen during the period of abstinence, being one of the main factors of relapse (e.g., Roehrs et al., 2021). However, after the treatment period, a decrease in alcohol, cannabis, and tobacco use may have the potential to increase sleep hours, insomnia, latency improvement, etc. in adult clinical samples (Huhn et al., 2022).

Regarding sleep, there are still few studies analyzing the impact of improving sleep on reducing drug use (Hasler et al., 2024). In one study, the implementation of a treatment to improve sleep in adolescents who have stopped using substances seems to maintain abstinence and improve self-efficacy to abstain from using (Bootzin & Stevens, 2005; Britton et al., 2010). However, further examination of this association among adolescents is needed to confirm these findings. Particularly, because heavy drinking individuals may be more receptive to sleep-focused interventions than alcohol-focused ones (Fucito et al., 2015).

In this regard, transdiagnostic sleep interventions have contributed to the reduction of internalizing/externalizing symptoms (e.g., Harvey & Sarfan, 2024). A recent review (Bacaro et al., 2024) supports that sleep is a central component in the remission of anxiety and depression, as well as impulse control. The focus on increasing the number of hours, may contribute to reducing access to nighttime activities with greater access to drug consumption. Overall, improved quantity and quality of sleep seems to positively contribute to better health (Bacaro et al., 2024). Considering the close link between sleep, drugs, and emotional regulation, sleep could be a potential key factor in preventing and reducing substance use in adolescents.

A relationship exists between good sleep and higher levels of psychological well-being over time in adolescents. Previous research has proven that good sleep serves as a protective factor against electronic nicotine devices in adolescents and also alcohol use. The daily interplay between better overall sleep quality during monitoring was associated with a decreased likelihood of alcohol use in adolescents with regular consumption of alcohol (Pielech et al., 2023). Therefore, although sleep has been considered a secondary health symptom, the literature suggests it could have a greater implication in the remission of psychopathological symptoms in addictive behaviors.

In this regard, further research is needed to understand the relationship between improving sleep and its potential benefits in addictive behaviors, particularly in adolescents, which seem to be a key target group (Fucito et al., 2015; Hasler et al., 2024). Future studies should be conducted to evaluate the effectiveness of incorporating a sleep treatment component into drug prevention programs.

1.4. KNOWLEDGE GAPS AND RATIONALE

Previous research has made significant advances in understanding the relationship between sleep and substance use in adolescents. Although the impact of substance use on sleep has been largely studied, in the last five years, more attention has been given to how sleep might influence the development and management of addictive behaviors. Despite this, there are still several limitations that limit progress in this field and some knowledge gaps exist in the literature.

Need to improve sleep quality assessment tools in non-clinical and adolescent populations.

As mentioned in the introduction of this dissertation, one of the most widely used sleep questionnaires globally, also in substance use treatment is the Pittsburgh Sleep Quality Index (PSQI) (Huhn et al., 2022; Mollayeva et al., 2016). Currently, the PSQI is the only self-reported tool that measures different components of sleep quantitively and qualitatively while providing a global sleep quality dimension. However, it has certain limitations that need to be addressed, particularly when used to evaluate adolescents.

First, the length of the PSQI can be reduced to improve the applicability of the measure, improve the correction method, as well as to decrease the time required for assessment and mitigate response errors associated with lengthy questionnaires. This is particularly important when assessing adolescents in educational settings, as there are difficulties in completing lengthy instruments, leading to low reliability of responses. Therefore, shorter measures would be more suitable than longer ones for evaluating adolescents' sleep. Second, some of the PSQI items are redundant measuring the same sleep dimensions (e.g., night awakenings) and some are not relevant to the adolescent population, such as those related to driving (though this may vary depending on the country and legal age). Therefore, a review of those items seems relevant to improve the properties of the measure.

Regarding adolescents' sleep, the measure does not consider the recommended amount of sleep for maintaining adolescent health. According to the National Sleep Foundation, young people aged between 14 and 17 should get between eight and ten hours of sleep each night, whereas sleeping less than seven or more than eleven hours is considered inadvisable (Hirshkowitz et al., 2015). Nevertheless, the original scoring algorithm of the PSQI categorizes the number of sleep hours based on recommendations for adults (between 7 and 9 hours), suggesting that sleeping seven hours signifies good quality sleep in adolescents. This could have clinical implications for evaluating teenagers' sleep quality because their assessment could be underestimated, particularly when a larger proportion of adolescents fail to meet sleep recommendations (Robbins et al., 2020).

Need to explore sleep patterns in the adolescent population according to gender.

As poor sleep in adolescence is likely to carry over to adult life affecting physical and mental health, it is important to gain insight into the determinants that help to understand sleep patterns already in adolescence (Medic et al., 2017; Ramar et al., 2021). Despite this need, little research has investigated the sleep patterns among adolescents and their association with other key factors influencing sleep health. Additionally, while sleep patterns have been recently studied across different populations, there is still a lack of research analyzing these patterns in Spanish adolescents and analyzing these patterns based on different sleep dimensions. For example, most studies on sleep patterns have focused solely on the number of hours of sleep or specific disorders (e.g., insomnia), neglecting other important sleep dimensions (e.g., sleep efficiency) (Bauducco et al., 2022; Cooper et al., 2023; Saelee et al., 2023; Yue et al., 2022).

Additionally, while literature has shown differences in sleep quality between sexes, little attention has been given to evaluating how sleep patterns vary based on sex. As a result, it remains unknown whether these sleep patterns show similar characteristics for male and female adolescents or if their prevalence differs significantly (Baker et al., 2023). Thus, a tool that is invariant across sexes is necessary for assessing sleep, especially since there is a lack of training to detect and avoid gender biases in pediatric care (Carrilero et al., 2023).

Lack of studies analyzing sleep patterns association with drug use in the adolescent population.

In line with the insufficient number of studies that have identified sleep patterns in adolescents, it is also necessary to analyze how latent sleep patterns during adolescence relate to substance use. As previously mentioned, the quality of sleep can vary considerably during adolescence, especially with the use of substances (Kwon et al., 2019; Roehrs et al., 2021). Although previous studies have demonstrated a relationship between these two factors, the association between latent sleep patterns and drug use remains unexplored. This includes examining how different dimensions of adolescent sleep (e.g., sleep latency onset, duration, efficiency, etc.) are related to various aspects of substance use such as quantity, frequency, and history of use. Given the limited number of empirical studies on sleep patterns in adolescents and their relationship with substance use, further research is needed to fully understand the quality of adolescents' sleep from a broader perspective. This includes exploring various dimensions and how different sleep patterns may interact with aspects of drug use.

Lack of longitudinal studies analyzing how changes in sleep over time may affect alcohol use in adolescents.

The research on the prospective relationship between sleep and addictive behaviors has highlighted a bidirectional association between these two factors. However, further exploration is necessary to understand in depth their interplay during adolescence and the potential benefits of improving sleep quality in preventing drug use. While there are potential beneficial effects of good sleep on improving internalizing and externalizing symptoms related to substance use, the available studies in which the direct effect of sleep changes on drug use remain insufficient and need updating (Bootzin & Stevens, 2005; Britton et al., 2010).

Regarding this, alcohol use is particularly important to consider, as it is the most used substance and often accompanies the use of other drugs, serving as a gateway to further substance use (Barry et al., 2016). Preliminary findings suggest that better overall sleep quality is associated with a decrease in alcohol use among adolescents with regular alcohol use (Pielech et al., 2023). However, the potential impact of how improving sleep may contribute to reducing drinking in adolescents remains unexplored. Addressing this literature gap may contribute to developing new experimental studies to analyze the effectiveness of implementing sleep treatment in selective and indicated prevention of drug consumption in adolescents (Salazar De Pablo et al., 2021). This, in turn, could improve preventive strategies and reduce drug use during adolescence and associated problems.

RATIONALE FOR THE DISSERTATION

In conclusion, and based on the existing scientific literature, the motivation behind this doctoral dissertation stems from addressing identified gaps in research. For instance, there is a lack of tools tailored to assess the quality of sleep considering the measurement of its components specifically for the adolescent population, thus limiting a comprehensive grasp of adolescents' sleep patterns. Additionally, while there is an increasing number of studies on the prospective link between sleep and substance use, it remains unclear whether improvements in sleep could help reduce alcohol or drug use among adolescents.

It is essential to tackle the previously mentioned limitations and knowledge gaps to enhance the understanding of the association between sleep quality and substance use among adolescents. Therefore, this dissertation aims not only to contribute new insights to this field but also to offer valuable foundations for future research. This includes studies that focus on developing effective interventions aimed at improving sleep health and reducing substance use among adolescents. Ultimately, by bridging these gaps in the scientific knowledge, research efforts and practical initiatives focused on promoting adolescent well-being and encouraging healthier behaviors could be advanced.

Part 2.

EMPIRICAL EVIDENCE

2.1. RESEARCH OBJECTIVES

Given the current gaps in knowledge in the literature and the increasing importance of adolescent sleep health and substance use, the **general aim** of this dissertation was to evaluate the quality of sleep of adolescents and its association with the use of alcohol and other drugs. For this purpose, the following specific aims were established:

OBJECTIVE 1 *(Study I)***.** To develop and study the psychometric properties of a brief version of the Pittsburgh Sleep Quality Index (B-PSQI) to evaluate the quality of sleep and its components in the general population.

OBJECTIVE 2 *(Study II)***.** To adapt the B-PSQI measure to the sleep recommendations for the adolescent population and to study its psychometric properties.

OBJECTIVE 3 *(Study III)***.** To identify adolescents' latent sleep patterns considering the quality of the sleep components, and to analyze patterns' invariance across sexes.

OBJECTIVE 4 *(Study III)***.** To analyze the association between adolescents' sleep patterns and the use, frequency of use, and quantity of alcohol, tobacco, cannabis, and other drugs.

OBJECTIVE 5 *(Study IV)***.** To explore the impact of sleep quality changes over time on the likelihood of using alcohol in adolescents.

2.2. MATERIALS AND METHODS

To achieve the research objectives of this doctoral thesis, two different samples were worked with: initially an adult population and secondly an adolescent population. The non-clinical adult sample was used for developing a brief version of the Pittsburgh Sleep Quality Index (B-PSQI) and the adolescent sample was subsequently used to analyze the psychometric properties of the B-PSQI adapted to adolescents. After achieving this first research objectives, the work continued to focus on the adolescent population to achieve the remaining aims of this doctoral thesis.

Therefore, this thesis is framed within two research projects: one related to the adult population titled "*Sleep Quality and Sleep Hygiene*", and the second related to the adolescent population "*Guided Self-Change Prevention Program for Alcohol Abuse in Adolescents in Educational Settings (PREVENALC)*". Both projects were conducted at the Addictive Behaviors and Brief Intervention Unit (UCAB) of Miguel Hernández University of Elche, with José Luis Carballo as the principal investigator. Funding for the PREVENALC project was granted by the Spanish Ministry of Science, Innovation, and Universities (PID2019-110400RB-I00), and was preregistered by Clinical Trials (NCT05281172). This project was tied to funding the predoctoral contract founded by the Ministry of Innovation, Universities, Science and Digital Society of Generalitat Valenciana, and the European Social Fund. Ethical approval for this project was granted by the Clinical Research Ethics Committee of the General University Hospital of Alicante (CEIm: PI2019/112).

2.2.1. Participants' characteristics

Sample 1

As previously mentioned, the initial sample was used to develop the brief version of the Pittsburgh Sleep Quality Index and corresponded to a non-clinical sample of adults **(Objective 1)**. For this first sample, Spanish males and females were selected. The inclusion criteria included being over 18 years old, having Spanish nationality, completing the entire PSQI questionnaire, and providing written informed consent. Those who provided duplicated responses were excluded as well as those individuals reporting receiving medical or psychological treatment for a sleep disorder, as they were considered part of a clinical sample.

The final sample consisted of 609 adults with an average age of 37.3 years (SD=11.9) ranging from 18 to 75. Most participants were female adults (71.8%; n=437), current employees (70.9%; n=432), with university studies or higher (65.7%; n=400). Moreover, half of the sample (49.8%; n=303) reported being married or in a stable relationship. Approximately, half of the adult sample (47%; n=286) experienced poor sleep according to the scoring method for the original PSQI version (Buysse et al., 1989).

Sample 2

The second sample comprised high school students of the Alicante region between 15 and 17 years old. Inclusion criteria included being under 18 years old, being high school students from 10th to 12th grade (i.e., *4ºESO to 2ºBachillerato*), understanding Spanish, and providing written consent from parents/caregivers as well as from the students themselves. Students who did not respond to all self-reports, those with comprehension difficulties (e.g., cognitive impairment), and duplicate responses or cases with the same anonymous identification code were excluded. Similarly, outlier cases and/or dishonest responses evaluated with the Oviedo Infrequency Scale were excluded (Fonseca-Pedrero et al., 2008).

The sample size and the characteristics of participants vary according to the aim of the objective (e.g., due to the study design, the inclusion/exclusion criteria, or the variables collected). For achieving **Objective 2**, 1065 participants were selected, of which 56.8% (n=606) were female adolescents and 43.1% (n=459) were male. For archiving **Objectives 3** and **4**, a total of 1391 adolescents were evaluated to identify latent sleep patterns and their association with substance use, with most participants being female adolescents (56.4%; n=784). Regarding **Objective 5**, a total of 257 participants were assessed to analyze the longitudinal association between sleep quality and alcohol use after six months. In this sample, 53.3% (n=137) corresponded to female adolescents and the retention rate was 76.7% (N=197).

According to the criteria of the B-PSQI scoring method and recommendations for sleep duration in adolescents, about 43% of adolescents reported poor sleep.

2.2.2. Variables and measurement tools

To achieve the objectives of the doctoral thesis, various measures to assess sleep, substance use, as well as anxiety and depression were used. For those measures that have not been tested for their validity in the Spanish adolescent population, psychometric properties (e.g., ISI) were previously assessed.

Sociodemographic and exclusion criteria variables

For measuring sociodemographic variables, we included single-item questions for assessing sex (i.e., birth sex), date of birth, and the area of school location (urban vs. rural). For the exclusion criteria, we included several single-item measures with dichotomized responses (yes/no) to determine if participants were diagnosed with any sleep disorder or receiving medical/psychological treatment. To exclude invalid responses, we used the **Oviedo Infrequency Scale** (Fonseca-Pedrero et al., 2008). This tool identifies random/dishonest responses by using items likely to obtain affirmative answers (e.g., Do you know anyone who wears glasses?). Item responses follow a Likert-type format with 5 categories ranging from 1, *completely disagree*, to 5, *completely agree*. Responding correctively to most of the questions is indicative of response validity, and participants responding wrong with more than 3 mistakes should be excluded (Fonseca Pedrero et al., 2018).

Sleep variables

Sleep quality. The **Pittsburgh Sleep Quality Index** (PSQI; Buysse et al., 1989) was used to evaluate the quality of sleep and seven sleep components: duration, latency, efficiency, awakenings, daytime dysfunction, use of sleep medication, and subjective sleep quality. The PSQI includes 18 questions with different response options scaled from 0 to 3 points, with a total sum score ranging between 0 to 21. Higher scores are indicative of worse quality of sleep and a cutoff point above 5 is used to classify poor sleepers.

For the objectives of this dissertation, the PSQI was used to develop a shorter version, the **Brief version of the Pittsburgh Sleep Quality Index** (B-PSQI; Sancho-Domingo et al., 2021). The 6-item B-PSQI measures sleep quality of last month and five sleep dimensions: sleep latency (minutes), sleep duration (hours), night awakenings (frequency), sleep efficiency (percentage), and subjective sleep quality. The global score ranges from 0 to 15, with higher scores representing poorer sleep. The B-PSQI has demonstrated adequate reliability (ω=0.91) and validity in the adult population REF. Although the psychometric properties of the B-PSQI have not been analyzed previously in the adolescent population, the original 18-item PSQI version showed adequate reliability (α=0.73-0.66) and validity in adolescents (de la Vega et al., 2015; Guo, 2022; Passos et al., 2017; Raniti et al., 2018).

Likewise, the short form of **the Patient-Reported Outcomes Measurement Information System** (PROMIS; Forrest et al., 2018) was developed to measure child-reported difficulties in falling and maintaining sleep. The 4-item PROMIS evaluates the frequency of experiencing sleep difficulties in the past two weeks using a 4-point Likert scale ranging from 1, *never*, to 4, *always*. This scale has demonstrated good reliability (α=0.88) and validity in the adolescent population.

Sleepiness. The **Epworth Sleepiness Scale** (ESS; Johns, 1991) was used to measure the degree of daytime sleepiness in eight daily situations (e.g., reading). The ESS uses 8 items in which responses are given following a 4-point Likert scale, from 0, *never*, to 3, *high probability*. The total score ranges from 0 to 24, with higher scores indicating greater sleepiness. For this dissertation, the ESS adolescent adaptation was used that has demonstrated adequate reliability and validity (α>0.70) in teenagers (Janssen et al., 2017; Wang et al., 2022).

Insomnia. The **Insomnia Severity Index** (ISI; Bastien et al., 2001) measures the severity of insomnia using seven items rated on a 5-point Likert scale, from 0 *none* to 4 *very severe* (e.g., Difficulty falling asleep). The global score ranges from 0 to 28, with higher scores representing greater insomnia, and scores ≥9 representing a clinical indication of insomnia in adolescents (Chung et al., 2011). The ISI has good internal consistency (α>0.75) and validity in samples of adolescents (Chehri et al., 2021).

Cognitive and physical arousal before sleep. The **Pre-Sleep Arousal Scale** (PSAS; Nicassio et al., 1985) is a tool that evaluates the degree of arousal before sleep. The PSAS uses eight items to assess the subscale of cognitive arousal (e.g., Worry about problems other than sleep), and another eight to measure physical arousal (e.g., Heart racing, pounding, or beating irregularly). Items responses follow a 5-point Likert-type scale, with 1 signifying *not at all*, and 5 *extremely* intensity. The PSAS has shown adequate reliability in both dimensions ($\alpha > 0.80$) and concurrent validity with other sleep measures in the adolescent population (Jansson-Fröjmark & Norell-Clarke, 2012; Okajima et al., 2020; Ruivo Marques et al., 2018).

Substance use variables

Lifetime and past year frequency of drug use. The **Drug Use History Questionnaire** (DUHQ; Sobell et al., 1995) was used to assess the lifetime use of alcohol, tobacco, cannabis, and other illegal drugs (e.g., cocaine), as well as the frequency of use during the past 12 months. Given this measure was used in the adolescent sample, the time using any of the substances was measured in months, instead of years due to the short history of use among adolescents. The DUHQ provides adequate temporal stability and validity in this population (Hawes et al., 2020; Sobell et al., 1995; Wasserman et al., 2020), and for the studies, the Spanish adaptation and translation was included (Carballo et al., 2014).

Past month drug use and binge drinking. The **TimeLine Follow-Back** (TLFB; Sobell & Sobell, 1992) was used to measure the use of alcohol and cannabis in the past month. The TLFB is a calendar in which retrospectively participants register the use of drugs during a specific period. For the studies comprising this dissertation, the use in the past 30 days was assessed. In the TLFB, alcohol use was measured in Standard Drinking Units (SDUs), with one SDU corresponding to 10g of pure alcohol (Rodríguez-Martos et al., 1999). Likewise, binge drinking in the last month was also measured considering the following thresholds: drinking >3 SDUs on one occasion for females and >4 SDUs for males (NIAAA, 2023). Also, the TLFB was used to evaluate the number of joints smoked in the past month. This tool has proven adequate reliability and validity across diverse populations (Kuteesa et al., 2019; Robinson et al., 2014).

Problematic drinking. The **Alcohol Use Disorders Identification Test** (AUDIT; Saunders et al., 1993) was used to measure problematic drinking. This self-reported questionnaire includes ten items to assess the quantity, frequency, and alcohol-related problems of the past 12 months. The total score of the AUDIT ranges from 0 to 40, with higher scores representing more problems associated with drinking, and scores over 5 suggest the presence of problematic use (Liskola et al., 2018). The AUDIT has demonstrated adequate reliability (α>0.75) and factorial validity in the adolescent population (Cortés-Tomás et al., 2016; Hallit et al., 2020).

Anxiety and depression

The **Depression, Anxiety, and Stress Scale** (DASS-21; Antony et al., 1998; Fonseca et al., 2010) was used to evaluate the subdimensions of anxiety and depression. The two subdimensions are evaluated using 7 items each with a 4-point Likert scale (e.g., I felt I wasn't worth much as a person). The item responses range from 0, *did not apply to me at all*, to 3, *applied to me very much*, and provide a total score between 0 and 21 in each subscale. For the adolescent population, a DASS-D cutoff score of 4 in males and 5 in females is indicative of depression, and a DASS-A cutoff of 5 in males and 6 in females is indicative of anxiety (Evans et al., 2021). The DASS has proven to be a reliable and valid tool for evaluating both dimensions (α>0.80) in adolescents (Szabó, 2010).

2.2.3. Study design and procedure

Objective 1. *(Study I)*

To achieve **Objective 1**, a descriptive cross-sectional study was conducted. An online survey was created to access the adult population through a snowball sampling technique. First, a group of 24 seed participants was selected as the first wave for the chain recruitment process, ensuring variation in sex, age, education level, and geographic location within Spain (Wejnert & Heckathorn, 2008). These seed participants were then approached to explain the study's objectives and requested to collaborate by disseminating the online questionnaire among their acquaintances and friends through various means such as instant messaging and social media posts.

Objective 2–5. *(Study II – IV)*

To achieve **Objectives 2 to 4**, a descriptive cross-sectional study was conducted. For this study, thirty secondary high schools in Alicante region were randomly selected, with sixteen of them agreeing to participate. After obtaining approval from the principals of the public schools, students and their parents/guardians were notified about the study. This included assuring confidentiality and anonymity for the provided data. All interested students and parents/tutors gave their written informed consent to participate in the study. Subsequently, a health psychologist attended schools to assess students in their school classrooms using an online survey. This online assessment was accessed with the students' mobile phones and adapted for easy use to optimize usability on mobile interfaces (Elosua et al., 2023). The access to the survey was granted via a QR code, allowing adolescents to generate an anonymous ID and complete the survey, which typically lasted 45 minutes. Those participants without mobile phones could complete the survey printed on paper. The data were collected between November 2021 and May 2023.

For **Objective 5**, a two-wave prospective correlational study was conducted. In this case, adolescents were assessed at an initial assessment (Time 1) and after six months (Time 2). The first five schools from the pool of Alicante's secondary schools were selected. After receiving approval from four schools, written informed consent was requested from students and their guardians. The two assessments were conducted using the same online procedure as aforementioned for cross-sectional data. To maintain anonymity and enable matching the follow-up assessment, an anonymous identification code was created. Participants received no compensation for their participation. Once the data were collected, they were encoded and included in databases to be analyzed using various statistical programs.

2.2.4. Statistical plan and analyses

To achieve the research objectives of this doctoral thesis, various statistical analyses were conducted using the R and SPSS v.26 software. These analyses included descriptive, mean differences, psychometric, cluster, and regression analyses. For the interpretation of the results, a confidence level of 95% was used.

Descriptive, pair-wise comparisons, and multivariant analyses. Frequencies, mean, and standard deviation were estimated to describe sample characteristics. For non-continuous variables (e.g., sex), Chi-square (χ^2) tests were used to analyze distribution differences, and Cramer's V effect size was calculated, with values >0.07 representing weak effect size, >0.21 moderate, and >0.35 strong. For pair-wise comparisons in continuous variables (e.g., number of SDUs) Mann–Whitney U nonparametric (Z) test was conducted (due to violation of normality and independence).

Psychometric analyses. To develop a brief version of the PSQI and analyze its psychometric properties in an adolescent population (**Objectives 1 and 2**), various analyses were conducted. The process to reduce the length of the PSQI involved reducing the number of items while simultaneously testing internal consistency with ordinal alpha/omega. Exclusion criteria for the items comprised (1) checking for item collinearity, (2) values <0.4 for corrected item-total correlation, and (3) improvement of ordinal alpha/omega when items were excluded. Once the items of the Brief PSQI (B-PSQI) were selected, a Confirmatory Factor Analysis (CFA) was conducted followed by testing measurement invariance across sexes and across three different age groups in the adult population. The models' goodness of fit was evaluated with the Satorra–Bentler scaled χ^2 statistic indicated for nonnormal data, and relative fit indexes: Comparative Fit Index (CFI), Normed Fit Index (NFI), Tucker–Lewis index (TLI), Root Mean Squared Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). CFI, NFI, and TLI values ≥0.95 were considered as optimal fit. RMSEA values ≤0.08 and SRMR values <0.05 were considered to indicate a satisfactory fit (Hu & Bentler, 1999). To test measurement invariance, three models that increase invariance stringency were compared: (a) configural invariance model or baseline model, which implies equivalence of model form; (b) metric or weak factorial model, which refers to equivalence of loadings across groups; and (c) scalar or strong factorial model, which denotes equivalence of loadings and items thresholds. Models' differences were tested based on differences in χ^2 ($\Delta\chi^2$), CFI (ΔCFI), RMSEA (ΔRMSEA), and SRMR (ΔSRMR) indexes. Values ≤ 0.01 of ΔCFI, ≤ 0.015 of ΔRMSEA, and values ≤ 0.03 of ΔSRMR were considered adequate to maintain the most stringent model (Chen, 2007). Because items' responses are categorical, values of ΔRMSEA<0.05 were also accepted for metric invariance (Rutkowski & Svetina, 2017). Convergent and concurrent validity were examined through the Spearman correlation coefficient (Fieller et al., 1957) between B-PSQI, and several sleep measures (ISI, ESS, PROMIS, etc.). Likewise, Receiver Operating Characteristic (ROC) analysis was conducted to analyze B-PSQI's ability to differentiate between good and poor sleepers based on the ISI criterion cutoff of ≥ 9 for adolescents (Chung et al., 2011). The Area Under the Curve (AUC) was calculated and interpreted using thresholds of discrimination power: 0.5 to 0.7 for low discrimination, 0.7 to 0.9 for moderate, and >0.9 for high discrimination levels. The optimal cutoff point was selected based on the global score that maximizes both sensitivity and specificity criteria. Additionally, Positive Predictive Value, Negative Predictive Value, and Youden Index were calculated as measures of classification accuracy.

For the B-PSQI adaptation in adolescents, the psychometric properties were evaluated considering the recommended sleep hours for young people between 15 and 17 years old (Hirshkowitz et al., 2015). Once the correction algorithm of the B-PSQI was adapted, internal consistency with alpha and omega, factorial validity and invariance based on gender, concurrent validity, discriminant, and construct validity, as well as cut-off points to classify good and poor sleepers were examined using ROC analysis. To differentiate between good and poor sleepers, criteria of ISI ≥ 9, and PROMIS t-scores>55 were considered.

Multigroup Latent Class Analysis. To identify the latent patterns of sleep among adolescents and to test if they are similar between female and male adolescents, a Multigroup Latent Class Analysis was performed (MGLCA) (**Objective 3 and 4).** The MGLCA model included the 5 sleep dimensions of the B-PSQI: sleep latency, duration, night awakenings, sleep efficiency, and subjective sleep quality. LCA was first conducted separately between females and males to estimate the optimal number of classes in each group. Two-to-six-category models were examined using the Likelihood-Ratio Test

(χ^2) and by considering the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), where lower values indicate better data fit. Entropy was also computed, aiming for values closer to 1 which imply higher accuracy in categorizing participants. Once an equal number of categories in both sexes was confirmed, the equality of model fit was assessed by imposing constraints on item-response probabilities across groups, followed by comparison with the non-constrained model. Subsequently, the prevalence of category membership was compared between different groups. Pairwise Logistic Regressions were performed to analyze the strength of association between the sleep patterns and drug use, including alcohol, tobacco, cannabis, and other illicit substances. Regression models were adjusted by sex and polysubstance use.

Generalized Linear Mixed Models. To investigate the longitudinal effects of sleep quality on alcohol use (**Objective 5**), Generalized Linear Mixed Models (GLMMs) with random intercepts were used. To assess the impact of sleep quality on the prevention and reduction of alcohol use, separate GLMMs were tested for adolescents who either did not use alcohol or used it sporadically in the past year, and those who reported monthly use in the past year. Poisson distribution was used for continuous outcomes (number of SDUs, binge drinking episodes, and AUDIT scores), and binomial for dummy outcomes (reducing alcohol use after six months, reducing binge drinking, and reducing AUDIT scores). Models were adjusted with covariates of sex, anxiety, depression, and initial sleep quality. Nested model tests were conducted to determine the inclusion of sex interactions in all GLMMs. In addition, distinct GLMMs were calculated to determine the sleep dimensions that could impact variations in drinking. Predictors included changes over time in sleep duration, time taken to fall asleep, efficiency of sleep, and frequency of waking up at night. Using a dose-response approach, the Effective Dose needed to elicit an effect in 75% of the participants was computed. Conversely, GLMM analyses were conducted in reverse order to examine how alcohol affects sleep.

2.3. RESULTS

During the doctoral period, it was possible to achieve the five research objectives, leading to the development of a total of 4 scientific articles. These articles present the results and findings of the research objectives and are provided in the Appendix. Besides this, a summary of the main results from the statistical analyses is provided below.

OBJECTIVE 1 *(Study I).* Development of a brief version of the PSQI questionnaire.

Reduction of items and reliability

The original 18-item PSQI was reduced to 6 items. First, a polychoric correlation matrix indicated a strong correlation ($r=0.71$) between the items "*How long does it usually take you to fall asleep each night?*" and "*Cannot get to sleep within 30 minutes*" suggesting both items measure the same sleep dimension, the latency of sleep. As a result, only the item providing the minutes of sleep onset was kept due to the clinical relevance of collecting continuous data rather than categorical. Second, a total of 11 items were identified for removal: nine because their corrected item-total correlation was below 0.4, and two because dropping them maintained or improved alpha. As a result, the Brief PSQI (B-PSQI) comprised 6 items that provide a global score ranging between 0 and 15. The B-PSQI yielded good internal consistency, with ordinal $\alpha=0.79$ and $\omega=0.91$, and excellent discrimination index values of items, with corrected item-total scale correlations ranging from 0.51 to 0.78.

Factorial validity and measurement invariance

The unifactorial structure of the B-PSQI was satisfactory ($\chi^2(5)=39.865$; $p<0.05$; CFI=0.97; NFI=0.98; TLI=0.94; RMSEA=0.08; SRMR=0.05). According to CFI, NFI, and TLI indexes, the B-SPQI model showed optimal goodness of fit. Regarding RMSEA and SRMR, only the B-PSQI model reached acceptable values compared with the original PSQI. Likewise, the B-PSQI items achieved satisfactory standardized factor loadings (range $\lambda=0.51$ to 0.81).

Regarding measurement invariance, the B-PSQI demonstrated partial scalar invariance between male and female adolescents, which indicates the same factorial structure, item loadings, and response thresholds of items. Invariance across age groups was only achieved for model structure, with a significant decrease in model fit for metric and scalar invariance.

Concurrent and convergent validity and classification ability

Spearman correlations indicated that the B-PSQI was significantly associated ($p<0.01$) with high scores of the ISI ($r_s=0.671$) and the original PSQI ($r_s=0.895$). The AUC value was over the threshold of acceptable discrimination power of 0.846 to identify poor sleepers. The optimal cutoff for classifying poor sleepers with the B-PSQI was >5, maximizing rates of sensitivity (75.8%) and specificity (76.9%).

Table 2. Questions of the Brief Pittsburgh Sleep Quality Index (B-PSQI)

1. During the past month, when have you usually gone to bed at night?	Usual bed time: ______*hh:* ______*mm*
2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?	Time in minutes: ___________ *min.*
3. During the past month, when have you usually gotten up in the morning?	Usual get up time: _____*hh:* ____*mm*
4. During the past month, how many hours of actual sleep did you get at night? *(This may be different than the number of hours you spend in bed).*	Hours of sleep per night: _______ *hrs.*
5. During the past month, how often have you had trouble sleeping because you woke up in the middle of the night or early morning?	□ Not during the past month □ Less than once a week □ Once or twice a week □ Three or more times a week
6. During the past month, how would you rate your sleep quality overall?	□ Very good □ Fairly good □ Fairly bad □ Very bad

OBJECTIVE 2 ***(Study II).*** Psychometric validity of the B-PSQI adolescents' adaptation

Global score and internal consistency

For the adolescent adaptation of the B-PSQI, the global score of the B-PSQI was estimated considering sleep hours recommendations for adolescents. In this adaptation, the item of sleep hours was coded as 0 for sleeping *10-9 hours*, 1 for sleeping *9-8 hours*, 2 for sleeping *8-7 or 10-11 hours*, and 3 for *<7* or *>11* hours. The percentage of those sleeping the recommended amount of sleep (8-10 hours) was 20.9% (n=223). The mean score of the age-adjusted B-PSQI score was 5.4 (SD=2.8), slightly superior to the score provided by the original B-PSQI of 4.5 (SD=2.9).

The original B-PSQI version and the age-adjusted B-PSQI showed similar coefficients of α=0.76 and ω=0.84, indicating that the age-adjusted version is a reliable measure for assessing sleep quality in adolescents.

Factorial validity and measurement invariance

The age-adjusted B-PSQI showed a good fit onto a unidimensional factor according to goodness of fit indexes ($\chi^2(4)$=53.882; $p<0.01$; CFI=0.97; TLI=0.92; RMSEA=0.108; SRMR=0.05), and proved configural, metric, and scalar invariance across sexes. This suggests that the unifactorial structure of age-adjusted B-PSQI applies equally to males and females, with items' weights. The age-adjusted B-PSQI items achieved satisfactory standardized factor loadings (range λ=0.46 to 0.85).

Concurrent, convergent, and discriminant validity

Spearman correlations showed that the age-adjusted B-PSQI was positively correlated ($p<0.001$) with other sleep measures ISI (r_s=0.667), the PROMIS (r_s=0.708), the ESS (r_s=0.287), and the subscales of anxiety (r_s=0.401) and depression (r_s=0.417). Moderate to strong correlations were found for the ISI, the PROMIS, and the DASS subscales supporting convergent and concurrent validity. Regarding ESS, a significant weak correlation was observed suggesting B-PSQI discriminant validity.

Classification ability

The age-adjusted B-PSQI yielded satisfactory AUC values above the threshold of moderate discrimination power (AUC=0.83 for the ISI criterion, and AUC=0.86 for the

PROMIS criterion). The optimal cutoff point to classify poor sleep was ≥6, with high and balanced rates of sensitivity (73.5-79.2%) and specificity (78.4-79.7%). According to the ≥6 cutoff, the base rate of poor-quality sleepers was 41.9% (n=446).

OBJECTIVE 3 ***(Study III).*** Identification of adolescents' sleep patterns

Latent sleep patterns between male and female adolescents

Between the two- to six-class models, the model with four classes provided the most optimal fit for the whole sample (χ^2(960)=-7081.6; AIC=14289.2; BIC=14619.2), as well as for male and female adolescents. The entropy was satisfactory classifying 72% of participants into the four classes.

The first class comprised 43.4% of participants (n=603) and was characterized by a low likelihood of experiencing sleep problems, with less than 20% probability of experiencing difficulties in any of the sleep components. This pattern was labeled "Good Sleep". The second class (31.8%; n=442) was characterized by a higher frequency of night awakenings (56% probability), a high probability of reporting good sleep (60%), and a low probability of experiencing other sleep problems. This pattern was named "Night Awakenings". The third class represented the smallest subgroup, (9.4%; n=131) with adolescents most likely reporting low sleep efficiency (<85%; 100% probability), experiencing difficulties falling asleep after 30 minutes (34% probability), and insufficient hours of sleep (63% probability). This pattern was named "Poor Efficiency and Sleep-Onset". Lastly, the fourth class (15.5%; n=215) was characterized by a high likelihood of reporting sleep problems in all sleep parameters. This included taking >30 minutes to fall asleep (43% probability), insufficient hours of sleep (90% probability), night awakenings more than three times per week (70% probability), and subjective poor sleep (93% probability). This sleep pattern was named "Poor Sleep".

Invariance across sexes of sleep patterns

Response probabilities to sleep parameters were consistent between female and male adolescents (p=0.14). However, the prevalence of class membership was different across the two groups (p<0.001). A higher proportion of females were observed in the sleep pattern "Poor Efficiency and Sleep-Onset " (11.9% females vs. 6.3% males), and the pattern “Poor sleep” (19.4% females vs. 10.4% males). The proportion of females and males was similar in the pattern “Night Awakenings” (33.7% females vs. 29.3% males; p>0.05). Therefore, males were more likely to belong to the “Good Sleep” pattern (35% females vs. 54% males) which indicates a substantial sex discrepancy regarding the sleep quality.

OBJECTIVE 4 *(Study III).* Association between sleep patterns and substance use

Sleep patterns and alcohol

Alcohol use was associated with the pattern of “Poor Efficiency and Sleep Onset”. Adolescents who had trouble falling asleep demonstrated more than twice the odds of engaging in binge drinking in the past month (OR=2.4; 95% CI=1.1–4.9) compared to those adolescents with a “Good Sleep” pattern. Likewise, using alcohol for a longer period was associated with higher odds of experiencing “Poor Efficiency and Sleep Onset” pattern (OR=1.03; 95% CI=1–1.1).

Sleep patterns and tobacco

A significant association was observed between the patterns "Night Awakenings" and the use of tobacco. Adolescents experiencing night awakenings presented 2.2 times higher odds (95%CI=1.1–4.5) of past month tobacco use compared to good sleepers. This association was significant despite the moths smoking (p=0.125) or the average of cigarettes (p=0.461).

Sleep patterns and cannabis and other drugs

The use of cannabis and other illicit drugs showed a significant association with the pattern of “Poor Sleep”. Adolescents reporting poor sleepers were twice as likely to use cannabis in the past month (OR=2.4; 95%CI=1.1–5.1) regardless of the number of joints (p=0.971) and the time of use (p=0.673). Likewise, poor sleepers showed a significantly higher likelihood of lifetime use of other illicit drugs (OR=2.6; 95% CI: 1.2–5.9) compared to good sleepers.

OBJECTIVE 5 ***(Study IV).*** Impact of sleep changes on alcohol use in adolescents

Prospective association between good sleep and alcohol use

Among adolescents who drank monthly in the past year (n=91), a significant interaction effect was observed between changes over time in alcohol use and sleep quality. The interaction between time and B-PSQI showed that experiencing good sleep was associated with a steeper negative slope for SDUs (OR=0.68; 95%CI= 0.55–0.85; p=0.001) and episodes of BD over time (OR=0.29; 95%CI=0.10–0.87; p=0.028). The odds of using more SDUs and engaging in BD episodes decreased by 32% and 71%, respectively, in adolescents with good sleep quality compared to those reporting poor sleep. No significant impact was observed for the AUDIT scores (p=0.424).

Among adolescents who do not use alcohol (n=106), a significant increase in SDUs (OR=2.64; $p<0.001$) and AUDIT scores (OR=6.26; p=0.001) was observed. However, no significant associations were found between sleep quality and alcohol use ($p>0.05$).

Impact of sleep quality changes over time on alcohol use

Good sleep was significantly linked to a decreased likelihood of alcohol use among monthly drinkers, so the probability of reducing alcohol use through changes in sleep was analyzed. A decrease in B-PSQI scores (improvement of sleep quality) was significantly associated with a reduction of BD episodes after 6 months (OR=2.25; 95%CI=1.08–4.67; p=0.031). This effect was consistent regardless of the initial quality of sleep (p=0.145). No significant effect was observed for reducing SDUs (p=0.429) or AUDIT scores (p=0.169). Moreover, the ED75 corresponded to a -0.5 unit change in the B-PSQI, indicating the change associated with a reduction in at least one BD episode in 75% of the drinking adolescents.

Impact of sleep dimensions on alcohol use

In those adolescents who drank monthly, reducing sleep latency after six months was linked to a higher probability of reducing BD (OR=1.08; 95%CI=1.01–1.15; p=0.026) with ED75 at -7.7 minutes. Likewise, reducing the frequency of night awakenings tripled the likelihood of reducing AUDIT scores (OR=3.03; 95%CI=1.51–6.06), with the ED75 at -0.6 (See Figure 6). The inverse analysis was also estimated and indicated that changes in BD did not significantly predict changes in B-PSQI scores (p=0.893), or sleep latency (p=0.296). Regarding hours of sleep or sleep efficiency, no significant association was found with a decrease in alcohol use or related problems

2.4. DISCUSSION

The general aim of this doctoral dissertation was to evaluate the quality of sleep among adolescents and its association with the use of alcohol and other drugs. Based on the limitations and gaps identified in the literature, as well as the results obtained in the studies of this doctoral dissertation, a comprehensive discussion of the findings of each objective is described below.

OBJECTIVE 1 ***(Study I).*** Development of a brief version of the PSQI questionnaire.

Given the significance of the PSQI and the benefits of concise questionnaires in both research and clinical settings, a shorter version of the PSQI was developed while maintaining adequate validity and reliability in a population-based sample. The number of PSQI questions was reduced by 70%, condensing the original 18 items to only 6. The findings indicate that the new B-PSQI is shorter than a previously proposed short PSQI version of 13 items (Famodu et al., 2018), demonstrating satisfactory psychometric properties including internal reliability, validity, and discriminative ability between poor and good sleepers.

The B-PSQI demonstrated good internal consistency aligning with validation studies of the PSQI in nonclinical populations, (Magee et al., 2008; Tomfohr et al., 2013). Interestingly, the reduction of items led to the exclusion of the sleep components *daytime dysfunction* and the *use of sleeping medication*, which is supported by previous works aiming to improve the properties of this tool (Kotronoulas et al., 2011; Mollayeva et al., 2016). Likewise, other sleep components such as sleep latency or disturbances were reliably assessed with fewer items, optimizing the efficiency of the questionnaire (e.g., sleep latency).

The CFA results supported sleep quality as a unidimensional construct measured with the B-PSQI, aligning with findings from previous validation studies (de la Vega et al., 2015; Manzar et al., 2018; Zhu et al., 2018). The unidimensional model performed equally between male and female adults, but only in similar age groups.

These results concur with the original PSQI, where partial invariance across sex is achieved (Li et al., 2019), but invariance across age is only satisfactory at the configural level (Jia et al., 2019). The lack of age invariance implies that at least one item could be measured differently across different age groups, or that the defined thresholds for quantitative items, such as hours of sleep, do not account for changes in sleep patterns associated with aging (Gadie et al., 2017; Hirshkowitz et al., 2015). Researchers should consider these findings when analyzing sleep quality in different age groups.

Furthermore, the items of the B-PSQI provide mainly numeric indicators of sleep, such as the minutes to fall asleep, the sleep schedule, or hours of sleep. This permits standardized sleep criteria and improves operational metrics (Yu et al., 2011). For example, the PROMIS item "I got enough sleep" is answered on a Likert-type scale from *never* to *always*, but the term "enough sleep" is not stipulated. Therefore, collecting numeric data can allow the standardization of a criterion for the recommended number sleep duration.

The B-PSQI, holds great significance in both clinical practice and research efforts. The measure ensures accurate assessment, providing health professionals with an ample understanding of individuals' sleep patterns and disturbances, while reducing evaluation time and, therefore, the healthcare burden, which is a weakness often reported by healthcare personnel (Guilabert et al., 2024). The information that the B-PSQI provides is also relevant for diagnosing sleep and psychological disorders, monitoring treatment progress, and identifying potential risk factors for other health conditions (Feld & Feige, 2021). Furthermore, the B-PSQI has the potential to develop targeted and evidence-based treatment plans tailored to address specific sleep-related issues. For example, sleep problems could be related to nighttime awakenings or to difficulties falling asleep, therefore, behavioral interventions can be adapted and implemented accordingly (Harvey & Buysse, 2018; López Núñez et al., 2021; Salazar De Pablo et al., 2023).

In sum, the developed brief PSQI has proven to be a reliable and valid sleep-quality measure for the non-clinical population that permits easy and rapid administration and correction.

OBJECTIVE 2 ***(Study II).*** Psychometric validity of the B-PSQI adolescents' adaptation

The adaptation of the B-PSQI in adolescents was appropriate yielding a satisfactory reliability similar to the adult version, and slightly higher than the original PSQI used in adolescents (de la Vega et al., 2015; Raniti et al., 2018). The results of the Study II revealed that nearly 80% of adolescents do not get the recommended hours of sleep, leaving only 20% with adequate sleep duration, a finding consistent with rates observed in similar samples (Martinez-Gomez et al., 2022). This finding supports the need to adjust the scoring algorithm to the sleep recommendations for different age groups. Similarly, the high prevalence of sleep problems among adolescents emphasizes the need to improve sleep measures and sleep health to prevent other related health problems (Blake et al., 2018; Buysse, 2014).

Consistent with previous research, higher B-PSQI scores were associated with greater symptoms of insomnia, internalizing problems, and sleepiness, as observed in both adult and adolescent samples (Gerber et al., 2016; Raniti et al., 2018; Sancho-Domingo & Carballo, 2023). Moreover, the adequacy of the one-factor structure of the B-PSQI confirmed the unidimensionality of the sleep quality construct based on its five sleep components as occurred in the adult version (de la Vega et al., 2015; Manzar et al., 2018; Mollayeva et al., 2016; Sancho-Domingo et al., 2021). The B-PSQI proved measurement invariance across sexes, as opposed to the original PSQI and the partial invariance obtained for the B-PSQI (Li et al., 2019; Sancho-Domingo et al., 2021). Therefore, the differences found in the B-PSQI scores between sexes are due to differences in the construct of sleep quality rather than to possible measurement bias (Byrne, 2008). Regarding this, young females reported poorer sleep quality than young males, and they had greater daytime sleepiness and insomnia symptoms, as observed in previous studies (Baker et al., 2023; Madrid-Valero et al., 2017; Mallampalli & Carter, 2014).

Like the brief PSQI for adults, the adaptation for adolescents showed adequate psychometric properties while adjusting the clinical criterion of the recommended hours of sleep (Hirshkowitz et al., 2015). This adjustment provides a more accurate assessment of sleep quality in adolescents and allows for rapid and easy administration, making it particularly useful in research and clinical settings.

In this regard, early detection of sleep problems is essential for preventing the development of sleep disorders and associated health issues during adolescence (Bacaro et al., 2024). By using a reliable measure, such as the B-PSQI, prompt identification of sleep disturbances can be achieved, allowing for early intervention and management to mitigate potential adverse health effects. Moreover, reliable self-reported measures of sleep quality are needed to advance scientific knowledge in the field, particularly when objective measures are not feasible or accessible (Walia & Mehra, 2019). Regarding this, national and international researchers have already used the B-PSQI to investigate the prevalence of sleep quality, validate other sleep measures, evaluate treatment effectiveness, and explore associations between specific sleep dimensions and various health outcomes (e.g., Bi et al., 2022; Donisi et al., 2023; Falkingham et al., 2022; Kolivas et al., 2023; Li et al., 2024; Liu et al., 2024; Martínez Vázquez et al., 2023; Peltzer, 2023; Pengpid & Peltzer, 2022; Serrat et al., 2022; Sheng et al., 2023; Sun et al., 2024; van Dijk et al., 2023; Yao et al., 2023; Zak et al., 2022). Future adaptations of the B-PSQI should aim to extend its applicability to diverse cultural and linguistic contexts, as well as adapt it to new technologies through adaptive applications (Hernández et al., 2022; Muñiz et al., 2016; Muñiz & Fonseca-Pedrero, 2019).

OBJECTIVE 3 ***(Study III).*** Identification of adolescents' sleep patterns

A high prevalence of poor sleepers was observed similar to the rates of European samples, with 43% experiencing poor sleep in the past month and the majority reporting insufficient hours of sleep (Bauducco et al., 2022; Gariepy et al., 2020). Although most adolescents perceived their quality of sleep as good, their scores in the sleep self-reported measures were similar to clinical samples (e.g., Michaud et al., 2021).

The identification of sleep patterns revealed that the majority of adolescents encounter some form of sleep issue, with only a minority being classified as good sleepers, contrary to what has been found in previous studies (Yue et al., 2022). Among the sleep patterns identified in Study III, roughly one-third of adolescents reported frequently waking during the night and struggling to maintain sleep, while another subgroup experienced difficulties initiating sleep and exhibited low sleep efficiency.

Additionally, nearly a quarter of participants reported experiencing poor sleep across all components. Unlike findings from previous research (Gariepy et al., 2020; Saelee et al., 2023; Yue et al., 2022), none of the identified patterns was solely characterized by insufficient sleep duration; instead, this condition was prevalent across all patterns. In this regard, a significant portion of adolescents face challenges in falling asleep, as observed in previous studies (Cooper et al., 2023; Saelee et al., 2023). This highlights the importance of addressing inadequate sleep from multiple dimensions rather than solely focusing on increasing the number of sleep hours.

This suggests a need for personalized treatment approaches tailored to individual sleep patterns and underlying psychological factors. For example, while difficulties in maintaining sleep may benefit from sleep restriction and stimulus control (Jansson-Fröjmark, Nordenstam, et al., 2023), individuals with difficulties in falling asleep may benefit from cognitive distraction or restructuring, as well as paradoxical intention (Harvey & Buysse, 2018; Jansson-Fröjmark, Sandlund, et al., 2023). In this regard, health professionals should consider that inadequate sleep could co-occur with other sleep or psychological problems (e.g., substance use) and expand the focus beyond solely increasing the number of sleep hours.

Another aspect to consider is that while female and male adolescents may share similar sleep patterns, females were found to be more prone to exhibiting patterns of "Poor Sleep" and "Poor Efficiency and Sleep-Onset", which aligns with the previous literature (Meers et al., 2019). Sex differences underscore the need for sex-specific factors influencing sleep and substance use interventions that should be addressed accordingly. In addition to these considerations, research has also shown a correlation between mental health issues and variations in substance use based on sex, indicating additional efforts for further research to study these associations.

Findings from Study III offer a comprehensive insight into the sleep patterns of adolescents and highlight the primary sleep issues that need attention. Addressing adolescents’ sleep concerns involves considering various dimensions, rather than just categorizing individuals as good or poor sleepers, as different problems may necessitate distinct treatment strategies (e.g., pre-sleep arousal can hinder the ability to fall asleep).

OBJECTIVE 4 *(Study III).* Association between sleep patterns and substance use

Regarding the association with substance use, it was found that adolescents' poor sleep is linked to the use of alcohol, tobacco, cannabis, and other illicit drugs. However, the association with sleep patterns varied depending on the type of substance, the quantity consumed, and the history of regular use. Consistent with findings from national and European surveys, approximately half of the adolescents reported alcohol use in the past month, with 70% of them engaging in binge drinking (EMCDDA, 2020; OEDA, 2023a). These rates raise concerns due to the adverse health consequences associated with binge drinking, particularly its impact on the development of sleep disorders (Kwon et al., 2019; Ogeil et al., 2019). Engaging in at least one episode of binge drinking in the past month doubled the likelihood of poor efficiency and difficulties in falling asleep, aligning with longitudinal findings linking short sleep (Kwon et al., 2019; Miller et al., 2017). Conversely, longer time using alcohol regularly was associated with this sleep pattern, which could be associated with initial perceptions of alcohol's sleep-inducing effects may lead to disrupted sleep over time (Meneo et al., 2023). In this regard, prolonged alcohol consumption could also affect sleep schedule, as drinking behaviors principally occur during the evening, underscoring the impact of contextual factors in the relationship between sleep and substance use (Finan & Lipperman-Kreda, 2020; Haynie et al., 2018).

Additionally, adolescents who smoked tobacco within the last month seemed to have a higher likelihood of experiencing more night awakenings than non-smokers, as observed in previous studies, particularly when smoking occurs during the night (Kwon et al., 2019; Nuñez et al., 2021). This association remained consistent regardless of the frequency of regular use or the quantity of cigarettes consumed, suggesting that adolescents may be more susceptible to experiencing sleep disturbances even with sporadic tobacco use (Troxel et al., 2021).

Besides alcohol and tobacco, those adolescents using cannabis were twice as likely to experience more sleep problems, and therefore higher levels of insomnia, sleepiness, and pre-sleep arousal (Kwon et al., 2019; Miller et al., 2017; Troxel et al., 2021). This was consistent regardless of the number of joints or the months of using cannabis, which is noteworthy given the myths about the sleep benefits of cannabis. Also, adolescents who used illicit drugs were 2.6 times more likely to experience worse sleep, even after controlling for polysubstance use, supporting the idea that substance use is linked to different aspects of sleep (Troxel et al., 2021).

OBJECTIVE 5 ***(Study IV).*** Impact of sleep changes on alcohol use in adolescents

The longitudinal association between sleep and alcohol use was consistent with previous research, with good sleep quality associated with a decrease in alcohol use among drinking adolescents (Kwon et al., 2019; Miller et al., 2017; Pielech et al., 2023). Adolescents with good sleep quality decreased their likelihood of alcohol use and binge drinking after six months, with no sex effects. Interestingly, and contrary to theoretical models and empirical data, the inverse analyses showed no effect of alcohol use on sleep quality (Pielech et al., 2023). This could be explained by the tendency of sleep problems to become more apparent during early adulthood and the following years (Helaakoski et al., 2022). Nevertheless, the findings of this dissertation contribute to updating and expanding knowledge of the literature regarding sleep and alcohol use association.

In this regard, the findings suggest a predictive effect of improving sleep quality on reducing alcohol use over time. Reducing B-PSQI scores increased twice the likelihood of reducing binge drinking, regardless of adolescents' initial sleep quality. A dose-response association was observed where greater improvements in sleep quality led to a lower probability of binge drinking. This was characterized specifically by a reduction in sleep latency and a lower frequency of experiencing night awakenings. Although there are not enough studies to contrast these results regarding how changes in sleep affect substance use, the findings align with existing literature and the improvement in mental health issues (Bootzin & Stevens, 2005; Britton et al., 2010; Hasler et al., 2024; Scott et al., 2021). Again, increasing the number of hours might not be enough to address substance use issues in adolescents. Instead, improving sleep quality, especially aspects related to starting and maintaining sleep during the night, might be more effective in reducing alcohol use. These findings underscore the need to analyze sleep as a key component for selective and indicative prevention programs for alcohol use in adolescents, as recently suggested (Hasler et al., 2024; Salazar de Pablo et al., 2021). This includes designing and testing sleep interventions through experimental studies to determine if improving sleep quality could potentially serve as a preventive measure against alcohol use.

Interestingly, no significant effect was observed between sleep quality and alcohol use among non-drinking adolescents, which suggests that improved sleep does not seem to be associated with abstaining from drinking alcohol, as previously noticed (Hasler et al., 2024). This underscores the importance of designing interventions based on diverse risk profiles and behaviors exhibited by adolescents (Salazar De Pablo, 2023). Likewise, future studies should be considered to analyze this association during earlier adolescence since it can provide different results considering the changes from preadolescence (Becker et al., 2015; Maslowsky & Ozer, 2014; Miller et al., 2017; Nguyen-Louie et al., 2018).

GENERAL IMPLICATIONS FOR INTEGRATIVE THEORETICAL MODELS

The previous general findings also contribute to theoretical models by providing empirical evidence that helps define the association between sleep quality and substance use in adolescents. Although the validation of theoretical models was not among the objectives of this dissertation, the findings obtained may contribute to shaping theoretical frameworks, or at least contrasting them. The longitudinal data showed that the relationship between sleep and alcohol use did not maintain bidirectionality, and although there are not enough waves to strongly assume such association, the results support the model proposed by Nguyen-Louie et al. (2018). This model established a unidirectional association between experiencing sleep problems during early adolescence and posterior initiation in substance use. This is noticeable, given that many studies support a bidirectional model; which could indicate that the two-way association may be different during adolescence, and more prominent in late adolescence to adulthood (Troxel et al., 2021, 2022). Substance use typically occurs around the age of 14, and only in some individuals consolidating in late adolescence, whereas sleep problems or related psychosocial variables (e.g., internalizing and externalizing symptoms) may occur at earlier ages, during preadolescence (Kocevska et al., 2021; OEDA, 2023a). Therefore, it may be expected that the development of sleep problems due to alcohol use appears during the transition to adulthood as observed in longitudinal studies (Troxel et al., 2021, 2022), which would align with the Edwards et al. (2015) integrative model. Despite this, the impact of substance use on sleep should not be dismissed, yet this relationship may occur during shorter/longer intervals than six months of follow-up (e.g., the night after consuming a drug), or based on the time consumed or the quantity, as observed in the cross-sectional results obtained in the Study III. The use of drugs can strongly contribute to the maintenance of sleep disturbances, as seen with other psychological issues (Kortesoja et al., 2020).

In this regard, cross-sectional data showed a relationship between drug use and sleep patterns similar to previous longitudinal studies. On one hand, binge drinking, and longer time of use were associated with greater difficulty falling asleep and poorer sleep efficiency, consistent with results from sleep studies (e.g., Kwon et al., 2019; Martin-Willett et al., 2022). This result was also consistent with longitudinal data collected with objective measures, in which greater alcohol use and longer time using drugs are associated with alteration of sleep architecture, specifically with a longer sleep onset latency and altered sleep continuity (Kiss et al., 2023). Similarly, smoking tobacco was related to a higher number of awakenings, perhaps due to the stimulating effect of the substance, and cannabis appears to negatively impact various dimensions of sleep. The association of cannabis and sleep seemed comparable to the sleep alteration observed in the hypnograms c and d of Figure 2, related to prolonged use of the substance and the withdrawal period (Kaul et al., 2021).

Again, although results are based on cross-sectional data, they seem to align with a bidirectional relationship, as in the Edwards et al. (2015) model, but further studies are required to validate these findings comprehensively. In this regard, increasing the number of measurement waves throughout adolescence would offer a more nuanced understanding of the dynamic relationship between sleep patterns and drug use behaviors. This could contribute to establishing new theories and models to better explain the multicausal complexity of addictions (Carballo, 2023).

2.4.1. METHODOLOGICAL LIMITATIONS

The findings from the studies included in this doctoral thesis are not without methodological limitations. The following section will detail some of these limitations that should be taken into consideration when interpreting the results.

- One limitation pertains to the use of self-reported measures, which may introduce biases such as social desirability or recall errors. This could potentially impact the accuracy of reported sleep quality and patterns, and substance use behaviors. Nonetheless, several tools adapted to the adolescent population were simultaneously used, providing consistent support for the obtained results. Furthermore, since there may still be errors in the self-reported measures provided, duplicate cases, outliers, and anomalous were identified and discarded, as well as dishonest responses using the Oviedo Infrequency Scale. Future studies should replicate these works with laboratory drug detection analyses or objective sleep measures such as actigraphy to support the obtained results.
- Additionally, the approach to examining sleep patterns may be limited by the lack of longitudinal data to analyze latent sleep pattern trajectories during adolescence. This could have provided a more nuanced understanding of how sleep patterns evolve and their associations and dynamics over time with changes in substance use. Despite this, the results of cross-sectional data concur with findings of prospective studies indicating similar sleep patterns and similar associations between specific sleep issues and drugs. Regarding this, another limitation relates to the number of waves included in the longitudinal study design. Multiple waves of data collection, at least more than two, could have provided a more robust assessment of the bidirectional relationship between sleep and substance use in adolescents. Future studies should consider implementing additional waves of assessments to thoroughly analyze the association between sleep and substance use.
- Similarly, the sample size for longitudinal data analysis may have restricted the ability to explore more in-depth subgroups of adolescents related to the quantity or frequency of alcohol use. For example, categorizing adolescents into those who

drink on a weekly basis, those who do so monthly, and those who are lifetime users. This could provide insights into potential differences in the association between sleep quality and alcohol use among different demographic or behavioral groups. Nevertheless, in this thesis, this longitudinal work has been included as an exploratory study to understand how changes in sleep might impact the reduction of alcohol use. Future studies should investigate with experimental designs how sleep improvement can contribute to reducing drug use.

- In this regard, the prospective effect of sleep on other substances such as tobacco or cannabis was not explored. Understanding how sleep quality influences the use of these substances could provide a more comprehensive understanding of the relationship between sleep and substance use among adolescents. Regarding this, self-medication for sleep problems with alcohol and other drugs should also be examined, because it could contribute to a more complete understanding of theoretical models. This also applies to the evaluation of other variables that may explain or contribute to understanding how sleep quality is related to drug consumption in adolescents, such as impulsivity, rumination, sleep hygiene, etc.

Based on the results and limitations of this dissertation, future research is needed. This includes analyzing the psychometric properties of the B-PSQI across different populations and age groups, as well as developing further studies to explore how sleep patterns may longitudinally influence drug use among adolescents. Additionally, there is a need to examine how improvements in sleep may enhance substance abuse prevention programs.

2.4.2. FUTURE DIRECTIONS

To enhance our understanding of the relationship between sleep quality and substance use, as well as the impact of sleep patterns on substance use among adolescents, future research endeavors should focus on several key areas. This involves gaining a deeper understanding of integrative models and mediating mechanisms, conducting validation studies on the B-PSQI in diverse populations, as well as making methodological advancements in order to comprehend the relationship between sleep and substance use in adolescents.

Prospective Longitudinal Studies: Conducting prospective studies with multiple waves would be necessary to understand and analyze the temporal sequence of events. By tracking participants over time, researchers could determine whether changes in sleep patterns precede or follow the onset of substance use, providing valuable insights into causality and potential predictive factors. As a future research line, this would provide a better understanding of the chicken-and-egg paradox and how each factor contributes to maintaining each other.

Likewise, longitudinal studies should also be considered when assessing the psychometric properties of the B-PSQI. Sleep is a phenomenon that can change considerably in a short period of time; therefore, longitudinal data could contribute to analyzing other metric aspects of the measure, such as temporal stability or invariance across time points.

Comprehensive Integrative Models: Future studies should consider a comprehensive approach to test integrative models related to factors influencing both sleep quality and substance use behaviors. By examining individual-level determinants such as personality traits, mental health status, and socio-environmental factors, researchers could better understand the complex interplay between sleep and substance use. Longitudinal analyses, such as Generalized Linear Mixed Models and Structural Equation Modeling, could make a valuable contribution to this aim. Based on the existing literature and the findings of the studies in this dissertation, it is important to consider additional factors related to sleep and drug use, and explore how these variables interact both cross-sectionally and longitudinally. Contextual factors such as school schedules, academic demands, family dynamics, and peer influences can significantly impact both sleep patterns and substance use behaviors among adolescents. Investigating these factors will facilitate the development of tailored interventions, particularly in the school-based context, that address the unique needs and challenges faced by adolescents (Fonseca-Pedrero et al., 2023).

Identification of Mediating Mechanisms: Research efforts should focus on identifying specific mechanisms that mediate the relationship between sleep patterns and substance use initiation. For example, exploring the role of impulsivity and other behavioral or cognitive factors in maintaining good sleep and abstaining from substance use can provide valuable insights. Understanding these underlying mechanisms can inform the development of targeted interventions aimed at modifying behaviors and reducing substance use risk.

Methodological Improvements: Improvements in research methods, including the use of advanced statistical analyses, standardized assessment tools, and rigorous study designs, are necessary to ensure the validity and reliability of findings. This includes incorporating objective measures of sleep quality and substance use whenever possible, such as actigraphy and biomarkers, to increase the accuracy of collected data. Additionally, researchers should consider employing other statistical analyses, such as cross-lagged panel models or latent transitional analyses, which could provide a deeper understanding of the interaction between sleep and drug use. Finally, other study designs may contribute to reinforcing the results obtained in the studies of this thesis. For example, selecting experimental designs to evaluate whether efforts to improve sleep can contribute to the reduction of alcohol and drug use, thus enhancing prevention programs.

2.5. CONCLUSIONS

As a conclusion to the work of this doctoral thesis, it is necessary to mention some key aspects of the findings obtained.

1. The development of the brief version of the PSQI questionnaire (B-PSQI) involved a significant reduction in the number of items, leading to a concise yet reliable and valid measure of sleep quality.
2. The B-PSQI offers a comprehensive evaluation of sleep quality, incorporating five key dimensions. The B-PSQI items mainly consist of numerical indicators, enabling standardized sleep criteria and improved operational metrics. Likewise, measurement invariance across sexes was supported but not across different age groups. This supports the need for an age-adjusted scoring algorithm.
3. In addition, findings from Study II support the psychometric adaptability of the B-PSQI to align with age-specific recommendations for good sleep quality among adolescents, as suggested by the National Sleep Foundation.
4. Reliability and validity analyses confirmed the adequacy of B-PSQI use in adolescents, enabling valid comparisons across sexes when evaluating sleep quality.
5. Female adolescents exhibited lower sleep quality than their male counterparts. This difference was particularly prominent in difficulties falling asleep, shorter sleep duration, and higher frequency of night awakenings.
6. Findings indicate that many adolescents experience poor sleep, with a small subgroup getting the recommended amount. Higher scores of the B-PSQI were associated with anxiety and depression, as well as insomnia and sleepiness.
7. Likewise, four distinct sleep patterns were identified among adolescents. These include one characterized by good sleep quality, other difficulties in initiating and maintaining sleep, a third related to experiencing night awakenings, and a fourth characterized by sleep complaints in all dimensions.
8. More than half of adolescents reported experiencing one of three poor sleep patterns. Those with more severe sleep problems also showed greater insomnia,

sleepiness, and pre-sleep arousal. Interestingly, all sleep patterns showed short sleep durations with no distinctive pattern found for insufficient sleep.

9. The poor sleep patterns showed significant associations with substance use, including alcohol, tobacco, cannabis, and other illicit drugs.
10. Adolescents who experience "Night Awakenings" exhibited twice the odds of using tobacco in the past month than good sleepers. The "Poor Efficiency and Sleep Onset" pattern showed twice the odds of past-month binge drinking and more time using alcohol regularly. "Poor Sleep" was linked to past-month cannabis use, regardless of the quantity or months of use, and lifetime use of other illicit drugs.
11. The findings fill a literature gap by exploring links between sleep patterns and drug use behaviors in adolescents, including frequency, occurrence, and quantity of consumption.
12. Longitudinal data suggests that good sleep could act as a protective factor against alcohol use in regular drinkers. Improvements in various dimensions of sleep, such as reduced sleep latency and decreased sleep fragmentation, are related to a reduction of drinking alcohol among adolescents.
13. Future studies examining how interventions targeting sleep issues could contribute to reducing drinking and enhancing the effectiveness of substance use prevention programs.

In conclusion, understanding the relationship and developmental pathways of sleep problems and substance use during adolescence can provide valuable insights into the development of effective and more specific interventions. Future studies should examine the effectiveness of integrating sleep improvement-focused interventions into substance use prevention programs tailored to adolescents. In this case, greater attention should be given to improving overall sleep quality rather than solely focusing on increasing its duration. Thus, sleep-focused interventions could represent a key component for preventing alcohol and other substance use, as well as contributing to improving adolescent sleep problems. The research work in this thesis highlights the importance of enhancing overall sleep quality and provides valid and reliable tools for its assessment. This way health professionals and researchers can strive towards an improvement in mental health outcomes for adolescents.

2.5. CONCLUSIONES

Como conclusión del trabajo de esta tesis doctoral, a continuación, se mencionan algunos aspectos clave de los hallazgos obtenidos.

1. El desarrollo de la versión breve del cuestionario PSQI (B-PSQI) mostró una reducción significativa del número de ítems, lo que resultó en una medida concisa, fiable y válida de la calidad del sueño.
2. El B-PSQI ofrece una evaluación integral de la calidad del sueño, incorporando cinco dimensiones clave. Los ítems del B-PSQI consisten principalmente en indicadores numéricos, lo que permite criterios de sueño estandarizados y métricas operativas mejoradas. Asimismo, se confirmó medida de invarianza entre los sexos, pero no entre diferentes grupos de edad, lo cual apoya la necesidad de un algoritmo de puntuación ajustado por edad.
3. Asimismo, los hallazgos del Estudio II respaldan la adaptabilidad psicométrica del B-PSQI para alinearse con las recomendaciones específicas de edad para una buena calidad de sueño entre adolescentes, tal como lo sugiere la National Sleep Foundation.
4. Los análisis de fiabilidad y validez confirmaron la adecuación del uso de B-PSQI en adolescentes, lo que permite comparaciones válidas entre sexos al evaluar la calidad del sueño.
5. Las adolescentes mostraron una peor calidad del sueño que los varones adolescentes. Esta diferencia fue particularmente destacada en dificultades para conciliar el sueño, duración del sueño más corta y mayor frecuencia de despertares nocturnos.
6. Los hallazgos indican que muchos adolescentes duermen un número insuficiente de horas de sueño, con un pequeño subgrupo que obtiene la cantidad de sueño recomendada. Asimismo, las puntuaciones más altas en el B-PSQI se asociaron con ansiedad y depresión, así como con insomnio y somnolencia.
7. Del mismo modo, se identificaron cuatro patrones de sueño distintos entre los adolescentes. Estos incluyen un patrón caracterizado por una buena calidad de sueño, otros con dificultades para iniciar y mantener el sueño, un tercero

relacionado con experimentar despertares nocturnos, y un cuarto caracterizado por problemas de sueño en todas las dimensiones.

8. Más de la mitad de los adolescentes informaron experimentar uno de los tres patrones de sueño de pobre calidad. Aquellos con problemas de sueño más graves también mostraron mayor insomnio, somnolencia y activación antes de dormir. Curiosamente, todos los patrones de sueño mostraron un número insuficiente de horas de sueño, sin encontrar un patrón distintivo para el sueño insuficiente.
9. Los patrones de sueño de pobre calidad mostraron asociaciones significativas con el consumo de drogas, incluyendo alcohol, tabaco, cannabis y otras drogas ilícitas.
10. Los adolescentes que experimentan "Despertares nocturnos" mostraron el doble de probabilidad de consumir tabaco en el último mes que los adolescentes con buena calidad de sueño. El patrón de "Pobre eficiencia y dificultad para conciliar el sueño" mostró el doble de probabilidad de hacer consumo en atracón y llevar más tiempo consumiendo alcohol de forma regular. El patrón de "Pobre calidad" se relacionó con el uso de cannabis, independientemente de la cantidad o meses consumiendo, y también con el uso de alguna vez en la vida de otras drogas ilícitas.
11. Los hallazgos contribuyen a la literatura científica al explorar los vínculos entre los patrones de sueño y las conductas de consumo de drogas en adolescentes, incluyendo la frecuencia, ocurrencia y cantidad de consume.
12. Los datos longitudinales sugieren que el sueño de buena calidad podría actuar como un factor protector contra el uso de alcohol en bebedores regulares. Las mejoras en diversas dimensiones del sueño, como la reducción de la latencia y la disminución de la fragmentación del sueño, parecen estar relacionadas con una reducción del consumo de alcohol en los adolescentes.
13. Futuros estudios podrían examinar cómo las intervenciones dirigidas a problemas de sueño podrían contribuir a reducir el consumo de alcohol y otras sustancias, así como mejorar la efectividad de los programas para prevenir el consumo de drogas.

En conclusión, comprender la relación y las trayectorias de desarrollo de problemas de sueño y el uso de sustancias durante la adolescencia puede proporcionar información valiosa sobre el desarrollo de intervenciones eficaces y más específicas. Futuros estudios deberían examinar la efectividad de integrar intervenciones centradas en la mejora del sueño dentro de los programas preventivos de uso de sustancias adaptados a adolescentes. En tal caso, convendría poner mayor atención a la mejorar general de la calidad de sueño en lugar de únicamente centrarse en aumentar su duración. De este modo, las intervenciones centradas en sueño podrían representar un componente clave para la prevención del uso de alcohol y otras sustancias, y contribuir en la mejora de los problemas de sueño de la población adolescentes. El trabajo de investigación de esta tesis resalta la importancia de mejorar la calidad general del sueño y proporciona instrumentos válidos y fiables para evaluarla. De esta manera, los profesionales sanitarios e investigadores pueden trabajar hacia una mejora en los resultados relacionados con la salud mental de los adolescentes.

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Part 3.

APPENDIX

3.1. DISSERTATION STUDIES

Through the achievement of the objectives of this doctoral thesis, four scientific articles have been developed. Three of them have already been accepted for publication in JCR journals, and the fourth is currently undergoing peer review. Below, the four dissertation articles are indexed:

STUDY I. ***"Validation of the Brief version of the Pittsburgh Sleep Quality Index (B-PSQI) and measurement invariance across gender and age in a population-based sample"****. 2021. Psychological Assessment. Published*

STUDY II. ***"Psychometric adaptation of the Spanish Brief Pittsburgh Sleep Quality Index in adolescents"****. 2024. Journal of Pediatric Psychology. Published.*

STUDY III. ***"Identification of sleep patterns in adolescents and their association with substance use"****. Under review*

STUDY IV ***"Examining the impact of sleep changes on adolescents' alcohol use: A two-wave prospective study"****. Under review*

STUDY I.

"Validation of the Brief version of the Pittsburgh Sleep Quality Index (B-PSQI) and measurement invariance across gender and age in a population-based sample".

METRICS

JOURNAL: PSYCHOLOGICAL ASSESSMENT

PUBLISHER: AMERICAN PSYCHOLOGICAL ASSOCIATION

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STUDY I

Brief Version of the Pittsburgh Sleep Quality Index (B-PSQI) and Measurement Invariance Across Gender and Age in a Population-Based Sample

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Miguel Hernández University of Elche

Daniel J. Buysse
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The Pittsburgh Sleep Quality Index (PSQI) is the most widely used questionnaire in research and clinical practice to assess sleep quality. However, a brief version of this measure would improve its efficiency and applicability. This study aimed to develop a brief form of the PSQI and to study measurement invariance across gender and age in a nonclinical population. In total, 609 participants with a mean age of 37.3 years (standard deviation [*SD*] = 11.9) were recruited, of whom 71.8% ($n = 437$) were women. Participants completed online versions of the PSQI and the Insomnia Severity Index (ISI). Reliability analyses were performed to reduce the number of items, followed by validity and measurement invariance analyses for the new Brief Version of the PSQI (B-PSQI). Six questions were included in the B-PSQI out of the initial 18; the brief form had adequate internal consistency ($\alpha = .79$ and $\omega = 0.91$). Confirmatory factor analysis showed optimal fit of the B-PSQI ($\chi^2(4) = 22.428$; $p < .01$; comparative fit index (CFI) = 0.99; normed fit index (NFI) = 0.99; Tucker-Lewis index (TLI) = 0.98; root mean squared error of approximation (RMSEA) = 0.06; standardized root mean square residual (SRMR) = 0.04), achieving partial scalar invariance across gender-same factorial structure, loadings, and thresholds in the majority of the items. Invariance across age was only achieved for model structure. Additionally, the B-PSQI yielded favorable sensitivity (75.82%) and specificity (76.99%) for classifying poor sleepers, similar to values for the full PSQI. In conclusion, the B-PSQI is a brief, reliable, and valid measure that can be used as a screening tool, allowing valid score comparisons between men and women of similar age.

Public Significance Statement
A Brief Version of the Pittsburgh Sleep Quality Index (B-PSQI) was developed to improve its efficiency and applicability. The 6-item B-PSQI is a reliable and valid tool to assess sleep quality and identify poor sleepers. The B-PSQI achieved invariance across gender, allowing valid comparisons of sleep quality between men and women of similar age. The findings highlight the efficiency of the B-PSQI and its wide potential use in assessing sleep quality.

Keywords: sleep quality, Pittsburgh Sleep Quality Index, brief form, measurement invariance

Sleep problems have emerged as a public health concern because of their negative impact on physical and mental health (Ford, Cunningham, Giles, & Croft, 2015; Jike, Itani, Watanabe, Buysse, & Kaneita, 2018; Stranges, Tigbe, Gómez-Olivé, Thorogood, & Kandala, 2012). The importance of sleep quality as a correlate of physical, mental, and cognitive health is heightened by evidence from some studies that show an increasing prevalence of sleep problems worldwide (Adams et al., 2017; Buysse, 2014; Ford et al., 2015; Zomers et al., 2017).

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This research received no specific grant from any funding agency, commercial entity, or not-for-profit entity. The PSQI and B-PSQI are copyrighted by the University of Pittsburgh. Their use is offered free of charge to academic researchers and clinicians. The University of Pittsburgh licenses the PSQI and B-PSQI to commercial entities for a fee. Daniel J. Buysse receives a portion of these licensing fees. The tests were reprinted or adapted with permission.
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Although there is no consensus regarding the definition of sleep quality, it is often inferred from a combination of qualitative and quantitative sleep parameters and their impact on the waking state. Sleep parameters include subjective reports of satisfaction and quantitative estimates of sleep latency, number of awakenings, sleep duration, and sleep efficiency (percentage of time asleep while in bed). Symptoms during wakefulness generally relate to the subjective perception of restful sleep, daytime fatigue, and sleepiness (Buysse, 2014; Goelema et al., 2018; Ramlee, Sanborn, & Tang, 2017; Svetnik et al., 2020). Among the variety of methods intended to assess sleep, polysomnography is often considered the "gold standard" objective measure. However, this measure has a relatively high cost and is unfeasible when used in large samples. Moreover, polysomnography is typically conducted for one or a few nights, which may not be typical of the individual's usual pattern, and it does not capture the subjective experience of sleep. Consequently, more cost-effective methods for assessing habitual sleep are often used, such as actigraphy and self-reported measures (Corlateanu, Covantev, Botnaru, Sircu, & Nenna, 2017; Landry, Best, & Liu-Ambrose, 2015).

The Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) is the most frequently used sleep-quality questionnaire in research and clinical practice (Mollayeva et al., 2016). This self-reported 18-item measure assesses sleep quality within the past month and includes a global score comprising seven sleep components. Because the PSQI also provides adequate sensitivity and specificity for classifying good and bad sleepers (Buysse et al., 1989), it has been often used as a screening tool (Mollayeva et al., 2016). Psychometric studies have demonstrated that the PSQI is a reliable and valid standardized measure of sleep quality in clinical and nonclinical populations (Manzar et al., 2018; Mollayeva et al., 2016). Several discrepancies have also been reported in the literature regarding the optimal PSQI factor structure or dimensionality, where one-, two-, and three-factor models have each shown adequate fit (Mollayeva et al., 2016). These types of psychometric differences could be influenced by a disparate treatment of PSQI data, such as considering data as continuous rather than ordinal, or performing analyses using the PSQI items individually versus using its seven sleep components defined in the original study (Babson, Blonigen, Boden, Drescher, & Bonn-Miller, 2012; Otte, Rand, Carpenter, Russell, & Champion, 2013).

Nevertheless, the PSQI has been used in at least 1,500 scientific studies and tested in more than 35 validation studies for diverse populations (Mollayeva et al., 2016), achieving invariance across different languages and ethnicities (Otte et al., 2013; Tomfohr, Schweizer, Dimsdale, & Loredo, 2013). PSQI invariance should also be tested across groups with expected differences in sleep quality, such as men and women or different age groups (Gadie, Shafto, Leng, & Kievit, 2017; Madrid-Valero, Martínez-Selva, do Couto, Sánchez-Romera, & Ordoñana, 2017; Mallampalli & Carter, 2014). With regard to gender, women generally report worse sleep quality than men, with a greater number of sleep disturbances, wakefulness during sleep, and longer sleep latency. These subjective reports are often inconsistent with objective sleep measures, which supports the need for testing invariance in self-reported sleep questionnaires (Mallampalli & Carter, 2014). Gender differences have also been found with polysomnography, mainly concerning the distribution of sleep stages, which can also be influenced by age (Gadie et al., 2017; Mallampalli & Carter, 2014). Across the life span, sleep duration gradually shortens and sleep efficiency decreases, particularly after age 50 (Gadie et al., 2017; Hinz et al., 2017). Older adults report greater difficulty falling asleep, more sleep disturbances, and reduced sleep efficiency compared with young and middle-aged adults (Gadie et al., 2017). Again, because of the sleep differences found between age groups, testing multiple-group invariance is important; an invariant sleep measure can ensure that the group differences are due to the sleep-quality construct rather than possible measurement errors (Byrne, 2008).

The length of the PSQI and the complexity of its scoring algorithm may limit its utility and application for some types of studies. Given the widespread use of the PSQI, a short version has been previously developed, with the purpose of reducing the burden of extensive surveys and batteries (Famodu et al., 2018). This short PSQI version was performed by testing a six-factor structure model, yielding a 13-item form. However, the reduction in the number of items from 18 to 13 is rather limited. In addition, reliability analyses were not conducted in this study but are needed to achieve an optimal reduction of items, as recommended in the literature (Widaman, Little, Preacher, & Sawalani, 2011). A substantially shorter version of the PSQI that is easier to score could provide multiple advantages, including reduced completion time, improved efficiency of data collection, and improved accuracy of responses (Galesic & Bosnjak, 2009; Rolstad, Adler, & Rydén, 2011). Other short sleep-quality measures, such as the eight-item PROMIS Sleep Disturbance and Sleep-Related Impairment (Yu et al., 2012) and the single-item Sleep Quality Scale (SQS; Snyder, Cai, DeMuro, Morrison, & Ball, 2018), provide a fast and reliable method to assess sleep quality. Unlike the PSQI, however, these sleep measures only include items with graded-response categories (e.g., never, rarely, sometimes, often, always) and do not include quantitative data (e.g., number of hours of sleep). Although such quantitative data can limit operational metrics (Yu et al., 2012), they are often useful in sleep research.

Therefore, the aim of the present study was to develop a brief form of the PSQI that includes the minimum number of items while maintaining satisfactory psychometric properties in a nonclinical population. In order to address the sleep-quality differences often found between men and women and between age groups, a second aim of this study was to analyze the measurement invariance of the brief form of the PSQI across gender and age.

Method

Participants

The estimated minimum sample size required to conduct this study was calculated according to a 10:1 ratio recommendation to perform confirmatory factor analysis (CFA; Kline, 1998). Considering that 53 parameters of variance, covariance, and regression coefficients are obtained from the 18 items of the PSQI, a ratio of 10 participants to parameters suggested a minimum of 530 individuals. We recruited a total of 665 adults of Spanish nationality, of whom 609 were used for data analyses, ensuring adequate statistical power.

Figure 1 shows a flowchart of the sample selection. From the initial sample, we first excluded individuals under age 18 ($n = 8$)

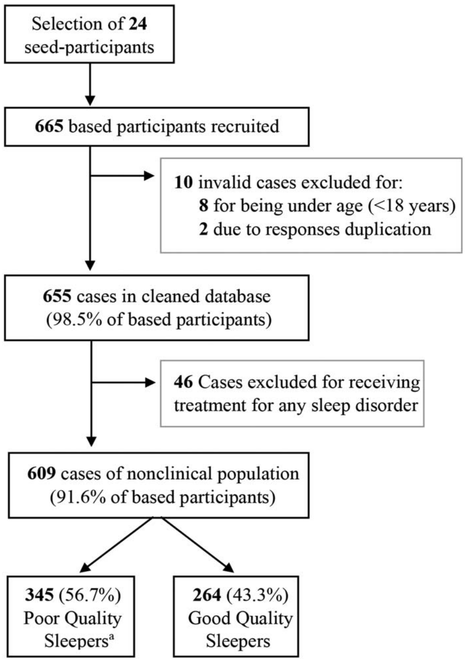

Figure 1. Flowchart of sample selection. [a] Score over 5 in the *Pittsburgh Sleep Quality Index.*

and those with duplicate responses identified through data ID code (n = 2). Additionally, 7% (n = 46) were excluded because they had been referred for medical or psychological treatment for a sleep disorder and therefore were considered to represent a clinical sample.

Participants had a mean age of 37.3 years (standard deviation [SD] = 11.9) and age range from 18 to 75. The majority were women 71.8% (n = 437), were part-time or full-time employees 70.9% (n = 432), and had university studies or higher 65.7% (n = 400). Likewise, approximately half of the sample, 49.8% (n = 303), was married or in a stable relationship. No significant differences were found between good and poor sleepers (PSQI >5; Buysse et al., 1989) for any sociodemographic variables.

Measures

Sociodemographic variables. Gender, age, level of education, employment status, and marital status were assessed by self-report. Likewise, an item was included to identify participants who were receiving treatment for any sleep disorder.

Sleep quality. We used the PSQI (Buysse et al., 1989), which assesses the quality of sleep in the past month with 18 items, with responses including self-reported times and durations or a 4-point Likert scale for frequency. The items are grouped and scored in seven sleep components: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, night disturbances, use of sleeping medication, and daytime dysfunction. The sum of components scores (also coded on a Likert scale ranging from 0 to 3) results in a total global score from 0 to 21, where scores above 5 indicate poor sleep quality. The PSQI has demonstrated adequate internal consistency (Cronbach's alpha ≥ .70) and validity in diverse types of populations (Mollayeva et al., 2016).

We used the PSQI Spanish version, which has demonstrated good reliability (Cronbach's alpha = .81) and validity among the Spanish population, with an 88.6% sensitivity and a 74.2% specificity (Royuela & Macías Fernández, 1997).

Participants also completed the Insomnia Severity Index (ISI; Bastien, Vallières, & Morin, 2001), one of the most widely used measure to assess insomnia (Ibáñez, Silva, & Cauli, 2018). The ISI was included in this study in order to test the convergent validity of the brief form of the PSQI because a strong relationship between these sleep measures has been found in previous studies (Chiu, Chang, Hsieh, & Tsai, 2016; Morin, Belleville, Bélanger, & Ivers, 2011). The ISI is composed of seven items rated on a 5-point Likert scale. The questionnaire provides information about insomnia symptoms, level of satisfaction with sleep, and impact on quality of life. Global scores range from 0 to 28, where values between 0 and 7 indicate an absence of sleep problems, scores between 8 and 14 indicate subthreshold insomnia, scores between 15 and 21 indicate moderate insomnia, and scores above 22 indicate severe insomnia. This measure has demonstrated excellent validity and reliability for a community sample, with Cronbach's alpha = .9 (Morin et al., 2011). For this study, we used the ISI Spanish version (Fernandez-Mendoza et al., 2012), which has been shown to be reliable (Cronbach's alpha = .82) and valid for measuring insomnia.

Procedure

We used a web-based participant-recruitment method, which reaches a large number of people from a wide range of sociodemographic backgrounds in a cost-effective manner (Christensen et al., 2017; Kesse-Guyot et al., 2013). The Survio website platform was used to create an online survey. This survey included an initial message in which we informed participants about voluntary participation, confidentiality, and anonymity of data and asked for their informed consent. Likewise, we provided information about how to complete the survey and the estimated completion time (approximately 10 min).

We linked the completed survey to a free-access URL link in order to disseminate it online through a snowball-sampling technique. We selected a first wave of participants as chain-recruitment precursors (seed participants) from the authors' community (Wejnert & Heckathorn, 2008). Because this convenience sampling could generate a sample with similar characteristics, seed participants were selected based on differences in gender, age, level of education, and region of Spain to which they belonged, in order to ensure a varied and diverse sample. In total, 24 seed participants were recruited with diverse sociodemographic characteristics: 4 with primary education (below university level), 4 with higher education (university level or higher), 3 between 18 and 30 years old, 3 above 50 years old, 3 from the north of Spain, 4 from the south, and 3 from the center.

Once the seed participants were selected, we contacted them to inform them about the aims of this study and to ask them for their collaboration as disseminators of the online questionnaire. They were asked to share the URL link with their acquaintances and friends, for example, through instant messaging and posts in social media. To perform this task, we established a standard message to be used for all seed participants in which future participants were invited to complete the questionnaire:

> Researchers from Miguel Hernández University are conducting a sleep quality study, and they would like to count on your participation. Please complete the following questionnaire that will take you about 10 minutes to answer and share it with your contacts! Please note that your answers will be confidential and anonymous; therefore, we ask you to answer honestly to all questions. Data collected will only be used for research purposes and won't be shared with third parties. Click here for more information and to access the questionnaire.

After their completion of the questionnaire, we asked participants to share the URL link. As compensation for disseminating the questionnaire, we offered them the option of receiving their sleep-quality results via e-mail. Because compensation was not offered in the initial message, bias associated with appealing only to people interested in their sleep was reduced.

This study was reviewed and approved by the Department of Health Psychology of Miguel Hernández University of Elche. Ethical approval was not required because this was a descriptive study that did not collect personal data, and all participants gave their informed consent.

Data Analysis

To evaluate the sociodemographic characteristics, descriptive (frequencies, mean, and standard deviation) and bivariate analyses were performed using Statistical Package for the Social Sciences (SPSS) Version 24.0. Chi-square (χ^2) tests were used to analyze noncontinuous variables, and Mann–Whitney U nonparametric (Z) tests were used for continuous variables because of normality violation. The results of data analyses were interpreted while working with a 95% confidence level.

Item reduction and internal consistency. Given that PSQI data are ordinal rather than continuous, internal consistency reliability was assessed using ordinal alpha estimated with polychoric correlations. Ordinal omega was also calculated, which is an appropriate estimator when the parameters of the measure are not essentially tau equivalent, but congeneric, and when items are skewed (Gadermann, Guhn, & Zumbo, 2012; Trizano-Hermosilla & Alvarado, 2016). As a reliability criterion, a value of alpha and omega greater than 0.7 was considered acceptable (Cortina, 1993).

Reduction of the 18 PSQI items was performed sequentially, selecting items according to the following exclusion criteria: (a) presence of collinearity between items, which was examined with a polychoric correlation matrix; (b) values with corrected item-total correlation below 0.4 because values greater than 0.4 indicate better item quality (Ebel & Frisbie, 1991); and (c) maintenance or improvement of ordinal alpha when the item was excluded.

The analyses performed for item reduction and internal reliability were estimated using the *psych* package for R statistical software (Revelle, 2018).

Confirmatory factor analysis. Because the factor structure of the PSQI has shown good fit for a one-factor model (de la Vega et al., 2015; Manzar et al., 2018; Rener-Sitar, John, Bandyopadhyay, Howell, & Schiffman, 2014; Zhu, Xie, Park, & Kapella, 2018), we examined unidimensionality with CFA using the *lavaan* package for R statistical software (Rosseel, 2012).

The CFA was performed for the Brief Version of the PSQI (B-PSQI) and for the original PSQI in order to compare both versions. Because the literature indicates that PSQI psychometric properties can be analyzed using the individual items (PSQI-ITEM) and using the sleep components (PSQI-COMP), the CFA was performed for both options (Mollayeva et al., 2016).

The three examined models (B-PSQI, PSQI-ITEM, and PSQI-COMP) were estimated by robust diagonally weighted least squares (RDWLS), which provides more accurate parameter estimates and precise standard errors in skewed data compared with standard maximum-likelihood approaches (Yang-Wallentin, Jöreskog, & Luo, 2010). Furthermore, because the PSQI item sleep efficiency is derived from the item hours of sleep, we also compared the three models (B-PSQI, PSQI-COMP, and PSQI-ITEM) considering error covariance between those items (efficiency and hours of sleep), as recommended in previous studies (Ho & Fong, 2014; Raniti, Waloszek, Schwartz, Allen, & Trinder, 2018).

The models' goodness of fit was evaluated with the Satorra–Bentler scaled χ^2 statistic indicated for nonnormal data (Satorra & Bentler, 2001; Yang-Wallentin et al., 2010). Because the χ^2 statistic is sensitive to sample size and often rejects well-adjusted models (Ainur, Sayang, Jannoo, & Yap, 2017; Bentler & Bonett, 1980), we also relied on the following relative fit indexes: comparative fit index (CFI; Bentler, 1990), normed fit index (NFI; Bentler & Bonett, 1980), Tucker–Lewis index (TLI; Tucker & Lewis, 1973), root mean squared error of approximation (RMSEA; Browne & Cudeck, 1992), and standardized root mean square residual (SRMR; Chen, 2007). CFI, NFI, and TLI values ≥ 0.95 were considered as optimal fit (Hu & Bentler, 1999). RMSEA values ≤ 0.08 and SRMR values <0.05 were considered to indicate satisfactory fit (Hu & Bentler, 1999).

Measurement invariance across gender and age. Measurement invariance was tested considering the recommendations of Bowen and Masa (2015) for ordinal data. We first tested the best-fit model from CFA in men and women separately and also in three different age groups: young adults (18–34 years; $n = 292$), middle adults (35–49 years; $n = 202$), and older adults (50–75 years; $n = 115$). Next, we studied the equivalence of the B-PSQI between groups by testing three models that increase invariance stringency: (a) configural invariance model or baseline model, which implies equivalence of model form; (b) metric or weak factorial model, which refers to equivalence of loadings (λs) across groups; and (c) scalar or strong factorial model, which denotes equivalence of loadings and items thresholds (τs).

These models were estimated using RDWLS based on the Satorra–Bentler scaled χ^2 statistic. Each model was compared with its preceding model (i.e., metric model compared with configural model, scalar model compared with metric model) to study whether model fit deteriorated significantly, based on the χ^2 difference test ($\Delta\chi^2$). Again, because of χ^2 sensitivity to sample size, we also relied on models' differences in CFI (ΔCFI), RMSEA (ΔRMSEA), and SRMR (ΔSRMR) indexes where values ≤ 0.01 of ΔCFI, values ≤ 0.015 of ΔRMSEA, and values ≤ 0.03 of ΔSRMR were used to identify the most stringent model (Chen, 2007). Because items are ordered categorically, we considered acceptable ΔRMSEA values of 0.05 for metric invariance and of 0.01 for scalar invariance, as indicated by Rutkowski and Svetina (2017).

In addition, partial invariance was tested when disparity between the models was found. The forward method was used, where parameters of the noninvariant model are sequentially added or constrained to the preceding model (Jung & Yoon, 2016). We sequentially fixed nonsignificant parameters because adding this constraint would not change the fit of the model, and we retested the model until partial invariance was achieved.

To perform these analyses, we utilized the *lavaan* and *semTools* packages (Jorgensen et al., 2018; Rosseel, 2012) for R statistical software.

Convergent and concurrent validity. Convergent and concurrent validity were examined using the Spearman correlation coefficient (Fieller, Hartley, & Pearson, 1957) between B-PSQI, PSQI, and ISI. In addition, we performed receiver operating characteristic (ROC) analysis for the B-PSQI and the original PSQI to compare both measures' ability to discriminate between good and poor sleepers according to the ISI criterion cutoff of ≥ 8 (Morin et al., 2011). The area under the curve (AUC) was calculated and interpreted based on the following thresholds of discrimination power: 0.5–0.7 indicates low discrimination, 0.7–0.9 indicates moderate discrimination, and > 0.9 indicates high discrimination (Swets, 1988).

The optimal B-PSQI cutoff for screening purposes was selected by considering the global score that maximizes both sensitivity and specificity (Pintea & Moldovan, 2009). Additionally, we calculated positive predictive value (PPV), negative predictive value (NPV), and the Youden index, where higher values represent better accuracy of classification (Youden, 1950).

Results

Item Reduction and Internal Consistency

The sleep-efficiency component was treated as a single item because it is calculated with rise-time and bedtime questions. Therefore, item reduction of the PSQI was performed with the remaining 17 PSQI questions.

The polychoric correlation matrix showed that the items "How long does it usually take you to fall asleep each night?" and "Cannot get to sleep within 30 minutes" were highly correlated (r = .71). Therefore, because both items seemed to measure the same sleep-quality facet (sleep latency), we excluded the item "Cannot get to sleep within 30 minutes" because the quantitative response to the item "How long does it usually take you to fall asleep each night?" has clinical relevance.

Reliability analysis with the remaining 16 items yielded an initial ordinal alpha of α = .81 and omega of ω = 0.85. In total, 11 items were identified for removal: 9 because their corrected item-total correlation was below 0.4 and 2 because alpha was maintained or improved when the item was dropped. Table 1 displays the process of item reduction and the corresponding ordinal alpha and omega at each stage.

The B-PSQI included six questions (see Table 2). Because bedtime and rise time are used to calculate sleep efficiency, the six questions of the B-PSQI yield five scored items. These five items provide a global score ranging from 0 to 15, where higher scores indicate worse sleep quality. The B-PSQI had good reliability, with a polychoric ordinal alpha of α = .79 and ordinal omega of ω = 0.91. Corrected item-total scale correlations ranged from 0.51 to 0.78, demonstrating excellent discrimination index values (see Table 2).

Confirmatory Factor Analysis

Table 3 presents the results of standard and error covariance CFA for the three PSQI versions: the B-PSQI, the model calculated with the seven original components (PSQI-COMP), and the model calculated with the original items (PSQI-ITEM).

Using standard CFA, all three models were rejected statistically based on the Satorra–Bentler scaled χ^2 statistic (p < .01). According to the CFI, NFI, and TLI, all three models showed an adequate fit, with the B-PSQI and PSQI-COMP models exhibiting optimal goodness of fit. Only the B-PSQI model reached acceptable values for RMSEA and SRMR. Therefore, the B-PSQI model provided a satisfactory data fit for unifactorial structure, $\chi^2(5) = 39.865$, $p <$ .05, CFI = 0.97, NFI = 0.98, TLI = 0.94, RMSEA = 0.08, SRMR = 0.05.

All B-PSQI standardized factor loadings were satisfactory (range λ = 0.505–0.806). By contrast, the PSQI-ITEM model included 10 variables with loadings below 0.5 (range λ = 0.247–0.770), and the PSQI-COMP model included 2 variables with loadings below 0.5 (range λ = 0.232–0.833). Based on these findings, the B-PSQI model displayed better unifactorial representation of the data than PSQI-ITEM and PSQI-COMP, with superior parsimony given the reduced number of items.

Table 1
PSQI Item Reduction and Polychoric Ordinal Alpha and Omega of Each Stage

Item exclusion criteria	Number of items excluded	Brief description of excluded items	α	ω
None	—	All items included.	.830	.862
Collinearity	1	Cannot get to sleep within 30 minutes	.814	.849
Item total correlation < .4[a]	9	Have to get up to use the bathroom	.805	.860
		Cannot breathe comfortably		
		Cough or snore loudly		
		Feel too cold		
		Feel too hot		
		Take medication to help sleep		
		Have bad dreams		
		Have pain while sleeping		
		Trouble staying awake during daytime activities		
Alpha maintained or increased when item deleted	2	Other reasons for trouble sleeping	.793	.910
		Problem in keeping up enthusiasm to get things done		

Note. PSQI = Pittsburgh Sleep Quality Index; α = ordinal alpha coefficient; ω = ordinal omega coefficient.
[a] Values ≥ .4 represent excellent item quality (Ebel & Frisbie, 1991).

Table 2
Reliability Coefficients of the Brief Version of the Pittsburgh Sleep Quality Index (B-PSQI) Questions

B-PSQI questions	*R* item total[a]
When have you usually gone to bed at night?[b]	.752[c]
When have you usually gotten up in the morning?[b]	
How long has it usually taken you to fall asleep each night?	.509
How many hours of actual sleep did you get at night?	.641
Have you had trouble sleeping because you wake up in the middle of the night or early morning?	.588
How would you rate your sleep quality overall?	.780

[a] Item-total scale correlations, corrected for item overlap and scale reliability. [b] Rise-time and bedtime questions are used to calculate sleep-efficiency component. [c] Item-total scale correlation of sleep efficiency.

CFA was also performed by correlating residual scores between sleep efficiency and hours of sleep because of their internal communalities (Ho & Fong, 2014; Raniti et al., 2018; see Figure 2). Error covariance CFA showed goodness-of-fit improvement for the three models, indicating satisfactory fitting for the PSQI-COMP model, $\chi^2(13) = 50.418$, $p < .05$, CFI = 0.99, NFI = 0.98, TLI = 0.98, RMSEA = 0.05, SRMR = 0.06, and optimal fit for the B-PSQI model, $\chi^2(4) = 22.428$, $p < .01$, CFI = 0.99, NFI = 0.99, TLI = 0.98, RMSEA = 0.06, SRMR = 0.04 (see Table 3).

Measurement Invariance

The error covariance B-PSQI model was selected to perform measurement invariance across gender and age because it provided the best-fit model in CFA while reducing the information shared between sleep efficiency and hours of sleep. This model showed acceptable fit for men, $\chi^2(4) = 8.535$, $p > .05$, CFI = 0.99, RMSEA = 0.037, SRMR = 0.047, and women, $\chi^2(4) = 14.772$, $p > .01$, CFI = 0.99, RMSEA = 0.049, SRMR = 0.037, and also for the groups of young adults, $\chi^2(4) = 23.362$, $p < .01$, CFI = 0.98, RMSEA = 0.09, SRMR = 0.048; middle-aged adults, $\chi^2(4) = 7.200$, $p > .05$, CFI = 0.99, RMSEA = 0.02, SRMR = 0.036; and older adults, $\chi^2(4) = 8.469$, $p > .05$, CFI = 0.99, RMSEA = 0.04, SRMR = 0.047. The results for the invariance models' fit are presented in Table 4.

Invariance across gender. The configural invariance model reached satisfactory values of fit indexes (CFI = 0.99, RMSEA = .079, SRMR = 0.028), which suggested that the unifactorial structure of sleep quality applied to men and women equally. The comparison of configural and metric models showed nonsignificant $\Delta\chi^2(p > .05)$, with low values of ΔCFI, ΔRMSEA, and ΔSRMR. These findings indicate that the fit of metric invariance did not change significantly from the configural model, and therefore items' weights were similar in both groups.

On the other hand, differences between metric and scalar models showed that $\Delta\chi^2$ was statistically significant ($p < .05$), which indicated a substantial decrease in model fit. These results suggested noninvariance of thresholds across gender, meaning that at least one item measured responses differently in men and women. To identify which items had noninvariant thresholds, we examined partial invariance. The resultant partial invariance model contained all B-PSQI items fixed except one: "Have you had trouble sleeping because you wake up in the middle of the night or early in the morning?" As Table 4 reports, the $\Delta\chi^2$ of the partial invariance model was nonsignificant ($p > .05$) compared with the metric

Table 3
One-Factor Model Goodness-of-Fit Indexes of CFA for the Original Pittsburgh Sleep Quality Index (PSQI) and the Brief Version (B-PSQI)

Models	SB-χ^2 (*df*)	CFI	NFI	TLI	RMSEA [95% CI]	SRMR
Standard CFA						
PSQI-ITEM	767.532** (119)	.879	.858	.862	.090 [.083, .096]	.100
PSQI-COMP	82.373** (14)	.973	.964	.959	.069 [.050, .089]	.073
B-PSQI	39.865** (5)	.969	.983	.937	.078 [.048, .111]	.050
Error covariance CFA						
PSQI-ITEM	709.046** (118)	.891	.870	.874	.086 [.079, .092]	.097
PSQI-COMP	50.418** (13)	.987	.978	.979	.049 [.028, .071]	.061
B-PSQI	22.428** (4)	.994	.991	.984	.060 [.024, .098]	.039

Note. CFA = confirmatory factor analysis; SB-χ^2 = Satorra–Bentler scaled chi-square; *df* = degrees of freedom; CFI = comparative fit index scaled; NFI = normed fit index scaled; TLI = Tucker–Lewis index scaled; RMSEA = root mean squared error of approximation with coefficient intervals; SRMR = standardized root mean square residual; PSQI-ITEM = CFA model of the original PSQI calculated using its 18 items; PSQI-COMP = CFA model of the original PSQI calculated using the 7 sleep components; B-PSQI = CFA model of the developed 6-item Brief Version of the PSQI.
** $p < .01$.

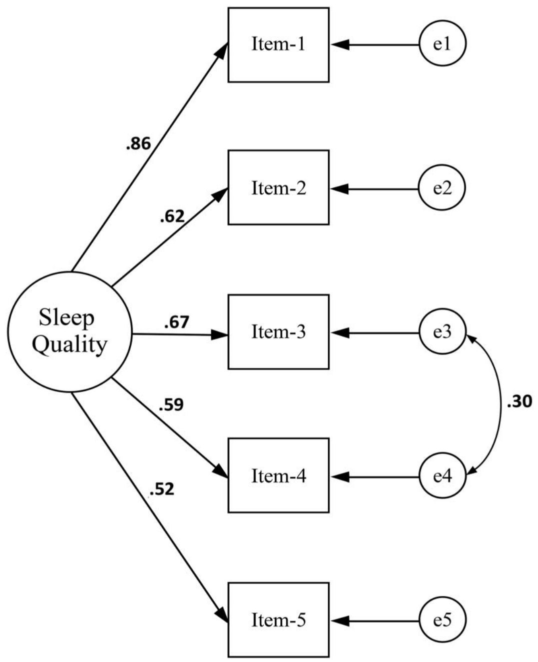

Figure 2. Standardized factor loadings of confirmatory factor analysis for the B-PSQI and residual scores correlations between sleep efficiency and hours of sleep. Item-1: sleep quality; Item-2: night awakenings; Item-3: sleep efficiency; Item-4: hours of sleep; Item-5: sleep latency.

model, and the overall fit criteria of the partial invariance model were adequate (ΔCFI = 0.007, ΔRMSEA = 0.03, ΔSRMR = 0.001), suggesting minor fit change. Because of the small number of parameters released from the model (no more than 20%), partial strong invariance across gender was considered satisfactory (Dimitrov, 2010).

Invariance across age. From a global examination, the model for configural invariance showed satisfactory goodness of fit (CFI = 0.98, RMSEA = 0.105, SRMR = 0.036). RMSEA values (above cutoff 0.08) were inconsistent with the CFI and SRMR, which may be due to data distribution and fit function rather than a problem in model fit (Lai & Green, 2016). Therefore, the structure of the B-PSQI appeared to be invariant across the three age groups. The comparison of configural and metric models showed a significant $\Delta\chi^2$ statistic ($p < .01$) and a difference in CFI values sufficiently large (ΔCFI = 0.018) to consider a major decrease in the model fit (see Table 4). Because metric invariance was not supported, we did not proceed to the scalar testing.

Convergent and Concurrent Validity

Spearman correlations between sleep self-reported measures indicated that the PSQI and B-PSQI were highly correlated (r = .895) and that high scores on these measures were significantly associated ($p < .01$) with high scores on the ISI (r = .738 for PSQI and r = .671 for B-PSQI).

As shown in Table 5, the PSQI and the B-PSQI yielded AUC values over the threshold of acceptable discrimination power (0.882 and 0.846, respectively) to identify people reporting sleep problems, indicated by ISI scores $\geq$ 8.

ROC analysis indicated that scores on the B-PSQI of > 5 were optimal to classify poor sleep quality, maximizing rates of sensitivity (75.82%) and specificity (76.99%). For the original PSQI version, the optimal cutoff point to classify poor sleepers was > 6, demonstrating similar rates of sensitivity (82.38%) and specificity (76.71%) compared with the B-PSQI (see Table 5). These cutoff points (B-PSQI > 5 and PSQI > 6) showed high PPV, NPV, and Youden index values associated with the minimum proportion of true positives recommended for screening purposes.

Using these cutoff values, the base rate of poor-quality sleepers was 47% (n = 286) for the PSQI (score > 6) and 44.2% (n = 269) for the B-PSQI (score > 5). As shown in Figure 3, the two measures differed in classifying 4.8% (n = 43) of poor sleepers and 5.2% (n = 32) of good sleepers, suggesting that the PSQI and the B-PSQI are statistically and clinically analogous.

Discussion

Given the relevance of the PSQI and the benefits of short questionnaires in research and clinical practice, the aim of this study was to develop the shortest PSQI version that could provide adequate validity and reliability properties in a population-based sample. The B-PSQI reduces the number of questions by 70%, going from the 18 items of the original version to 6 items. This study demonstrated that the new six-item B-PSQI is considerably shorter than the short version proposed by Famodu et al. (2018) and that it has satisfactory psychometric properties in terms of

Table 4
Measurement Invariance in the Brief Version of the Pittsburgh Sleep Quality Index (B-PSQI) Across Gender and Age

Model	SB-χ^2 (df)	CFI	RMSEA [95% CI]	SRMR	$\Delta\chi^2(df)$	ΔCFI	ΔRMSEA	ΔSRMR
Gender invariance								
Configural	23.204 (8)**	.986	.079 [.043, .117]	.028	—	—		—
Metric (λs)	25.421 (12)*	.988	.061 [.027, .093]	.030	4.364 (4)	.002	.018	.002
Scalar (λs + τs)	43.693 (21)**	.980	.060 [.034, .084]	.032	19.203 (9)*	.008	.001	.002
Partial scalar invariance	25.884 (20)	.995	.031 [.001, .062]	.031	7.231 (8)	.007	.030	.001
Age invariance								
Configural	39.083 (12)**	.978	.105 [.070, .143]	.036	—	—	—	—
Metric (λs)	68.708 (20)**	.960	.110 [.082, .138]	.046	30.199 (8)**	.018	.005	.01

Note. SB-χ^2 = Satorra–Bentler scaled chi-square; df = degrees of freedom; CFI = comparative fit index; RMSEA = root mean squared error of approximation; SRMR = standardized root mean square residual; $\Delta\chi^2(df)$ = χ^2 difference test per degree of freedom; ΔCFI = models' CFI difference; ΔRMSEA = models' RMSEA difference; ΔSRMR = models' SRMR difference.
* $p < .05$. ** $p < .01$.

Table 5
Sensitivity and Specificity of the Pittsburgh Sleep Quality Index (PSQI) and the Brief Version (B-PSQI) According to the Insomnia Severity Index (ISI; ≥ 8)

Measure	Cutoff points	Sensitivity,[a] %	Specificity,[b] %	Youden index	PPV, %	NPV, %	Base rate,[c] % (*n*)
B-PSQI AUC = .846							
	≥1	≤100	≤18.08	.173	≤49.8	≥96.4	≥88.8 (541)
	>2	97.54	32.33	.299	54.1	94.1	79.6 (485)
	>3	93.03	49.59	.426	60.2	89.7	67.5 (411)
	>4	84.43	66.03	.505	67	83.8	54.2 (330)
	>5	**75.82**	**76.99**	**.528**	**72.9**	**79.6**	**44.2 (269)**
	>6	64.75	85.21	.500	78.2	74.7	34.8 (212)
	>7	56.15	93.15	.493	87	72.2	26.6 (162)
	>8	36.89	95.34	.322	86.6	64.9	17.6 (107)
	>9	≤23.77	≥97.81	.216	≥89.9	≤61.1	≤10.8 (66)
PSQI AUC = .882							
	≥1	≤100	≤4.38	≤.044	≤46.1	100	≥97.4 (593)
	>2	100	15.62	.156	49.2	100	90.6 (552)
	>3	99.59	29.32	.289	53.5	98.9	82.3 (501)
	>4	95.49	48.77	.443	60.4	93	69.0 (420)
	>5	89.34	65.21	.545	67.8	88.2	56.7 (345)
	>6	**82.38**	**76.71**	**.591**	**74.3**	**84.2**	**47.0 (286)**
	>7	69.26	88.22	.575	82.8	77.8	34.8 (212)
	>8	58.61	93.97	.526	88.8	73.5	27.1 (165)
	>9	≤45.49	≥96.99	≤.425	≥92.5	≤68.5	≤20.0 (122)

Note. PPV = positive predictive value; NPV = negative predictive value; AUC = area under the curve. Bold values indicate optimal cutoff performance. [a] Sensitivity = true-positive rate. [b] Specificity = true-negative rate. [c] Base rate = percentage of people referring poor sleep quality based on B-PSQI and PSQI cutoffs.

internal reliability, validity, and ability to discriminate between poor and good sleepers. Moreover, the B-PSQI has simpler and more straightforward scoring than the original version, which improves the efficiency of its use.

Despite the small number of items in the B-PSQI, reliability results maintained good internal consistency (α = .79 and ω = 0.91), agreeing with PSQI validation studies targeting a nonclinical population, where internal consistency ranges from α = .67 to 0.77 (Magee, Caputi, Iverson, & Huang, 2008; Tomfohr et al., 2013). The reduction of items discarded two of the seven PSQI sleep components: daytime dysfunction and the use of sleeping medication. Similar to previous studies, the measurement properties of the PSQI improved when the medicine-use component was excluded (Mollayeva et al., 2016) or clustered together with the daytime-dysfunction component in a two-factor model (Kotronoulas, Papadopoulou, Papapetrou, & Patiraki, 2011). Daytime dysfunction and use of sleeping medication appear to have the greatest divergence from other PSQI components on conceptual and content grounds. Other sleep components, such as sleep latency or sleep disturbances, seemed to be reliably assessed with fewer items, optimizing the efficiency of the instrument. Interestingly, the largest item-total correlation for the B-PSQI was for the subjective sleep-quality component (0.78), which also shows the largest item-total correlation for the original PSQI (Buysse et al., 1989).

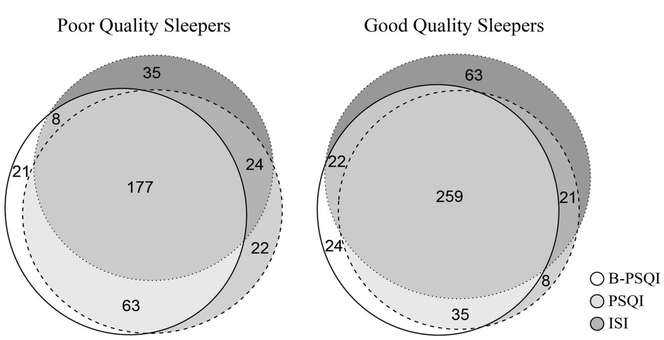

Figure 3. Venn diagram of the overlaps of good and bad sleepers (n) categorized by the Brief Version of the Pittsburgh Sleep Quality Index (B-PSQI) (score > 5), the Pittsburgh Sleep Quality Index (PSQI) (score > 6) and the Insomnia Severity Index (ISI) (score ≥ 8).

Regarding validity, CFA results showed adequate fit for the B-PSQI unidimensional structure, supporting sleep quality as a single construct, as observed in several PSQI validation studies (de la Vega et al., 2015; Manzar et al., 2018; Zhu et al., 2018). This unifactorial structure differs from the six-factor PSQI short version (Famodu et al., 2018) and from other multifactorial structure validations that have been demonstrated to yield good data representation (Mollayeva et al., 2016). The B-PSQI, with only six questions, would unlikely demonstrate adequate multifactor structure because it falls short of the recommended minimum number of three items per factor (Kline, 1998) and because of the elimination of the daytime dysfunction and medication components.

Furthermore, the results of this study indicate that the B-PSQI performs equally with men and women but only in similar age groups. Partial strong invariance was achieved across gender, suggesting that the B-PSQI provides valid mean scores in men and women and that their scores' differences reflect true differences in the sleep-quality construct. On the other hand, because age invariance was only achieved for factor structure, the comparison of B-PSQI scores is valid only among people of similar age.

These results concur with the original PSQI, where partial invariance across gender is achieved (Li, Sheehan, & Thompson, 2019), but invariance across age is only satisfactory at the configural level (Jia, Chen, Deutz, Bukkapatnam, & Woltering, 2019). The lack of metric and scalar invariance across age suggests that at least one B-PSQI item is more closely related to poor sleep in a particular age group than in another and/or that the thresholds cutoffs in the quantitative items (e.g., sleep latency) are not adapted to age-related sleep changes (Gadie et al., 2017; Hinz et al., 2017). Researchers should take into consideration these invariance results because the differences found could be due to measurement limitations (Byrne, 2008).

The B-PSQI was significantly related to PSQI and ISI scores, indicating concurrent and convergent validity, which coincides with previous PSQI validity studies (Chiu et al., 2016; Morin et al., 2011). Moreover, although the reduction of items could affect the psychometric properties of the B-PSQI, sensitivity and specificity rates were similar to the original PSQI version, with a B-PSQI cutoff of 5. This analogy with the original PSQI is also supported by the results of previous studies in which the percentage of poor sleepers among a nonclinical Spanish population (PSQI = 38.2%) was similar to the rates obtained in our study (B-PSQI = 44.2%) with similar sample characteristics (Madrid-Valero et al., 2017).

The B-PSQI seems to adequately represent sleep quality, showing slightly better adjustment for unifactorial structure than the original PSQI. The B-PSQI may provide benefits for large surveys and screening studies by improving the efficiency of assessment while preserving the ability to identify individuals with sleep problems or associated disorders and pathologies (Baglioni et al., 2016; Jike et al., 2018).

Interestingly, the B-PSQI includes mainly quantitative variables (efficiency, hours of sleep, sleep latency). Although self-reported sleep times are imprecise, these variables correspond with the assessment of sleep quality using objective measures such as actigraphy or polysomnography (Ibáñez et al., 2018; Svetnik et al., 2020). In this regard, the B-PSQI differs from other short self-reported sleep measures, such as the eight-item short-form PROMIS sleep scale and the one-item SQS, that include only graded qualitative items. The collection of sleep times allows for standardized sleep criteria and improves operational metrics (Yu et al., 2012). For example, when assessing hours of sleep, the PROMIS item "I got enough sleep" has to be answered using a Likert-type scale from *never* to *always*. However, the criterion "enough sleep" is not stipulated. By contrast, the B-PSQI item "How many hours do you sleep?" collects numeric information that allows for the standardization of a criterion for the recommended number of hours of sleep (e.g., young adults > 7 hr per night). Because of these differences in response types, the B-PSQI could potentially be used to identify sleep problems based on self-reported quantitative parameters, such as advanced sleep-phase disorder.

The B-PSQI excludes items relating to daytime symptoms, such as sleepiness, which may limit a relevant part of the sleep-quality construct (Buysse, 2014; Goelema et al., 2018; Ramlee et al., 2017). However, the item of the overall perception of sleep quality may in part reflect respondents' judgments about sleep impact during the waking period, as occurs with the one-item SQS (Snyder et al., 2018).

Several limitations are worth noting. First, this study was performed among the Spanish population, which could limit B-PSQI validity in other populations. However, the use of the original PSQI has demonstrated to be invariant across both English and Spanish languages and across different cultures (Otte et al., 2013; Tomfohr et al., 2013). This suggests that the derivative brief form may be invariant as well; further validation studies are necessary to ensure this. Second, the use of the snowball technique can lead to oversampling of a particular network, as suggested by the relatively high educational attainment of the current sample. However, the online recruitment method has been used to achieve large and diverse population samples cost-effectively in other studies (Christensen et al., 2017; Kesse-Guyot et al., 2013). Furthermore, as already mentioned, the percentage of poor sleepers in this study concurs with previous studies, regardless of sampling method (Madrid-Valero et al., 2017).

In conclusion, the B-PSQI is a reliable and valid sleep-quality measure for the general population that allows easy and rapid administration. The B-PSQI may be useful as a screening tool among researchers and general practitioners because it requires little time and may maximize response rates in questionnaires, which can mitigate response-bias effects (Galesic & Bosnjak, 2009; Rolstad et al., 2011). For instance, the B-PSQI may be a useful instrument to include in national health surveys, as well as to assess sleep-related symptomatology in psychological disorders and medical problems. Future investigations in different populations should be conducted to confirm these findings.

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Psychometric adaptation of the Spanish version of the Brief Pittsburgh Sleep Quality Index in adolescents

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STUDY II

Abstract

Objective: Good sleep quality is essential for adolescent health, yet sleep difficulties persist in this age group. The 6-item Brief Pittsburgh Sleep Quality Index (B-PSQI) was recently developed to improve sleep quality assessment, however, its validity in adolescents remains unexplored. This study examined the B-PSQI's psychometric properties in Spanish adolescents and adapted the scoring method to age-specific sleep recommendations.

Methods: A cross-sectional study involving 1,065 adolescents (15–17 years; 56.8% female) was conducted in public high schools. Sleep quality was measured using the B-PSQI, the Insomnia Severity Index (ISI), the short Patient-Reported Outcomes Measurement Information System (PROMIS), and the Epworth Sleepiness Scale (ESS). Additionally, depression and anxiety were assessed using the Depression, Anxiety, and Stress Scales. Reliability, validity, and measurement invariance were analyzed.

Results: The B-PSQI global scores were 4.5 ($SD = 1.9$) for the original scoring method and 5.4 ($SD = 2.8$) for the age-adjusted. The age-adjusted B-PSQI showed satisfactory reliability ($\omega = 0.84$) and concurrent, convergent, and discriminant validity (ISI $r_S = 0.67$; PROMIS $r_S = 0.71$; anxiety $r_S = 0.40$; depression $r_S = 0.42$; ESS $r_S = 0.29$). Adequacy for one-factor structure ($\chi^2(4) = 53.9$; CFI = 0.97; TLI = 0.92; RMSEA = 0.108; SRMR 0.05) and invariance across sexes were supported. Both B-PSQI scoring methods showed similar psychometric properties, but the original yielded a higher percentage of poor sleepers (43.1%; cutoff ≥5) than the age-adjusted version (41.9%; cutoff ≥6).

Conclusions: Findings suggest that the B-PSQI is a valid and reliable measure to assess adolescent sleep quality. Its scoring can be adjusted to provide age-specific criteria for good sleep. The B-PSQI has potential utility for screening sleep problems and facilitating overall health promotion in adolescents.

Keywords: sleep, adolescents, measure validation, health behavior.

Sleep quality plays a significant role in overall health during adolescence, with sleep disturbances linked to a range of adverse outcomes. For example, poor sleep has been associated to the onset of mental disorders (Scott et al., 2021), a decline in cognitive functioning and academic performance (Machado et al., 2022), obesity (Lee & Cho, 2022), hypertension (Wang et al., 2023), and addictive behaviors (Troxel et al., 2021). Nevertheless, sleep problems remain common among adolescents, with up to 50% experiencing sleep disturbances (Kocevska et al., 2020). Thus, assessment tools for sleep quality are essential to identify sleep problems and improve adolescents' health.

Various sleep measures have been adapted for adolescent populations, including the Pittsburgh Sleep Quality Index (Buysse et al., 1989). The PSQI is one of the most used questionnaires worldwide (Mollayeva et al., 2016) that assesses subjective sleep quality and its sleep components: sleep duration, sleep efficiency, sleep latency, sleep disturbances, use of medication, and daytime dysfunction (Buysse et al., 1989). Recently, a 6-item version of the PSQI, the Brief Pittsburgh Sleep Quality Index (B-PSQI) was developed to optimize its utility and feasibility (Sancho-Domingo et al., 2021). As in the original version, the B-PSQI assesses bed and wake-up times, sleep efficiency, hours of sleep, and the time to fall asleep, providing a global score for sleep quality. The B-PSQI has favorable psychometric properties including adequate reliability (Cronbach's $\alpha = 0.79$ and ordinal omega $\omega = 0.91$) as well as concurrent, convergent, and factor validity (Sancho-Domingo et al., 2021). However, this brief version has not yet been tested or validated in an adolescent population.

The original PSQI adaptation for adolescents has shown adequate psychometric properties (Passos et al., 2017; Raniti et al., 2018) and has undergone several modifications, including replacing adult-specific items (such as trouble staying awake while driving) with more relevant ones for teenagers (trouble staying awake while studying) (de la Vega et al., 2015). However, the method to calculate adolescents' PSQI global score remained the same as in the adult version. This is particularly relevant, since some criteria for good sleep may differ according to age (Ohayon et al., 2017), such as the recommended amount of sleep (Hirshkowitz et al., 2015). According to the National Sleep Foundation, the recommended sleep duration for healthy adults is between 7 and 9 h per night, while for teenagers is between 8 and 10 h (Hirshkowitz et al., 2015). Considering the sleep recommendations for different age groups, it might be necessary to adapt the current scoring criteria for the B-PSQI to align with adolescents' age-specific recommendations for good sleep quality.

It is also noteworthy to consider B-PSQI invariance across sex, since sleep differences may exist between men and women during adolescence, in both objective and subjective measures. Young women report more difficulties falling asleep, fewer hours of sleep, and higher sleepiness, than men; however, objective measures suggest that women have better sleep in terms of more slow-wave sleep and fewer night awakenings (Baker et al., 2023). Therefore, an invariant self-reported sleep measure across sex could ensure that score differences between men and women can be due to sex differences rather than measurement errors (Byrne, 2008).

In this regard, sleep quality is closely linked to the mood of adolescents, especially female adolescents who are more prone to being diagnosed with insomnia due to anxiety/depression symptoms (Lemke et al., 2023; Zhang et al., 2016). Several longitudinal studies have revealed that PSQI scores are linked to higher scores in anxiety and depression, and experiencing mood symptoms strongly predicts sleep problems (Kortesoja et al., 2020). As a result, various studies have utilized these variables to assess concurrent and convergent validity (e.g., Raniti et al., 2018).

The aims of this study were twofold: first, to examine the psychometric properties of the B-PSQI in an adolescent population, including reliability, validity, and measurement invariance across sex; and second, to compare B-PSQI psychometric properties when the measure is calculated using the original method versus using an adapted scoring method based on recommended sleep duration.

Methods

Participants

Participants in this study were students in 10th to 12th grades from public high schools in the region of Alicante, Spain. The inclusion criteria were native Spanish speakers aged between 15 and 17 years old, and without any difficulties in understanding (such as cognitive processing difficulties). For the aims of this study, a minimum sample size of 220 participants was estimated according to the recommendation of 10:1 ratio of participants to the number of B-PSQI model parameters (22) to conduct confirmatory factor analysis (Kline, 1998). Of the 1,294 adolescents initially invited to participate in the study, 5 declined to participate, 3 were excluded because they had trouble understanding, and 2 were not native speakers. Likewise, 44 were excluded because they were 18 years or older, 5 because they provided invalid responses on questionnaires (e.g., outliers identified for exceeding the established range of the measurement responses, or responses that did not align with the provided response options), and 170 for missing data on the PSQI items or other information related to the purposes of this study (e.g., sex).

The final sample included 1,065 Spanish adolescents, with an average age of 16.5 years ($SD = 0.6$). The sample comprised 606 (56.8%) female and 460 (43.2%) male adolescents (i.e., sex assigned at birth), with most of them (76.2%; $n = 811$) attending schools located in urban areas. The majority of the participants were from the lower-middle socioeconomic class, and they were of Caucasian origin. Likewise, the number of participants across the nine randomized schools was distributed as school 1: 219, school 2: 209, school 3: 157, school 4: 135, school 5: 119, school 6: 71, school 7: 58, school 8: 56, and school 9: 41.

Procedure

We conducted a descriptive cross-sectional study that was approved by the Clinical Research Ethics Committee of the General University Hospital of Alicante (GUHA; CEIm: PI2019/112). After receiving ethics approval, we randomly selected nine secondary schools in Alicante using a simple computerized procedure. We then contacted the school principals to request permission to conduct the study. Once permission was granted, we informed students and their parents/guardians about the study and data confidentiality. Those interested in participating provided written informed consent to participate in the study. No compensation was provided for participation in this study, due to funding not being designated for that purpose.

A team of health psychologists conducted the assessments during school hours in the classrooms, with each assessment lasting 50 min. The students were taught to complete a battery of measures online using their mobile phones and to create an individual identification code to ensure anonymity. The study was conducted between November 2021 and March 2023.

Variables and measures

The Brief version of the Pittsburgh Sleep Quality Index (B-PSQI; Sancho-Domingo et al., 2021) was used to measure sleep quality and test its psychometric properties. The B-PSQI consists of 6 items that allow to evaluate the quality of sleep of last month based on five dimensions: sleep efficiency, sleep latency (in minutes), subjective sleep quality, hours of total sleep, and frequency of night awakenings. Each dimension is scored according to the degree of sleep difficulty using a range between 0 and 3 points. As observed in Table 1, in the age-adjusted scoring the item of sleep hours is coded as 0 for sleeping *10–9 h*, 1 for sleeping *9–8 h*, 2 for sleeping *8–7 or 10–11 h*, and 3 for *<7 or >11 h*. The sum of the five dimensions yields a global score that ranges from 0 to 15, with higher scores representing poorer quality of sleep. Although the B-PSQI has not yet been used in an adolescent population, the original longer version showed adequate reliability ($\alpha = 0.73–0.66$) and validity in adolescents (de la Vega et al., 2015; Guo, 2022; Passos et al., 2017; Raniti et al., 2018). In this study, we used the Spanish brief version that was derived from the original PSQI (Sancho-Domingo et al., 2021), which has demonstrated invariance across different languages and cultures (Tomfohr et al., 2013).

We also used the Insomnia Severity Index (ISI; Bastien et al., 2001) because it strongly correlates with sleep quality measures as the PSQI (Chiu et al., 2016; Gerber et al., 2016; Sancho-Domingo et al., 2021). ISI consists of seven items rated on a 5-point Likert scale that provides information about insomnia symptoms, satisfaction with sleep, and its impact on quality of life. Scores on the ISI range from 0 to 28, with scores between 0 and 7 indicating an absence of sleep problems, 8 and 14 indicating subthreshold insomnia, 15 and 21 indicating moderate insomnia, and above 22 indicating severe insomnia. Previous studies have examined the ISI psychometric properties in the adolescent population demonstrating adequate internal consistency ($\alpha > 0.70$) and factor validity (Gerber et al., 2016). In this study, the ISI internal consistency was $\omega = 0.78$.

Table 1. Description of B-PSQI items and scoring adaptation of the sleep hour item for adolescents and adults.

	Item correction (score)			
Items	0	1	2	3
When have you usually gone to bed at night?/ When have you usually gotten up in the morning?[a]	≥85%	84–75%	74–65%	<64%
How long has it usually taken you to fall asleep each night?	<15 min	16–30 min	31–60 min	>60 min
Have you had trouble sleeping because you wake up in the middle of the night or early morning?	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
How would you rate your sleep quality overall?	Very good	Fairly good	Fairly bad	Very bad
How many hours of sleep did you get at night?				
Adolescents 14–17 years	10–9 h	9–8 h	8–7 or 10–11 h	<7 or >11 h
Adults 18–64 years	≥8 h	8–7 h	7–6 h	<6 h

Note. Responses given for the minutes taken to fall asleep and the number of sleep hours are assessed as numeric responses. The numeric value is then coded using the scoring algorithm provided above. Questions for trouble sleeping and subjective sleep quality are asked using the response categories provided.
[a] Rise-time and bed-time questions are used to calculate sleep efficiency component and are answered in a time format. Sleep efficiency corresponds to the percentage of sleep hours spent between bed and rise times. Access to the complete measure can be provided upon request.

The short form of the Patient-Reported Outcomes Measurement Information System (PROMIS; Forrest et al., 2018) was used to evaluate child-reported difficulties in falling asleep and maintaining sleep. The 4-item PROMIS evaluates the frequency of experiencing sleep difficulties in the past two weeks using a 4-point Likert scale ranging from 1, *never*, to 4, *always*. This tool has proven good reliability ($\alpha = 0.88$) and validity in adolescents. In this study, the PROMIS internal consistency was $\omega = 0.86$.

The Epworth Sleepiness Scale (ESS; Janssen et al., 2017; Johns, 1991) was used to measure the degree of sleepiness in eight different situations (e.g., sitting and reading). The ESS responses are rated on a 4-point Likert scale that ranges from 0, *would never fall asleep*, to 3, *high probability of falling asleep*. The sum of the eight items provides a global ESS score between 0 and 24, with higher scores representing greater sleepiness. ESS scores above 10 represent “excessive daytime sleepiness” and can indicate the existence of a sleep disorder (Johns & Hocking, 1997). For this study, we used the ESS adaptation for adolescents which has shown to be a valid and reliable measure ($\alpha = 0.73$–0.76) to assess sleepiness in teenagers (Janssen et al., 2017; Wang et al., 2022). In this study, the ESS internal consistency was $\omega = 0.78$.

Lastly, we assessed depression and anxiety with the subdimensions of the Depression, Anxiety and Stress Scales (DASS-21; Antony et al., 1998; Fonseca et al., 2010). The DASS uses 7 items to measure each subscale with a 4-point Likert scale (e.g., I felt I wasn’t worth much as a person). Item responses range from 0, *did not apply to me at all*, to 3, *applied to me very much*, and provide a global score to each subscale between 0 and 21. In adolescents, a DASS-D cutoff score of 4 in men and 5 in women is indicative of depression, and a DASS-A cutoff of 5 in men and 6 in women is indicative of anxiety (Evans et al., 2021). The DASS is a reliable and valid measure to assess depression (DASS-D $\alpha = 0.87$) and anxiety (DASS-A $\alpha = 0.79$) in adolescents (Szabó, 2010). In this study, the DASS internal consistency was $\omega = 0.89$ for the depression subscale and $\omega = 0.82$ for the anxiety subscale.

Statistical analysis

Sociodemographic and sleep characteristics were analyzed using descriptive and bivariate analyses using the software SPSS version 26. Chi-square (χ^2) tests were used to examine noncontinuous variables, and calculated Cramer’s V effect size, with values >0.05 indicating weak effect, >0.1 moderate, >0.15 strong, and >0.25 very strong (Cramér, 1946). Mann–Whitney U nonparametric (Z) test was used for continuous variables due to normality violation, and we estimated Rosenthal’s r effect size, with values >0.1 representing small effect size, >0.3 moderate, >0.5 large (Rosenthal, 1994).

To examine B-PSQI psychometric properties in adolescents we compared two different scoring methods: the original B-PSQI method adapted to adults’ recommendations of 7–9 h of sleep, and the age-adjusted B-PSQI method adapted to adolescents’ recommendations of sleeping 8–10 h (see Table 1). Internal consistency was examined using ordinal alpha and omega based on polychoric correlations due to items’ ordinal data (Gadermann et al., 2012). Values of alpha and omega greater than 0.7 were considered acceptable (Cortina, 1993). The *psych* package for R statistical software (Revelle, 2018) was used to conduct the analyses.

Unidimensionality of the two B-PSQI versions was examined by using Confirmatory Factor Analysis with the *lavaan* R package (Rosseel, 2012). A one-factor model was estimated by Robust Diagonally Weighted Least Squares (RDWLS) (Yang-Wallentin et al., 2010). Furthermore, since sleep efficiency is calculated from the hours of total sleep, models were estimated considering error covariance between those items as recommended in previous studies (Ho & Fong, 2014; Raniti et al., 2018; Sancho-Domingo et al., 2021). Models’ goodness of fit was evaluated with the Satorra–Bentler scaled χ^2 statistic indicated for nonnormal data

(Satorra & Bentler, 2001; Yang-Wallentin et al., 2010), the Comparative Fit Index (CFI; Bentler, 1990), the Tucker–Lewis Index (TLI; Tucker & Lewis, 1973), the Root Mean Squared Error of Approximation (RMSEA; Browne & Cudeck, 1992), and the Standardized Root Mean Square Residual (SRMR; Chen, 2007). CFI and TLI values ≥0.95 were considered to indicate adequate model fit (Hu & Bentler, 1999). RMSEA values ≤0.08 and SRMR values ≤0.05 were considered to indicate satisfactory fit (Hu & Bentler, 1999).

In addition, measurement invariance was analyzed considering ordinal data for B-PSQI items (Bowen & Masa, 2015), and three models that increase invariance stringency were compared: (a) the configural invariance model, which involves equivalence of model form; (b) the metric invariance model, which refers to equivalence of loadings (λs), across male and female adolescents; and (c) the scalar invariance model, which denotes equivalence of loadings and items thresholds (τs, taus). Each model was compared with its preceding model to test if model fit declined significantly based on χ^2 difference test ($\Delta\chi^2$), and differences in CFI (ΔCFI), RMSEA (ΔRMSEA), and SRMR (ΔSRMR). Values of $\Delta CFI \leq 0.01$, values of $\Delta RMSEA \leq 0.015$, and values of $\Delta SRMR \leq 0.03$ were used to identify the most stringent model (Chen, 2007). Because items are ordered categorically, we considered acceptable values of $\Delta RMSEA \leq 0.05$ for metric invariance (Rutkowski & Svetina, 2017).

Convergent, concurrent, and discriminant validity were examined with Spearman's rho correlation, r_S (Fieller et al., 1957), between B-PSQI, the ISI, the PROMIS, the ESS, and the DASS. Values of $r_S \leq \pm 0.3$ indicate weak association between measures, ≤±0.6 moderate, and ≥±0.7 strong. It is expected to observe a strong association between similar sleep measures, such as the ISI and PROMIS, a moderate association with mood measures like the DASS (e.g., Raniti et al., 2018), and a lower association with the ESS as a tool for discriminant validity, as observed in previous studies (e.g., Chehri et al., 2020). To examine B-PSQI classification power for identifying poor sleepers a receiver operating characteristic (ROC) analysis was conducted using the ISI criterion (cutoff of 9) for adolescents' sleep problems (Chung et al., 2011) and the short PROMIS for sleep quality (t-scores >55). The area under the curve (AUC) was estimated, with AUC values between 0.5 and 0.7 indicating low discrimination power, between 0.7 and 0.9 moderate, and above 0.9 high accuracy to discriminate poor sleep quality (Swets, 1988). The optimal B-PSQI cutoff was selected considering the global score that maximizes both sensitivity and specificity (Pintea & Moldovan, 2009), and Youden index (Youden, 1950). All data analyses were interpreted with a 95% confidence level.

Results

Sample sleep characteristics

The majority of adolescents reported having good sleep quality (72.5%; $n = 772$), as described in Table 2. However, the average bedtime was 11:31 p.m. ($SD = 1{:}06$) and average wake-up time 7:01 a.m. ($SD = 0{:}50$), leaving an inadequate amount of time to get the recommended minimum of 8 h of sleep per night. The total amount of sleep reported was approximately 7 h ($SD = 1.1$), with only 20.9% ($n = 223$) of adolescents reporting ≥8 h of night sleep. Mean sleep latency was approximately 20 min ($SD = 25.7$), and sleep efficiency was high, with adolescents spending 92% of their time in bed asleep. The mean B-PSQI score was 4.5 ($SD = 2.9$), but the age-adjusted B-PSQI score was 5.4 ($SD = 2.8$), which reflects the longer sleep duration considered ideal in adolescents. Scores on the ISI (7.7 ± 5), the PROMIS (raw scores 8.6 ± 3.9), the ESS (7 ± 5.1), the DASS-A (5.9 ± 4.9), and the DASS-D (6.9 ± 5.5) were low to moderate indicating low levels of sleep or emotional symptoms, albeit with individual differences.

Female adolescents had significantly worse sleep quality than male adolescents in almost all sleep parameters ($p < .05$), as observed in Table 2. A larger percentage of female adolescents reported experiencing more night awakenings (44.1% vs 30%) and having poorer subjective sleep quality (33.1% vs 8.7%) in the past month, corresponding to moderate effect sizes ($p < .001$; $\varphi_c = 0.14$). Similarly, female showed higher scores (with moderate effect sizes) on the B-PSQI (mean diff.: 1.2; $Z = 6.89$; $p < .001$; $r = 0.21$) and other sleep-related symptom measures, including ISI (mean diff.: 2.21; $Z = 7.13$; $p < .001$; $r = 0.22$), ESS (mean diff.: 2.76; $Z = 9.61$; $p < .001$; $r = 0.29$), DASS-A (mean diff.: 2.41; $Z = 8.21$; $p < .001$; $r = 0.25$), and DASS-D (mean diff.: 2.91; $Z = 9.03$; $p < .001$; $r = 0.28$).

Internal consistency

According to omega and alpha values, both B-PSQI versions exhibited high levels of internal consistency. The original B-PSQI version and the age-adjusted B-PSQI showed the same coefficients of $\alpha = 0.76$ and $\omega = 0.84$. This indicates that the B-PSQI is a reliable measure for assessing sleep quality in adolescents, even when the age-adjustment correction is applied. All item-total correlations showed positive associations with both B-PSQI versions, with correlation coefficients ranging from 0.65 to 0.79, indicating adequate levels of association.

Confirmatory factor analysis and measurement invariance

CFA showed similar and acceptable fit indices for the original B-PSQI ($\chi^2(4) = 52.281$; $p < .01$; CFI = 0.97; TLI = 0.92; RMSEA = 0.107; SRMR = 0.049) and the age-adjusted B-PSQI ($\chi^2(4) = 53.882$; $p < .01$; CFI = 0.97; TLI = 0.92; RMSEA = 0.108; SRMR = 0.05), suggesting that the B-PSQI adequately fits onto a unidimensional factor. Although the two models were rejected statistically based on the Satorra–Bentler scaled χ^2 statistic ($p < .01$), the CFI and TLI values were above the recommended threshold suggesting a good model fit. Likewise, SRMR values were below the recommended threshold of 0.08 (SRMR = 0.05), indicating good data adjustment. By contrast, RMSEA showed inadequate fit in both models, which could be due to data distribution and fit function rather than a problem in model fit (Lai & Green, 2016). In addition, factor loadings of all items were satisfactory and equal in both models, with values of lambda $\lambda > 0.4$. The loading for the sleep hours item was $\lambda = 0.49$, for sleep latency $\lambda = 0.57$, for sleep efficiency $\lambda = 0.46$, for night awakenings $\lambda = 0.70$, and for subjective sleep quality $\lambda = 0.85$.

Measurement invariance analysis indicated that both B-PSQI versions were invariant across sexes. As Table 3 displays, the configural model showed adequate fit indexes values for the original B-PSQI (CFI = 0.97; RMSEA = 0.105; SRMR = 0.051) and the age-adjusted version (CFI = 0.97;

Table 2. Sample's sleep characteristics (mean; *SD*) and sex differences.

	Total 100% ($n = 1{,}065$)	Male 43.2% ($n = 460$)	Female 56.8% ($n = 605$)	Z/χ^2 (p)	r/φ_c
Bedtime	23:31 (1:06)	23:33 (1:08)	23:30 (1:05)	0.49 (.626)	0
Wake-up time	07:01 (0:50)	7:10 (1:04)	6:54 (0:35)	4.33 (.001)**	0.13
Sleep latency (min)	21.0 (25.7)	18.1 (22.5)	23.2 (27.8)	2.20 (.028)*	0.07
Hours of total sleep	6.9 (1.1)	7.1 (1.2)	6.8 (1.1)	4.44 (.001)**	0.14
Sleep efficiency	91.5 (9.8)	92.7 (9)	90.6 (10.3)	3.58 (.001)**	0.11
Frequency of awakenings, % (n)					
< weekly	62 (660)	70 (322)	55.9 (338)	21.55 (.001)**	**0.144**
> weekly	38 (405)	30 (138)	44.1 (267)		
Subjective sleep quality, % (n)					
Good sleep	72.5 (772)	79.8 (367)	66.9 (405)	20.97 (.001)**	**0.142**
Poor sleep	25.5 (293)	8.7 (93)	33.1 (200)		
B-PSQI	4.5 (2.9)	3.9 (2.7)	5.0 (3)	6.88 (.001)**	**0.21**
B-PSQI *age-adjusted*	5.4 (2.8)	4.7 (2.6)	5.9 (2.9)	6.89 (.001)**	**0.21**
ISI	7.7 (5)	6.4 (4.5)	8.6 (5.1)	7.13 (.001)**	**0.22**
PROMIS *t*-scores	50 (10)	47.8 (8.7)	51.8 (10.6)	5.22 (.001)**	0.18
ESS	7 (5.1)	5.5 (4.7)	8.2 (5.1)	9.61 (.001)**	**0.29**
DASS-A	5.9 (4.9)	4.5 (4.3)	6.9 (5.1)	8.21 (.001)**	**0.25**
DASS-D	6.9 (5.5)	5.3 (5)	8.2 (5.6)	9.03 (.001)**	**0.28**

Note. SD = standard deviation; Z = Mann–Whitney U test; χ^2 = Chi-square tests; p = p-value; r = Rosenthal's r effect size; φ_c = Cramer's V effect size; B-PSQI = Brief version of the Pittsburgh Sleep Quality Index; DASS-A = factor for anxiety of the Depression, Anxiety and Stress Scale; DASS-D = DASS factor for depression; ESS = Epworth Sleepiness Scale; ISI: Insomnia Severity Index; PROMIS = raw scores of the Patient-Reported Outcomes Measurement Information System. Bold text indicates moderate to large effect size ($r > 0.2$; $\varphi_c > 0.1$).
* $p < .05$.
** $p < .01$.

RMSEA = 0.107; SRMR = 0.054), which suggested that the unifactorial structure of sleep quality applies to male and female adolescents equally. The comparison between the configural and metric models showed nonsignificant $\Delta\chi^2$ ($p > .05$) for the original B-PSQI ($\chi^2(4) = 2.59$; $p = .629$) and the adjusted version ($\chi^2(4) = 2.22$; $p = .694$) with low values of ΔCFI, ΔRMSEA, and ΔSRMR. These results indicate that items' weights remained similar for both groups in both B-PSQI scoring methods. Lastly, differences between metric and scalar models were not statistically significant neither in the original B-PSQI ($\chi^2(4) = 12.1$; $p = .207$) nor in the age-adjusted version ($\chi^2(4) = 10.8$; $p = .293$), and both models showed adequate ΔCFI, ΔRMSEA, and ΔSRMR values (see Table 3). This indicates that both versions of the B-PSQI support the invariance of item thresholds across sexes, which means that all items measure responses given by male and female adolescents similarly.

Concurrent validity and convergent validity

Spearman correlations showed that both versions of the B-PSQI were positively correlated ($p < .001$) with the ISI (B-PSQI $r_S = 0.667$; B-PSQI adjusted $r_S = 0.667$), the PROMIS (B-PSQI $r_S = 0.701$; B-PSQI adjusted $r_S = 0.708$), the ESS (B-PSQI $r_S = 0.290$; B-PSQI adjusted $r_S = 0.287$), the DASS-A (B-PSQI $r_S = 0.395$; B-PSQI adjusted $r_S = 0.401$), and the DASS-D (B-PSQI $r_S = 0.414$; B-PSQI adjusted $r_S = 0.417$). Moderate to strong correlations were found between the ISI, the PROMIS, and the DASS supporting convergent and concurrent validity. Regarding ESS, a significant but weak correlation was observed indicating discriminant validity. This supports that the B-PSQI accurately measures sleep quality while differentiating it from other specific sleep-related constructs, such as sleepiness. The original B-PSQI and the age-adjusted version also yielded similar AUC values which were above the threshold of moderate discrimination power (AUC = 0.83 for the ISI and AUC = 0.86 for the PROMIS). As shown in Table 4, ROC analysis indicated that scores on the original B-PSQI of ≥5 were optimal for classifying poor sleepers while maximizing rates of sensitivity (74.3–74.5%) and specificity (77–81.7%). For the age-adjusted B-PSQI version, the optimal cutoff point to classify poor sleep was ≥6, with similar rates of sensitivity (73.5–79.2%) and specificity (78.4–79.7%) than the original scoring method. Using these cutoff values, the base rate of poor-quality sleepers was 43.1% ($n = 459$) for the original B-PSQI and 41.9% ($n = 446$) for the age-adjusted B-PSQI. The two versions differed in classifying 1.2% ($n = 13$) of participants and rates were similar to ISI (39.1%) and PROMIS classification (35.5%). These results support criterion validity of the B-PSQI in adolescents and adequate discriminatory capacity for poor sleep.

Discussion

In this study, we examined the psychometric properties of the Brief Pittsburgh Sleep Quality Index (B-PSQI) in a Spanish adolescent population and adapted its scoring method to align with age-specific recommendations for good sleep quality (Hirshkowitz et al., 2015). Most adolescents (72.5%) reported perceiving their sleep quality as good, but they also indicated staying up late and waking up early, resulting in an average sleep duration of only 7 h per night. We found that 79% of adolescents did not get the hours of sleep recommended for this group and that the age-adjusted B-PSQI identified 41.9% (B-PSQI ≥ 6) of poor sleepers compared to 43.1% classified with the adults' scoring method. Both scoring methods yielded similar psychometric properties indicating that the age-adjustment method may be more adequate regarding the hours of sleep recommended in adolescents. Poor sleep among adolescents emphasizes the need to improve sleep measures and sleep health in order to prevent

Table 3. Goodness-of-it indexes for one-factor model and measurement invariance across sex.

Models	SB-χ^2 (*df*)	CFI	RMSEA	SRMR	$\Delta\chi^2$ (*df*)	ΔCFI	ΔRMSEA	ΔSRMR
B-PSQI *original*								
Configural	55.241 (8)**	0.966	0.105	0.051				
Metric (λs)	46.410 (12)**	0.976	0.073	0.054	2.589 (4)	0.010	0.032	0.003
Scalar (λs + τs)	60.934 (21)**	0.972	0.060	0.053	12.102 (9)	0.004	0.013	0.001
B-PSQI *age-adjusted*								
Configural	56.579 (8)**	0.970	0.107	0.052				
Metric (λs)	40.449 (12)**	0.980	0.067	0.054	2.225 (4)	0.010	0.040	0.002
Scalar (λs + τs)	53.019 (21)**	0.978	0.053	0.053	10.752 (9)	0.002	0.014	0.001

Note. B-PSQI age-adjusted = CFA model of the Brief Pittsburgh Sleep Quality Index calculated using the age-adjusted scoring method for hours of sleep; B-PSQI original = CFA model of the Brief Pittsburgh Sleep Quality Index calculated using the original scoring method; CFI = Comparative Fit Index scaled; *df* = degrees of freedom; RMSEA = Root Mean Squared Error of Approximation with Coefficient Intervals; SB-χ^2 = Satorra-Bentler scaled chi-squared; SRMR = Standardized Root Mean Square Residual; TLI = Tucker–Lewis Index scaled.

Table 4. Sensitivity and specificity of the B-PSQI and the age-adjusted version.

	ISI (≥9)			PROMIS (*t*-scores >55)			
Cutoff points	Sen.[a] %	Spe.[b] %	Youden index	Sen.[a] %	Spe.[b] %	Youden index	Base rate, % (*n*)
B-PSQI *original*							
≥1	≤100	≤5.7	0.057	≤100	≤6.1	0.061	96.5 (1,028)
≥2	98.3	21.8	0.201	97.6	21.5	0.191	86.1 (917)
≥3	94.0	42.0	0.360	94.8	41.8	0.366	72.1 (768)
≥4	86.5	61.2	0.477	89.3	61.6	0.509	57.4 (611)
≥5	**74.5**	**77.0**	**0.514**	**79.6**	**78.1**	**0.577**	**43.1 (459)**
≥6	61.7	87.3	0.490	67.1	88.6	0.557	31.8 (339)
≥7	45.5	93.0	0.386	51.6	94.9	0.464	22.0 (234)
≥8	≤34.7	≥96.9	≤0.316	≤38.8	≥97.5	0.363	≤15.2 (164)
B-PSQI *age-adjusted*							
≥1	≤100	≤0.9	0.009	≤100	≤1.0	0.010	99.4 (1,059)
≥2	100	6.8	0.068	100	7.2	0.072	95.9 (1,021)
≥3	98.3	21.6	0.200	97.6	21.7	0.193	85.9 (915)
≥4	93.5	42.8	0.361	94.8	43.0	0.378	71.4 (760)
≥5	85.8	62.3	0.481	89.3	63.3	0.526	56.4 (601)
≥6	**73.5**	**78.4**	**0.519**	**79.2**	**79.7**	**0.589**	**41.9 (446)**
≥7	59.8	88.9	0.486	65.7	90.7	0.564	30.1 (321)
≥8	≤44.1	≥93.8	≤0.379	≤50.5	≥95.8	0.463	≤20.9 (223)

Note. B-PSQI = Brief Pittsburgh Sleep Quality Index.
[a] Sensitivity = true-positive rate.
[b] Specificity = true-negative rate; base rate = percentage of people referring poor sleep quality based on cutoffs.

other related health problems (Blake et al., 2018; Buysse, 2014; Shimura et al., 2018).

The psychometric properties of the B-PSQI in Spanish adolescents were appropriate regardless of the scoring method. This study found satisfactory reliability similar to the adult version (Sancho-Domingo et al., 2021), and higher than the reliability of the original PSQI reported in a different sample of adolescents (de la Vega et al., 2015; Passos et al., 2017; Raniti et al., 2018). The B-PSQI also showed adequate concurrent and convergent validity based on B-PSQI correlations with other sleep-related measures. Consistent with previous research, higher B-PSQI scores were associated with greater symptoms of insomnia, and mood state problems, as well as with sleepiness with a lower association (Chiu et al., 2016; Gerber et al., 2016; Raniti et al., 2018; Sancho-Domingo et al., 2021; Shimura et al., 2018). Moreover, the B-PSQI adequacy for one-factor structure confirmed the unidimensionality of the sleep quality construct based on its five sleep components (de la Vega et al., 2015; Manzar et al., 2018; Mollayeva et al., 2016; Sancho-Domingo et al., 2021). This suggests that the age-adjusted method was adequate while maintaining the psychometric quality of the B-PSQI measure.

Furthermore, this study found that sleep quality in female adolescents was significantly worse than in male and highlighted the importance of considering sex differences when evaluating sleep quality. The B-PSQI proved complete measurement invariance across sex unlike the original PSQI and the B-PSQI validation for adults that achieved partial invariance (Li et al., 2019; Sancho-Domingo et al., 2021). This indicates B-PSQI structure, the item loadings, and item thresholds are the same for both male and female adolescents (Bowen & Masa, 2015). Therefore, the B-PSQI provides valid mean score differences between both groups that are due to the construct of sleep quality rather than to possible measurement bias (Byrne, 2008). In this sense, female adolescents reported more night awakenings and poorer subjective sleep quality than young men, and they had greater daytime sleepiness and insomnia symptoms. These findings are consistent with previous research indicating that female adolescents are more likely to report a greater number of night disturbances, wakefulness during sleep, and longer sleep latency than male adolescents (Baker et al., 2023; Madrid-Valero et al., 2017; Mallampalli & Carter, 2014). Furthermore, female adolescents in our sample also demonstrated higher scores in anxiety and depression, two factors that are related to an increased likelihood of experiencing sleep disturbances (Blake et al., 2018).

Several limitations should be taken into consideration for the interpretation of the results. First, sleep was assessed with self-reported measures, and since differences are commonly noted between self-report and objective sleep measures, further validation studies should consider the use of objective tools to confirm the psychometric validity of the B-PSQI. Second, cross-sectional data limited the analysis of the B-PSQI invariance over time which may be relevant considering sleep changes during adolescence (Troxel et al., 2021). In this regard, longitudinal data could contribute to examining if the B-PSQI can accurately sleep considering changes during adolescence. Likewise, in this study, other relevant sociodemographic variables were not assessed, such as ethnicity or race. Therefore, future studies are encouraged to analyze the psychometric properties of the B-PSQI measure across other racial/ethnic groups, or other countries/languages. This could ensure a broader applicability and generalizability of the study results. Despite these limitations, our results highlight the adequacy of using the B-PSQI in adolescents. This tool could be used to identify individuals for tailored interventions to improve sleep quality, with the ultimate goal of reducing the negative impact of sleep disturbances on health (Blake et al., 2018; Buysse, 2014).

In conclusion, The B-PSQI is a valid and reliable measure of subjective sleep quality in Spanish adolescents, and its scoring method can be adjusted to align with age-specific recommendations for good quality of sleep, such as the recommended sleep duration (Hirshkowitz et al., 2015; Ohayon et al., 2017). Additionally, it is important to consider sex differences when evaluating adolescent sleep quality, given that female adolescents generally report worse sleep quality and more problems associated with sleep disturbances (Baker et al., 2023; Mallampalli & Carter, 2014). The B-PSQI may be useful for reducing the length of assessments in clinical screening and research applications.

Author contributions

Clara Sancho-Domingo (Conceptualization [equal], Data curation [equal], Formal analysis [equal], Investigation [equal], Methodology [equal], Software [equal], Writing—original draft [equal]), Jose L. Carballo (Conceptualization [equal], Methodology [equal], Project administration [equal], Resources [equal], Supervision [equal], Writing—original draft [equal]), Ainhoa Coloma-Carmona (Investigation [equal], Visualization [equal], Writing—review & editing [equal]), and Daniel J. Buysse (Investigation [equal], Validation [equal], Writing—review & editing [equal])

Data availability

The data underlying this article cannot be shared publicly due to legal and ethical considerations. The consent form explicitly promised participants that the data would not be shared.

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STUDY III.

“Identification of sleep patterns in adolescents and the association with substance use”.

Identification of sleep patterns in adolescents and the association with substance use

Clara Sancho-Domingo and José Luis Carballo

Abstract

Objectives: Good sleep during adolescence is crucial for maintaining physical and psychological health; however, sleep disturbance during this period may contribute to health risks, such as substance use. This study aimed to identify the latent sleep patterns across male and female adolescents, and their association with drug use. **Method**: A cross-sectional study was conducted involving 1391 high school students (aged 15-17; 56.4% females). Participants completed the Brief Pittsburgh Sleep Quality Index alongside other sleep measures, and the Timeline Follow-Back and Drug Use History Questionnaire to measure substance use. A Multiple-Group Latent Class Analysis was used to identify sleep patterns across sexes, and pairwise Logistic Regression models to compare their association with substance use. **Results**: Four sleep patterns were identified with varying degrees of sleep difficulties: "Good Sleep" (43.3%), "Night Awakenings" (31.8%), "Poor Efficiency and Sleep Onset" (9.4%), and "Poor Sleep" (15.5%). Females were more likely to belong to “Poor Sleep” and "Poor Efficiency and Sleep Onset" patterns, and males to “Good Sleep”. Likewise, binge drinking and using alcohol for a longer period were associated with experiencing "Poor Efficiency and Sleep Onset" (OR=1.03 and 2.3, respectively); smoking tobacco within the past month was linked to "Night Awakenings" (OR=2.2); and using cannabis or illegal drugs to the “Poor Sleep” pattern (OR=2.4 and 2.6, respectively). **Conclusions**: Varied sleep difficulties exist among adolescents that significantly correlate with different aspects of drug use. Targeted interventions that address both sleep and drug prevention are recommended.

Keywords

Sleep patterns, adolescents, alcohol, cannabis, tobacco, latent class analysis

Introduction

Sleep quality is essential for maintaining adolescents' health, as sleep regulates physiological, cognitive, and emotional processes throughout this stage of maturation[1]. However, significant developmental changes occur during adolescence that can disturb the quality of sleep and increase the risk of physical and psychological problems[2–4]. These changes encompass an increase in social interactions with less parental control, a delay in the circadian clock leading to a preference for an evening chronotype, and the initiation of using drugs[5–7].

Social timing and social activities during adolescence may determine bedtime and wake-up times which can interfere with the circadian rhythm and lead to misalignment of sleep schedule[8]. In turn, adolescents who experience misaligned sleep, as well as trouble sleeping or later bedtimes are more likely to use tobacco, cannabis, and alcohol in emerging adulthood[9,10]. Both the tendency for evening activities and the onset of substances contribute bidirectionally to the development of night disturbances, social jetlag, and a deficit in sleep duration[5,8,10], with up to 70% of adolescents sleeping less than the recommended 8 hours per night[11,12].

Despite the relevance of sleep quality for adolescents' health, there is still a limited number of studies that explore the different sleep patterns among this population. Recent works have identified 3 to 4 patterns of how youth sleep, with subjective good sleep quality and short sleep as the most prevalent[13–15]. These studies concur with the identification of a specific poor sleep pattern among adolescents and children who experience problems in multiple sleep dimensions including short sleep, an evening chronotype, insomnia, and sleepiness[13–17]. Those with a poor sleep pattern seem to be at higher risk of experiencing both internalizing and externalizing problems, such as anxiety, depression, aggressive behaviors, as well as somatic problems[13,15]. Nevertheless, the identification of sleep patterns has primarily focused on sleep disorders or common sleep dimensions, as sleep duration[13,15,16,18], disregarding other key indicators (e.g., sleep efficiency) relevant for the evaluation of sleep health in non-clinical populations[19,20].

Likewise, although extensive literature supports a bidirectional association between substance use and sleep[5,21,22], the link between sleep patterns and substance use during adolescence remains unexplored. Analyzing various dimensions of sleep may provide a better understanding of which sleep patterns are associated with different substances[10,23]. Regarding this, the psychoactive effects of particular drugs, such as alcohol and cannabis, have sleep-inducing effects reducing sleep latency and prolonging the deep sleep phase[24,25]. However, these substances can produce sleep disturbances, especially with regular or excessive use, leading to tolerance and to difficulties falling asleep and sleep fragmentation, particularly in the case of alcohol use[21,26,27]. Regarding stimulant substances such as tobacco or cocaine, their effect may contribute to sleep fragmentation, impair sleep onset, reduce total weekly sleep hours, and increase daytime dysfunction[21]. Given that polysubstance use is common in adolescence, sleep problems could be exacerbated by the concurrent or simultaneous use of substances during this period[7,21].

Inversely, poor sleep seems to contribute to addictive behaviors through several neurocognitive and psychological pathways, including alteration of the reward system, and impulsivity traits[2,28,29], as well as the reinforcement of using drugs to improve sleep[30,31]. In this regard, adolescents with misaligned or delayed sleep patterns may be more prone to seeking immediate rewards like the short-term consequences of using alcohol and cannabis[28,30,32], which may also be linked to contextual and social factors. For example, the peers' influence on substance use behaviors, or activities with easier drug accessibility are predictive of consumption[5,33]. This includes engaging in evening or nighttime activities that contribute to reducing the likelihood of obtaining sufficient sleep at night while increasing access to substances[5]. Troxel et al.[10] found that having later bedtimes and trouble sleeping during adolescence were prospectively associated with a higher likelihood of alcohol and cannabis use. This association continues during emerging adulthood, wherein young individuals with persistent poor sleep are more likely to use alcohol and cannabis and develop related problems[23]. Besides neurological and contextual factors, some studies indicate that the use of substances in adolescence appears to be associated with self-medication behaviors, where young people may use drugs as sleep aids (e.g., cannabis) to help them with sleep problems[30,31]. However, further research is necessary to analyze how adolescents' sleep is associated with different aspects of substance use, such as the amount, the time using the drug, or the quantity.

Likewise, gender and sex differences can also have implications for the association between sleep and substance use[6]. Young girls generally report poorer sleep quality and longer latency of sleep, and they engage in more maladaptive sleep hygiene behaviors than boys[34]. Likewise, female adolescents are more likely to experience poor sleep, and be diagnosed with insomnia, which seems related to emotional difficulties[6]. In contrast, males maintain a shorter sleep pattern in the trajectory toward adolescence[14]. Although some studies support different sleep patterns across sexes, recent findings point out that the sleep patterns during early adolescence remain similar regardless of sexes[13]. However, more studies are needed to analyze the different sleep patterns based on sex/gender and for more precise findings on adolescent sleep patterns. Similarly, literature has revealed variations in substance use among male and female adolescents, which may differ across countries. Typically, males are more inclined towards illicit drug use at an earlier age, whereas females exhibit a greater tendency for binge drinking and smoking behaviors, mainly in Mediterranean countries[7]. Therefore, it is important to examine whether sleep differences are linked to drug use in male and female adolescents.

Given the lack of studies analyzing sleep patterns among adolescents while considering sex differences and the gap regarding their association with different aspects of substance use, the aim of this study was twofold. First, to identify sleep patterns in adolescents across sexes; and second, to analyze how these sleep patterns may be associated with drug use in adolescents.

Methods

Participants

The participants of this study were high school students from 10th–12th grade of public schools in Alicante province (Spain). Inclusion criteria involved students between 15–17 years of age, with Spanish as their primary language, and with no cognitive impairment that could hinder understanding the study or the self-reported measures. We initially assessed 1569 adolescents of which 8 declined to participate, 3 were discarded because they showed difficulties in understanding, 3 because they were non-native speakers, and 57 because they were 18 to 22 years old. This age range was excluded to specifically focus on adolescents and the goals of this study, preventing the introduction of confounding factors related to the transition into adulthood. Out of the 1498 participants, we excluded 107 due to missing values in the sleep and drug use questionnaires, with no significant differences observed between individuals with missing responses and the respondents on sociodemographic variables.

The final sample comprised 1391 adolescents with an average age of 16.2 years (SD=0.8). The majority were females (56.4%; n=784) and attended schools located in urban areas (78.8%; n=1096).

Procedure

This study corresponds to a cross-sectional descriptive design and is part of the preregistered PREVELANC project (Clinical Trials num.: NCT05281172). Initially, 30 secondary high schools of Alicante were randomly selected, of which 16 agreed to participate. After receiving approval from the public schools, students and their parents/guardians were informed about the study, and the confidentiality and anonymity of the provided data. All students and parents/ guardians interested in participating provided their written informed consent. Once consent was given, a health psychologist attended high schools to assist adolescents in completing the survey. The evaluation took place in school classrooms in groups of 25-30 participants during the school schedule using an online survey. Adolescents completed the survey independently, and voluntarily using their mobile phones, which took approximately 50 minutes to fulfill. For those who did not have a mobile phone or permission to use it, a paper version was provided. Those who chose not to participate did not proceed with completing the survey. Data were collected between November 2021 and May 2023 and no compensation was given for participation. The Clinical Research Ethics Committee of the General University Hospital of Alicante granted approval for this study (CEIm: PI2019/112).

Variables and Measures

Sleep characteristics

The Brief version of the Pittsburgh Sleep Quality Index (B-PSQI)[35] was used to identify sleep patterns. The 6-item B-PSQI measures sleep quality of last month and five sleep dimensions: sleep latency, sleep duration, frequency of night awakenings, sleep efficiency, and subjective sleep quality. Each dimension is scored in a range from 0 to 3 points, and the sum provides a global score from 0 to 15 with higher scores representing poorer quality of sleep. The B-PSQI has demonstrated adequate reliability (ω=0.91) and validity in the general population. In this study, the B-PSQI internal consistency was ω=0.71, and responses for the item of hours of sleep were coded according to the recommendations of the National Sleep Foundation[11].

Sleep functioning

The Epworth Sleepiness Scale (ESS)[36], the Insomnia Severity Index (ISI)[37], and the Pre-Sleep Arousal Scale (PSAS)[38] were also used to assess sleep characteristics. The ESS measures daytime sleepiness in eight situations (e.g., reading) using a 4-point Likert scale, from 0 (*never)* to 3 (*high probability*). The total score ranges from 0 to 24, with higher scores indicating greater sleepiness. The ESS adolescent adaptation was used in this study which has proven adequate reliability and validity (α>0.70) in teenagers [39]. The ESS internal consistency in this study was ω=0.78.

The ISI measures the severity of insomnia using seven items rated on a 5-point Likert scale. The global score ranges from 0 to 28, with higher scores representing greater insomnia, and scores >8 representing a clinical indication of insomnia in teens [40]. The ISI has demonstrated good internal consistency (α>0.75) and structural validity in adolescent samples[40]. In this study, the ISI internal consistency was ω=0.78.

The PSAS uses sixteen items to assess two dimensions of pre-sleep arousal: eight for cognitive and eight for physical arousal. The PSAS items responses are rated on a 5-point Likert-type scale from 1 (*not at all*) to 5 (*extremely*). The PSAS has shown concurrent validity and adequate reliability in both PSAS dimensions (α>0.80)[41]. In this study, the PSAS internal consistency was ω=0.91.

Substance use

Alcohol, tobacco, cannabis, and other drugs were evaluated using the TimeLine Follow-Back (TLFB)[42] and the Drug Use History Questionnaire (DUHQ)[43]. The TLFB uses a calendar to retrospectively measure drug use. We assessed Standard Drinking Units (SDUs) and binge drinking in the last month –drinking >3 SDUs in one occasion for females and >4 SDUs for males–, and the number of joints smoked. The DUHQ was used to measure lifetime drug use, frequency, and years using. For this study, time using was measured in months instead of years due to the teenagers' young age. The drugs that were evaluated included alcohol, tobacco, cannabis, and other illicit drugs (cocaine, amphetamine, benzodiazepines, hallucinogens, sedatives, heroin, opioid, and inhalants). The DUHQ has demonstrated its validity in adolescents[44] and has been used in the Spanish population[45].

Statistical analysis

A Multiple-Group Latent Class Analysis (MGLCA) was conducted using the *glca* package for R software[46] to identify adolescents' sleep patterns and test their invariance between sexes. The MGLCA model included the 5 sleep dimensions of the B-PSQI: (1) sleep latency categorized as *<15min, 16-30min, 31-60min,* and *>60min*; (2) sleep hours categorized as *≥9 hours, 9-8 hours, 8-7 hours, and <7 hours;* (3) night disturbances categorized as *Not during the past month, Less than 1 a week, 1-2 a week, ≥3 times a week*; (4) sleep efficiency categorized as *≥85%*, *84-75%*, *74-65%*, and *<64%*; and (5) subjective sleep quality categorized as *Very good, Fairly good, Fairly bad*, and *Very bad*. Based on the five sleep indicators, the sample size of this study remained sufficient (n=1391) to achieve 80% power to detect moderate to large effects of the latent profiles[47].

Latent Class Analysis (LCA) was first conducted separately between females and males to estimate the adequate number of patterns in each group. Two- to six-class models were analyzed by estimating the Likelihood-Ratio test (χ^2) and relying on Akaike information criterion (AIC) and Bayesian information criterion (BIC), with lower values representing better data fit. Entropy was also calculated, with values closer to 1 suggesting higher quality in classifying participants. After confirming an equal number of classes in both sexes, the invariance of model fit was tested by constraining item-response probabilities to be equal across groups, and compared with the variant model where item-response probabilities are not constrained. Then the prevalence of class membership was compared between groups. Differences between the latent profiles on sleep parameters we estimated with the analysis of variance (ANOVA) using the Games-Howell posthoc test.

Pairwise Logistic Regressions (LRs) were performed to analyze the strength of association between the sleep patterns and drug use. Four regression models were conducted considering the distinct effects each drug may have on sleep and the sleep differences identified in prior studies[21]. Model 1: included alcohol use in the last month (*yes/no)*, number of SDUs of past month, binge drinking in the last month (*yes/no)*, and months drinking alcohol. Model 2: included tobacco use in the last month (*yes/no)*, average number of cigarettes smoked per day of use, and months smoking tobacco. Model 3: included cannabis use in the last month (*yes/no)*, number of joints in the past month, and months using. Model 4: included lifetime use of other illicit drugs (*yes/no)*. All LR models were adjusted by sex and polydrug use (≥2 substances). Likewise, interaction effects between sex and substance use were also analyzed to test if sex differences in substance use may be related to the differences observed in sleep patterns. The results were interpreted with a 95% confidence level.

Results

Sample characteristics in sleep and substance use

Adolescents reported an average of 21.7 (SD=27.5) minutes taken to fall asleep and a sleep duration of approximately 6:57 hours (SD=1:06), with 74.3% (n=1033) sleeping less than 8 hours per night. Notably, most participants reported good sleep quality (70.5%; n=980) and experienced night awakenings less than once a week (60.6%; n=843). As observed in Table 1, the B-PSQI, ESS, ISI, and PSAS scores showed moderate sleep quality. This includes 56.6% (n=787) of good sleepers and 43.4% (n=603) of poor sleepers according to the B-PSQI.

Half of the sample used alcohol in the past month (51.1%, n=711), 19.2% (n=267) used tobacco, and 8.5% (n=118) used cannabis. For other drugs, 3.2% (n=45) reported lifetime use, including non-medical use of benzodiazepines (35.6%; n=16), followed by stimulants (e.g., cocaine) (33.3%; n=15), hallucinogens (22.2%; n=10), and inhalants (17.8%; n=8). Furthermore, the average duration of regular alcohol use was longer (5.3 months; SD=8.6) compared to tobacco (3.8 months; SD=9) or cannabis (2.4 months; SD=5.6), with over a third of participants (35.4%, n=492) reporting binge drinking.

Multi-Group Latent Class Analysis (MGLCA) across sexes

Model selection

Two- to six-class models were estimated. According to AIC and BIC values, the model with four latent classes provided the most optimal fit for the whole sample (χ^2(960)=-7081.6; AIC=14289.2; BIC=14619.2) with 72% entropy classifying participants. Consistently, the 4-class model showed better-fit statistics for females (χ^2(720)=-4105.6; AIC=8337.2; BIC=8631.1; Entropy=0.74). Regarding men, both 3- and 4-class models showed adequate fit with no major differences between them, therefore we continued the MGLCA using the 4-class model (χ^2(543)=-2907.9; AIC=5941.7; BIC=6219.5; Entropy=0.67) to analyze invariance between the two groups. MGLCA results are displayed in the Supplementary material.

Sleep patterns characteristics

As observed in Figure 1, the 4-class model yielded four sleep patterns in adolescents based on the response probabilities to the five sleep parameters. Pattern A was labeled

“Good Sleep” and represented 43.4% of the sample (n=603). This pattern was characterized by a low likelihood of experiencing sleep problems, with less than 20% probability of experiencing difficulties falling asleep, insufficient sleep hours, night awakenings, low efficiency, and subjective poor sleep. Pattern B (31.8%; n=442) was named "Night Awakenings" and was characterized by a high likelihood of of experiencing night awakenings during the week (56% probability), a high probability of reporting good sleep (60%), and a low probability of experiencing other sleep problems (see Figure 1). Pattern C was named “Poor Efficiency and Sleep Onset” and represented the smallest subgroup, comprising 9.4% (n=131) of adolescents who most likely reported <85% of sleep efficiency (100% probability). This group was more likely to experience difficulties falling asleep after 30 minutes (34% probability) and insufficient hours of sleep (63% probability). Lastly, Pattern D (15.5%; n=215) was named “Poor Sleep” and was characterized by a pronounced likelihood of experiencing sleep problems across all sleep indicators. This included taking >30 minutes to fall asleep (43% probability), sleeping <7 hours (90% probability), reporting night awakenings >3 times per week (70% probability), and reporting poor sleep (93% probability).

Consistent with MGLCA, the four sleep patterns differed in their B-PSQI scores and components, with "Poor Sleep" pattern showing the highest B-PSQI scores (10.1±1.9) followed by "Poor Efficiency and Sleep Onset" pattern (7.2±1.6), "NightAwakenings" pattern (6±1.2), and "Good Sleep" pattern (2.9±1.2). As shown in Table 2, the "Poor Sleep" pattern showed significantly higher scores in the ESS (9.0±4.9), ISI (14.1±4.6), and PSAS (44.8 ±13.8) compared to the other classes, suggesting clinical criteria for insomnia disorder in this subgroup.

The patterns "Night Awakenings" and "Poor Efficiency and Sleep Onset" did not differ in daytime sleepiness or arousal before sleep (see Table 2), and the differences in the ISI were statistically significant (p=0.032) but with a small effect size (η^2=0.01). The "Poor Efficiency and Sleep Onset" pattern showed a longer time to fall asleep (33.5±31.4 minutes), a 35-minute difference of less sleep, and a lower percentage of sleep efficiency compared to the "Night Awakenings" pattern. By contrast, the "Night Awakenings" pattern was particularly characterized by the disruption of sleep during the night and showed worse sleep only when compared with good sleepers.

Model invariance across male and female adolescents

Item-response probabilities of the 4-class model were constrained across sexes. The constrained model showed a similar fit to the variant model (p=0.14), indicating consistent responses to the sleep parameters within each pattern regardless of sex. However, the invariant model differed statistically from the 4-class model (p<0.001) suggesting that the pattern membership prevalence differed between males and females. Females were more likely to belong to the sleep pattern "Poor Efficiency and Sleep Onset " than males (11.9% females vs. 6.3% males), and to the pattern "Poor sleep" (19.4% females vs. 10.4% males). Consistently, males were more likely to belong to the "Good Sleep" pattern (35% females vs. 54% males) which indicates a substantial sex discrepancy regarding the quality of sleep. The proportion of females and males was approximately equal (p>0.05) in the pattern "NightAwakenings" (33.7% females vs. 29.3% males).

Association between sleep patterns and substance use

Figure 2 displays the results of the LRs comparing the odds of using drugs across the sleep patterns, with the “Good Sleep” as the comparison group. While controlling the effect of sex and polysubstance use, statistically significant differences were observed between the patterns “Good Sleep" and "Night Awakenings" in tobacco use. Individuals who most likely experience night awakenings exhibited 2.2 (95%CI=1.1–4.5) times higher odds of tobacco use in the past month compared to good sleepers. This association was sustained regardless of the time smoking (p=0.125), the average of cigarettes (p=0.461), or the sex. No significant interaction effects were observed between tobacco use variables and sex (p>0.05), nonetheless, female adolescents were more likely to belong to the "Night Awakenings" pattern than to the "Good Sleep" pattern (OR=1.7; 95% CI=1.4–2.2).

Likewise, the pattern “Poor Efficiency and Sleep Onset” showed significant differences compared with “Good Sleep” in alcohol use. Adolescents who had trouble falling asleep demonstrated more than twice the odds of engaging in binge drinking in the past month (OR=2.4; 95% CI=1.1–4.9) compared to good sleepers. Similarly, using alcohol for a longer period was associated with higher odds of experiencing difficulties falling asleep and lower sleep efficiency (OR=1.03; 95% CI=1–1.1). Regarding sex, female adolescents had 2.9 times higher odds of belonging to the "Poor Efficiency and Sleep Onset " pattern (95% CI=1.9–4.5), with no significant interaction effects with any of the alcohol use variables (p>0.05).

The pattern of “Poor Sleep” showed significant associations with cannabis and other illicit drugs compared to the pattern of “Good Sleep”. Poor sleepers were found to have twice the likelihood of using cannabis in the past month (OR=2.4; 95%CI=1.1–5.1) regardless of the number of joints (p=0.971) and the time of use (p=0.673), and a significantly higher likelihood of lifetime use of other drugs (OR=2.6; 95% CI: 1.2–5.9). Female adolescents were three times more likely to belong to the “Poor Sleep” pattern (OR=3.0; 95%CI=2.1–4.2), and no interaction effects were observed between sex and the use of cannabis or other illicit drugs (p>0.05).

Discussion

This study aimed to identify sleep patterns in adolescents and their association with substance use. A high prevalence of sleep problems was observed similar to other adolescent European populations, with 43% experiencing poor sleep in the past month and about 74% sleeping less than recommended by the National Sleep Foundation[16,18]. Although most adolescents perceived their quality of sleep as good, their scores in the sleep self-reported measures were higher than those found in other healthy populations[16], suggesting poor sleep comparable even to clinical samples[48].

Results also provided an overview of four specific sleep patterns among adolescents whose characteristics were similar among males and females. Most adolescents experience some sort of sleep problem, with only a minority being good sleepers. This contrasts previous studies in which there is a larger percentage of good sleepers[15], and aligns with the consistent decrease in sleep quality over time during the transition to adulthood[23]. We identified a pattern encompassing one-third of adolescents who experience more frequent “Night Awakenings”, another pattern associated with “Poor Efficiency and Sleep Onset”, and a third pattern with almost a quarter of participants, who reported overall “Poor sleep”. Compared to other works, we did not identify a pattern characterized solely by insufficient hours of sleep[14,15,18], which was an aspect generalized in all the patterns found in this study. Likewise, we did observe a similar pattern of sleep related to experiencing difficulties with sleep onset among adolescents[13,14,23], and a range of varying severity levels of sleep quality which was similar to patterns in emerging adulthood[23]. Interestingly, worse sleep patterns were also related to greater use of alcohol and cannabis[23]. This advises that interventions to prevent poor sleep and substance use should be implemented at earlier ages to mitigate long-term effects on sleep quality and overall well-being. Furthermore, the results indicate that different treatment approaches should be taken regarding adolescents’ sleep patterns. For example, while adolescents with difficulties in maintaining sleep may benefit from sleep restriction and stimulus control, those with difficulties in falling asleep may benefit from cognitive distraction.

On the other hand, the prevalence of sleep patterns differed across sexes, with the patterns “Poor sleep” and “Poor Efficiency and Sleep Onset” comprising almost double the percentage of females. This is consistent with sex differences found in the literature in which female adolescents had a greater probability of reporting disturbances in all sleep dimensions, particularly difficulties falling asleep, and worse sleep efficiency[6]. According to previous literature, this could be due not only to differences attributed to sex, but also to a higher tendency for episodic drinking among Spanish female adolescents which can disturb initiation and duration of sleep[7,21]. However, in this study, no interaction effects were observed between sex and substance use in the association with sleep patterns, indicating that both variables can independently relate to sleep disturbances.

Regarding substance use, the percentage found for alcohol use was similar to those reported in European surveys, but the prevalence of tobacco and cannabis use was slightly lower[7,49]. Half of the sample reported drinking alcohol in the last month of which 70% engaged in binge drinking. These rates are concerning given the negative consequences that binge drinking can have on health, particularly in the development of sleep disorders[21,26]. In this regard, the use of drugs was associated with poor sleep, however, the association with sleep patterns varied according to the type of substance, the quantity, and the time of regular use.

Having at least one episode of binge drinking doubled the association with the "Poor Efficiency and Sleep Onset" pattern, which is consistent with prospective associations found for short sleep[9,21]. According to this, both binge drinking and regular alcohol use over a longer period seem to be related to more difficulties falling asleep and spending more time awake while lying in bed. This may suggest that higher amounts of alcohol and increased tolerance can decrease the quality of sleep over time. The findings of this study support the idea that the initial perception of improved sleep could contribute to disturbed sleep[31]. Also, this suggests that an extended duration of drinking may directly impact the sleep schedule, given that drinking behaviors predominantly occur at night, emphasizing the influence of contextual factors[5]. However, the strength of the time-of-use association was small, possibly because adolescents have a relatively short history of alcohol consumption compared to adults. In this regard, it is important to address binge drinking among adolescents, as well as potential self-medication behaviors to reduce sleep onset to minimize both sleep and substance use problems, since both may contribute to each other[5].

Additionally, adolescents who smoked tobacco in the last month seemed to have a higher likelihood of experiencing more "Night Awakenings", a similar finding that has been found in previous studies, particularly when smoking occurs during night-time[21,50]. This association was significant regardless of the time smoking or the number of cigarettes, suggesting that adolescents may be more sensitive to experiencing sleep disturbances with sporadic use[10]. These findings underline the relevance of implementing preventive strategies for nicotine use at earlier stages as they can help prevent not only nicotine-related problems but also the occurrence and exacerbation of sleep fragmentation.

Besides alcohol and tobacco, using cannabis was linked to the "Poor Sleep" pattern. Those who used cannabis in the past month were twice as likely to experience more sleep disturbances[9,10,21], and therefore higher levels of insomnia, sleepiness, and arousal before sleep. Again, the results of this study indicate that the use of cannabis regardless of the amount or the time using appears to be associated with worse quality of sleep in adolescents. This is noteworthy given the myths about the sleep benefits of cannabis and self-medication behaviors that can lead to low-risk perception and therefore to a higher use among adolescents[51]. In this regard, the results support informative measures and interventions that are efficient in mitigating those myths and preventing the pejorative negative effects of cannabis on the overall sleep quality of adolescents. Also, the use of other illicit drugs was associated with experiencing sleep problems. Adolescents who used illicit drugs were 2.6 times more likely to experience worse sleep, even after controlling for polysubstance use, supporting the idea that substance use is linked to different aspects of sleep[10]. This indicates that drugs can have a significant impact on all sleep dimensions and suggests other latent factors contributing to this association. For example, psychological well-being, or even a profile of adolescents with a tendency toward immediate-reward behaviors, as previously observed[2,13]. Sleep interventions should consider addressing various aspects of sleep, and surpassing the aim of increasing sleep duration, given that all dimensions were related to substance use.

The results of this study should be interpreted considering several limitations. Firstly, self-report measures were used, which can bias the accuracy of sleep and substance use assessment. Nevertheless, the instruments used have shown adequate psychometric validity and findings concur with previous studies that use objective data. Furthermore, this is a cross-sectional study, so we cannot determine the direction of the association between variables. Future longitudinal studies would be necessary to understand how substance use may affect the sleep quality of adolescents and vice versa, and to understand the temporal dynamics between these two factors. Both, longitudinal data, and objective measures could help strengthen the validity and reliability of findings. In this regard, gender as a grouping variable should also be considered in future studies, so that the results can be compared with those obtained using sex. Despite this, a key strength of our study was the representative sample of Spanish high school adolescents, achieved through random sampling, a robust sample size, and effective management of non-response bias. Finally, the substance use patterns were unexplored, and although results allow a better understanding of the effects of different substances, future studies should analyze the relationship between different patterns of drug use and sleep problems, as well as explore the time of the day the drug is used.

Taking this into consideration, we conclude that identifying sleep patterns permits to gain a deeper understanding of how adolescents sleep and the implications of tailoring health programs to reduce risks associated with poor sleep. Our research fills a literature gap by exploring the connections between sleep patterns and the use of different substances, including their frequency, occurrence, and quantity of consumption. Understanding how diverse substances affect sleep quality differently enables the design of personalized interventions to mitigate the negative impacts of substance use on adolescent sleep. Regarding this, it would be advantageous to implement these interventions in early adolescence, before substance use initiation and the establishment of regular use, to minimize potential sleep problems during adolescence. Therefore, future experimental designs should explore how drug prevention efforts could alleviate the impact of poor sleep on adolescents. Additionally, findings suggest that integrating sleep improvement components into drug prevention programs could further enhance their efficacy by addressing both substance use and sleep health simultaneously. This can involve transdiagnostic sleep interventions that have already demonstrated effectiveness in improving sleep while addressing other risk behaviors[52]. A comprehensive approach that includes sleep education and substance use prevention may foster better long-term health outcomes for adolescents.

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Table 1. Sample characteristics (N=1391)

	mean (SD)/ %(n)
Sleep hours	6:57 (1:06)
Sleep latency *(min)*	21.7 (27.5)
Sleep efficiency	90.9 (11.4)
Night awakenings	
<weekly %(n)	60.6 (843)
>weekly %(n)	39.4 (548)
Subjective sleep quality	
Good %(n)	70.5 (980)
Poor %(n)	29.5 (411)
B-PSQI	5.4 (2.9)
ISI	7.9 (5.1)
PSAS	32.2 (12.5)
ESS	7.2 (4.8)
Alcohol use	
Last month use %(n)	51.1 (711)
SDUs of last month	15.7 (19.8)
Binge drinking %(n)	35.4 (492)
Months of regular use	5.3 (8.6)
Tobacco use	
Last month use %(n)	19.2 (267)
Cigarettes	2 (2.6)
Months of regular use	3.8 (9)
Cannabis use	
Last month use %(n)	8.5 (118)
Joints	3 (9.5)
Months of regular use	2.4 (5.6)
Other illicit drugs	
Lifetime use %(n)	3.2 (45)
Last year use %(n)	2.2 (31)

SD: Standard deviation; B-PSQI: Brief Pittsburgh Sleep Quality Index; ISI: Insomnia Severity Index; PSAS: Pre-Arousal Sleep Scale; ESS: Epworth Sleepiness Scale; SDU: Standard Drinking Units. Other illicit drugs include cocaine, amphetamine, stimulants, benzodiazepines, hallucinogens, sedatives, heroin, opioid, and inhalants.

Table 2. Mean differences across the four latent classes (N=1391).

	"Good Sleep" (A)	"Night Awakenings" (B)	"Poor Efficiency and Sleep-Onset" (C)	"Poor Sleep" (D)	F (*p*)	Games-Howell test	η^2
	43.3% (603)	*31.8% (442)*	*9.4% (131)*	*15.5% (215)*			
B-PSQI	2.9 (1.2)	6 (1.2)	7.2 (1.6)	10.1 (1.9)	1626.4 (.001)	A<B<C<D	**.78**
Latency	11 (14.2)	21.6 (20.3)	33.5 (31.4)	44.5 (44.2)	108.1 (.001)	A<B<C<D	**.19**
Hours	7:31 (0:52)	6:57 (0:51)	6:23 (0:48)	5:41 (1:08)	234.9 (.001)	A>B>C>D	**.34**
Awakenings	0.6 (0.6)	1.7 (0.8)	1.1 (0.7)	2.6 (0.7)	515.9 (.001)	AC<B<D	**.53**
Efficiency	94.8 (7.9)	94.7 (5.7)	78.8 (11.7)	81.5 (14.9)	252.2 (.001)	AB>D>C	**.35**
Sleep quality	0.4 (0.5)	1.5 (0.6)	1.2 (0.6)	2.3 (0.6)	754.1 (.001)	A<C<B<D	**.62**
ESS	5.9 (4.5)	8.1 (4.9)	7.5 (4.3)	9 (4.9)	31.6 (.001)	A<BC<D	**.06**
ISI	4.6 (3.4)	9.2 (4)	8.2 (4.1)	14.1 (4.6)	351.6 (.001)	A<C<B<D	**.43**
PSAS	26.1 (8.4)	34.2 (11.5)	33.2 (10.9)	44.8 (13.8)	170.2 (.001)	A<BC<D	**.27**

F: ANOVA F statistic; *p*: p-value; Games-Howell test: intergroup significant differences ($p<0.05$); η^2: eta-squared effect size. Bold typing indicates moderate to large effect sizes ($\eta^2>0.06$).

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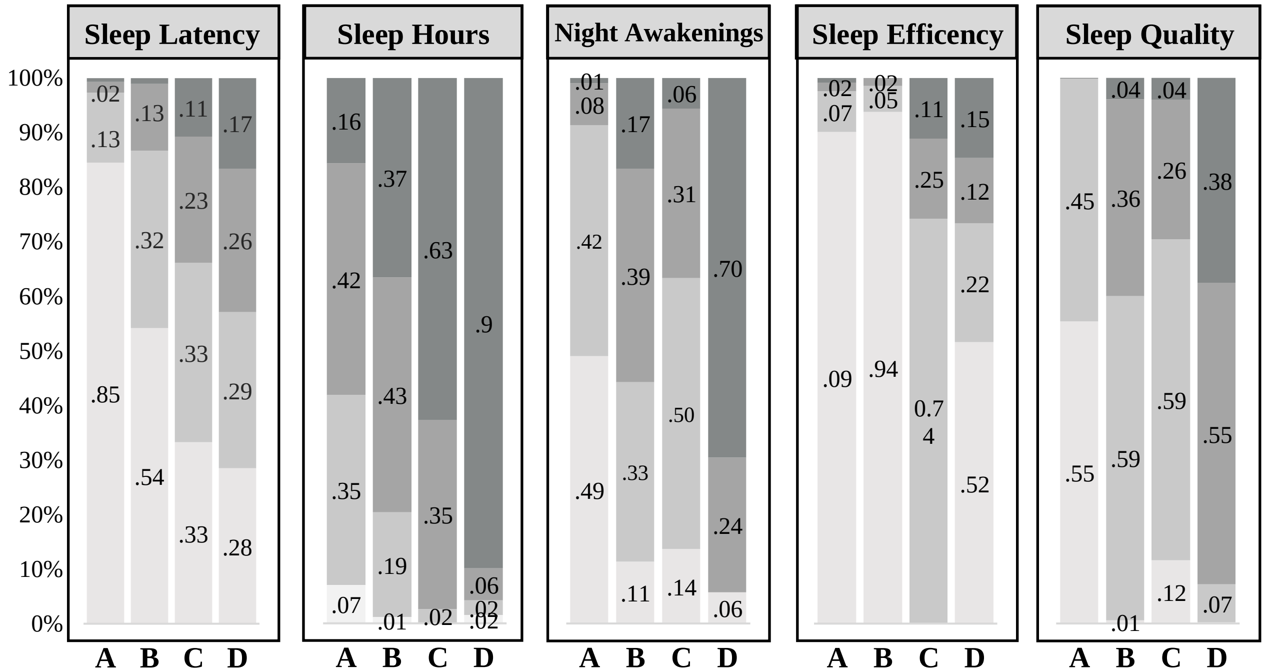
Figure 1. Response probabilities to the five sleep indicators in the 4-class model.



Note. A: "Good Sleep" pattern (n=603); B: "Night Awakenings" pattern (n=442); C: "Poor Efficiency and Sleep-Onset" pattern (n=131); D: "Poor Sleep" pattern (n=215).

Responses to sleep parameters are categorized into four alternatives represented from light to dark grey:

Sleep latency: ***<15min / 16-30min / 31-60min / >60min***

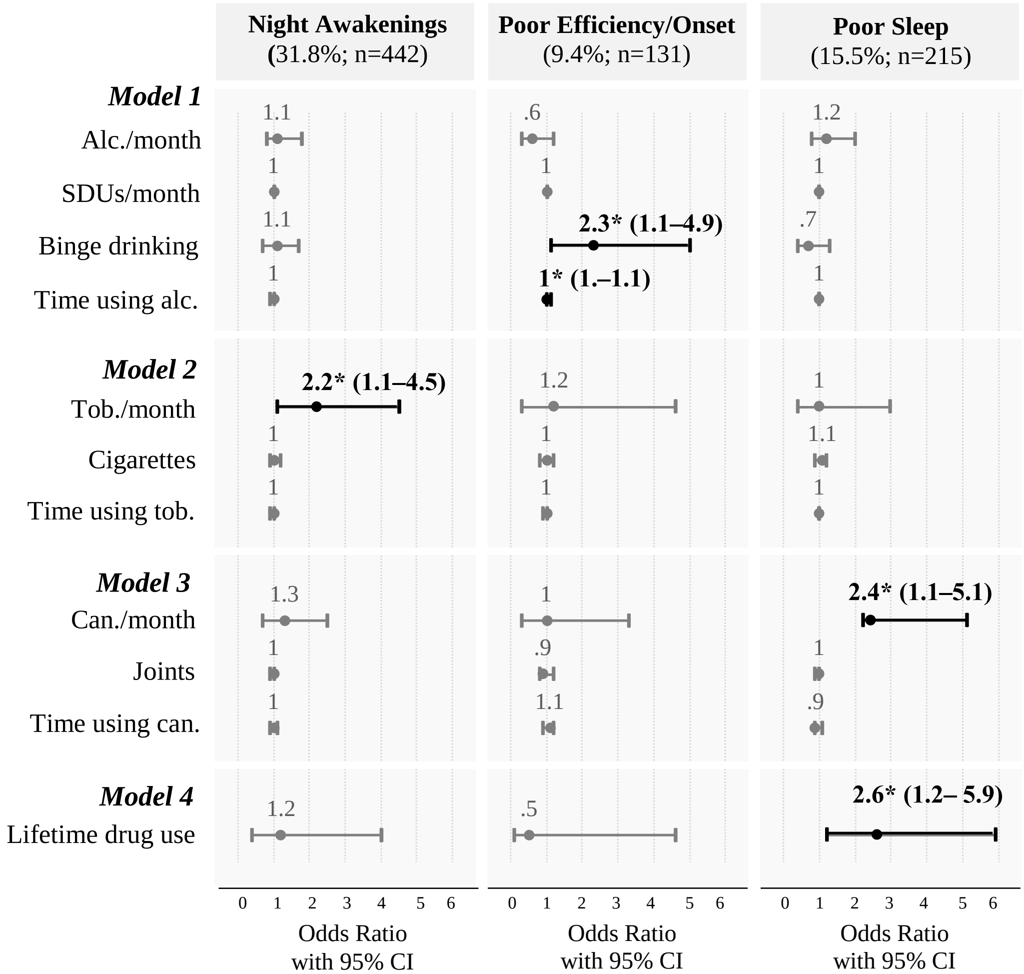
Sleep hours: ***≥9 hours / 9-8 hours / 8-7 hours / <7 hours***

Night awakenings: ***Not in the past month / < 1 a week / 1-2 a week / ≥3 times a week***

Sleep efficiency: **≥85% / 84-75% / 74-65% / <64%**

Subjective sleep quality: ***Very good / Fairly good / Fairly bad / Very bad***

Figure 2. Logistic regressions for substance use and poor sleep patterns



Note. "Good Sleep" group is used as the reference group (43.4%; n=603). Model 1 includes alcohol variables, Model 2 includes tobacco variables, Model 3 includes cannabis variables, and Model 4 includes lifetime use of other illicit drugs. All models were adjusted by sex and use of other substances. Alc: Alcohol use; SDUs: Standard Drinking Units; Tob: Tobacco use; Can: Cannabis use. 95% CI: 95% confidence interval; *p<.05; **p<.01

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STUDY IV.

“Examining the impact of sleep changes on adolescents’ alcohol use: A two-wave prospective study”.

Examining the impact of sleep changes on adolescents' alcohol use: A two-wave prospective study

Clara Sancho-Domingo & José Luis Carballo

Abstract

Introduction: A bidirectional association exists between sleep quality and alcohol use in adolescence. However, the impact of sleep improvement on alcohol use remains unexplored. Therefore, this study aims to analyze the prospective association between sleep quality and alcohol use, and the impact of changes in sleep over time on drinking behaviors among adolescents. **Methods**: A two-wave longitudinal study was conducted among 197 adolescents (aged 15–18 years; 58% female). Sleep quality was assessed using the Brief Pittsburgh Sleep Quality Index (B-PSQI), and alcohol use was self-reported with the TimeLine FollowBack at baseline and after 6 months. Generalized Linear Mixed Models were used. **Results**: Good sleep quality was associated with a reduced likelihood of alcohol use over time among drinking adolescents in terms of standard drinking units (SDUs; OR=0.68; 95%CI=0.55–0.85) and binge drinking (BD; OR=0.29; 95%CI=0.10–0.87). Likewise, adolescents who improved their sleep quality were twice as likely to reduce BD episodes (OR=2.25; 95%CI=1.08–4.67), with a dose-response relationship also observed for sleep latency (OR=1.08; 95%CI=1.01–1.15). Decreasing the frequency of night awakenings was associated with a higher likelihood of reducing AUDIT scores (OR=3.03; 95%CI=1.51–6.06). Inverse analyses showed no significant effect of drinking on sleep. In non-drinking adolescents, improving sleep quality had no significant impact on abstaining from drinking. **Conclusions**: These findings underscore sleep quality improvement as a potential protective factor against binge drinking and alcohol-related problems. Addressing sleep issues could enhance prevention efforts targeting adolescent alcohol use.

Keywords: sleep quality, alcohol use, binge drinking, adolescents, dose-response association

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Introduction

During adolescence, developmental changes can lead to sleep disturbances, a preference for delayed sleep patterns, and the initiation of substance use, particularly alcohol intake (ESPAD, 2020; Norell-Clarke & Hagquist, 2017). These changes can occur due to biological, contextual, and psychosocial factors such as delayed melatonin production or a preference for late activities involving easier access to substance use (Becker et al., 2015; Finan & Lipperman-Kreda, 2020). The prevalence of past-month alcohol use in adolescents is reported at 47%, with approximately one-third engaging in binge drinking (ESPAD, 2020). Regarding sleep problems, approximately 16.5% of adolescents report difficulty initiating sleep and 23.2% difficulties maintaining sleep, with most (>70%) reporting insufficient sleep (Hirshkowitz et al., 2015; Kocevska et al., 2021). These rates are concerning as both poor sleep and alcohol use are significant contributors to the development of health issues in adolescents (Bacaro et al., 2024), and maintain a bidirectional relationship throughout adolescence (Haynie et al., 2018; Kwon et al., 2019).

Alcohol use contributes to altering various sleep dimensions, including the quantity and quality of deep sleep and REM sleep, sleep schedule, and sleep onset latency (Hasler et al., 2024; Kwon et al., 2019; Ogeil et al., 2019). While alcohol tends to have an initial sleep-inducing effect, thereby reducing the time to fall asleep, its effect diminishes over time, leading to fragmented and disrupted sleep late at night (Colrain et al., 2014; Kwon et al., 2019). Adolescents who drink regularly experience a decreased REM sleep duration, increased nocturnal awakenings, prolonged sleep latency, and reduced total sleep (Colrain et al., 2014; Kiss et al., 2023). This is particularly prominent in adolescents who engage in binge drinking or exhibit alcohol-related problems who tend to experience a greater decline in hours of sleep over time. They also encounter difficulties with initiating and maintaining sleep, making them more likely to develop sleep disorders (Haynie et al., 2018; Lee et al., 2019; Ogeil et al., 2019; Patte et al., 2018).

Conversely, previous research indicates that poor sleep can predict alcohol use among adolescents (Kwon et al., 2019; Miller, Janssen, et al., 2017; Pielech et al., 2023). According to Troxel et al. (Troxel et al., 2022) poor sleepers show a higher frequency of alcohol use over time compared to good sleepers. Worsening sleep health, characterized by delayed bed and wake-up times, greater schedule misalignment, and increasing difficulty sleeping, has been linked to a higher likelihood of alcohol use in the transition to adulthood (Troxel et al., 2021). Similarly, Pielech et al. (Pielech et al., 2023) found that poor sleep is associated with higher levels of alcohol craving in female adolescents with regular use of alcohol. This association seems to be sustained by a preference for immediate rewards among poor sleepers, such as the short-term effects of alcohol use (Hasler et al., 2017, 2022; Hasler & Pedersen, 2020; Miller, DiBello, et al., 2017), but also as a self-medication behavior for sleep problems or internalizing symptoms such as anxiety or depression (Edwards et al., 2015; Graupensperger et al., 2023; Nguyen-Louie et al., 2018).

Most of the mentioned studies have focused on analyzing how poor quality increases the likelihood of use, while less is known about how good sleep or improvement of sleep can contribute to alcohol prevention (Bacaro et al., 2024). Although previous studies suggest that good sleep may have an effect on reducing drug use and related internalizing and externalizing symptoms (Bacaro et al., 2024), the available studies are insufficient and need updating (Bootzin & Stevens, 2005; Britton et al., 2010). Adolescents with a prior history of substance use who received treatment for sleep problems showed a tendency to decrease their substance use after 12 months, especially among females (Bootzin & Stevens, 2005; Britton et al., 2010). Specifically, an increased sleep duration has been associated with fewer substance use-related problems and self-efficacy to sustain abstinence (Britton et al., 2010). Likewise, a recent study where intensive longitudinal assessment was implemented, showed that the daily interplay between better overall sleep quality during monitoring was associated with a decreased likelihood of alcohol use in adolescents with regular alcohol use (Pielech et al., 2023). However, the potential impact of how the improvement of different aspects of sleep (e.g., sleep latency) can contribute to reducing and preventing alcohol use remains unexplored.

While there are potential beneficial effects of good sleep on reducing substance use and related problems (Bootzin et al., 2013; Scott et al., 2021), there is still a need to understand and explore the relationship between changes in sleep over time and the reduction of alcohol use among adolescents. For this reason, the aims of this study were: first, to analyze the prospective association between the quality of sleep and alcohol use in adolescents; and second, to explore the effect of sleep changes on reducing and preventing alcohol use over time. We hypothesized 1) that good sleep quality would be associated with lower levels of alcohol use over time, and 2) that improvement of sleep quality would be prospectively associated with a higher likelihood of reducing alcohol intake or abstaining from drinking.

Method

Participants

The initial sample consisted of 322 high school students from public schools in southeast of Alicante region. The inclusion criteria of this study comprised students between 15 and 18 years of age who responded correctly to the Oviedo Infrequency Scale (≤3 mistakes) –a tool to detect participants who have responded randomly or dishonestly to self-reported measures (Fonseca-Pedrero et al., 2008). The eligible participants were 257 adolescents with an average age of 16.2 years (SD=0.7). They were assessed at two time points with a 6-month interval (T1 and T2), and the retention rate was 76.7% (N=197). The average age was 16.1 years old (SD=0.7). At T1, the percentage of female respondents was 53.3% (n=137), and at T2 was 57.9% (n=114). Most respondents attended schools located in urban areas (T1=71.6%, and T2=65.5%). No significant differences in sociodemographic, substance use, and sleep variables were observed at baseline between those who did and did not complete the T2 follow-up.

According to Bono et al. (2023), a minimum of 72 participants was estimated for the sample size to ensure robustness and maintain a conservative approach toward Type I error rates. This sample size keeps the rates within a 5% margin of error in unbalanced groups and different correlations between repeated measures, providing valid estimations for group, time, and interaction effects in two-wave designs (Bono et al., 2023).

Procedure

A longitudinal prospective study was conducted in public schools and consisted of two waves: one conducted between November 2021 and May 2022 (T1), and the second one six months later, between May 2022 and November 2022 (T2). Five schools were randomly selected from a pool of secondary schools in Alicante region, of which four agreed to participate. After receiving approval from the school principals, students and their guardians were informed about the study's characteristics and requested to provide written informed consent. Following the receipt of consent, a psychologist visited school classrooms to assess students using an online survey accessible via mobile phones. The survey included different self-reported measures and took approximately 50 minutes to complete. To maintain anonymity and enable matching the follow-up assessment, an anonymous identification code was created. The follow-up assessment was conducted using the same procedure as the initial assessment.

Approval for this study was granted by the Clinical Research Ethics Committee of the General University Hospital of Alicante (GUHA; CEIm: PI2019/112). No compensation was provided for adolescents' participation.

Variables and measures

Sociodemographic variables and exclusion criteria

For sociodemographic variables, we included single-item questions for assessing sex (i.e., sex assigned at birth), age, and school location. To evaluate the validity of responses, we used the Oviedo Infrequency Scale (Fonseca-Pedrero et al., 2008). This tool permits the identification of random or dishonest responses by using items that are highly likely to elicit affirmative answers (e.g., *Do you know anyone who wears glasses?)*. Item responses follow a Likert-type format with 5 categories ranging from 1, *completely* disagree, to 5, *completely* agree. Responding correctly to 75% of items (up to 3 mistakes) is indicative of response validity (Fonseca Pedrero et al., 2018).

Alcohol use

Alcohol use was measured with the TimeLine Follow-Back (TLFB; Sobell & Sobell, 1992), a calendar to retrospectively register the number of Standard Drinking Units (SDUs) of the past month, with one SDU corresponding to 10g of alcohol (Rodríguez-Martos et al., 1999). The TLFB was also used to measure binge drinking episodes in the past month –consuming 4 or more SDUs on a single occasion for women and 5 or more for men (NIAAA, 2023). Likewise, regular alcohol use was assessed with the Drug Use History Questionnaire (DUHQ; Sobell et al., 1995). This DUHQ includes a 7-point response item to evaluate the frequency of use in the past 12 months. Problematic drinking was evaluated with the Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993), which uses 10 items to assess drinking quantity, frequency, and related problems in the past 12 months. Global scores range from 0 to 40, with higher scores indicating more drinking issues. In adolescents, scores over 5 indicate problematic alcohol use (Liskola et al., 2018). For this study, the time frame for the AUDIT questions was adapted at T2 to the past 6 months to avoid overlapping periods. The AUDIT has demonstrated adequate reliability (α>0.75) in the adolescent population (Cortés-Tomás et al., 2016; Hallit et al., 2020).

Sleep quality

Sleep quality was assessed with the Brief Pittsburgh Sleep Quality Index (B-PSQI; Sancho-Domingo et al., 2021). The B-PSQI uses 6 items to evaluate the overall sleep quality of the past month and five sleep dimensions: sleep latency (minutes), sleep duration (hours), sleep efficiency (percentage of time in bed while asleep), frequency of night awakenings, and subjective sleep quality. The dimensions are scored between 0 and 3 points, resulting in a total score between 0 and 15 with higher scores signify worse sleep quality. For this study, responses for the item hours of sleep were coded following National Sleep Foundation recommendations (Hirshkowitz et al., 2015) and the cutoff criteria for poor sleep was a score ≥6 in adolescents (Sancho-Domingo at al., 2024). The B-PSQI has demonstrated good reliability (ω=0.84-91) and validity in the general population (Sancho-Domingo et al., 2021; Sancho-Domingo at al., 2024).

Covariates

Anxiety and depression were assessed with the Depression, Anxiety and Stress Scale (DASS-21; Antony et al., 1998; Fonseca et al., 2010). The DASS includes 7 items to measure each subscale using a 4-point Likert scale ranging from 0, *did not apply to me at all*, to 3, *applied to me very much.* Global score oscillates between 0 and 21, with higher scores representing greater severity. The DASS has proven adequate reliability and validity to measure anxiety (DASS-A α=0.79) and depression (DASS-D α=0.87) in adolescents (Szabó, 2010).

Statistical analyses

Means comparisons and changes in the distribution of categorical variables for repeated measures were performed using Generalized Linear Mixed Models (GLMMs) with random intercepts. Initially, changes between T1 and T2 (Time) were examined for the following variables: alcohol use in the past month (yes/no), number of Standard Drinks Units (SDUs), Binge Drinking episodes (BD), AUDIT scores, B-PSQI scores, hours of sleep, sleep efficiency, sleep latency (minutes), and frequency of awakenings (less than once a month/weekly). Odds Ratios were estimated as the effect sizes.

Subsequently, GLMMs with random intercepts were used to investigate the longitudinal effects of sleep quality (good B-PSQI=1 vs. poor B-PSQI=0) on alcohol use outcomes. To evaluate the effect of sleep quality on preventing and reducing alcohol use after six months (Time), the GLMMs were tested separately between adolescents who reported no use or sporadic alcohol use in the past year, and those who reported using alcohol monthly (at least once a month in the past year), consistently to previous literature (Pielech et al., 2023). The response variables of the GLMMs included the number of SDUs in the past month, episodes of BD, and scores on the AUDIT, since these variables have been previously associated with sleep quality (Kwon et al., 2019). Poisson distribution was used and the GLMMs were adjusted for sex, anxiety, and depression as covariates. Nested model tests were conducted to determine the inclusion of sex interactions in all GLMMs.

Secondly, a GLMM analysis was conducted to explore the impact of sleep changes on alcohol use. This analysis focused on the changes in B-PSQI scores between T1 and T2 as a predictor of alcohol reduction after six months. Covariates for the model included sex, initial sleep quality, anxiety, and depression. A binomial distribution was used for modeling alcohol reduction. For adolescents with monthly alcohol use, the response variables encompassed reducing SDUs (by ≥1 SDUs), reducing binge drinking (by ≥1 episodes), and reducing AUDIT scores (by ≥1 scores); for non-drinking adolescents, abstaining from drinking, binge drinking, or scoring zero on the AUDIT was used as the response variables. Furthermore, separate GLMMs were estimated to identify which components of sleep quality could influence changes in alcohol use. In this case, predictors included changes over time in hours of sleep, sleep latency, efficiency, and frequency of night awakenings. Following a dose-repose approach, the Effective Dose to produce an effect in 75% of the sample (ED75) was estimated. GLMM analyses were also estimated in reverse order to analyze alcohol's effect on sleep. All analyses were conducted using the package *lme4* for the statistical software R (Bates et al., 2023), with a confidence level set at 95%.

Results

Alcohol and sleep characteristics at T1 and T2

Table 1 presents differences in alcohol use and sleep measures between baseline (T1) and the 6-month assessment (T2). At T1, 42.1% (n=83) of adolescents reported alcohol use in the past month, whereas at T2, the percentage increased significantly to 53.8% (n=106; p=0.005; OR=2.12). Initially, the monthly average of SDUs was 6.7 (SD=14.8) with one episode of binge drinking (SD=1.7), and no significant changes over time (p=0.224 and p=0.766, respectively). By contrast, AUDIT scores significantly increase from T1 to T2 (mean diff.: 0.9; p<0.001; OR=1.28) indicating potential changes in alcohol use patterns.

Likewise, improved sleep quality was observed based on a decrease in B-PSQI scores (mean diff.: -0.8; p=0.008; OR=0.88). Likewise, sleep latency was significantly prolonged after six months (mean diff.: 3.4; p<0.001), but the effect was small (OR=1.17). No significant changes were found for the other sleep dimensions (see Table 1). Initially, adolescents reported sleeping an average of 7 hours (SD=1.3) per night, and about 22 minutes (SD=28.4) to fall asleep. Around a third of participants reported experiencing night awakenings weekly in the past month (38.1% at T1, and 32.5% at T2) and good sleep efficiency (>90%).
At both assessments, non-drinking adolescents reported significantly lower scores ($p<0.05$) in the B-PSQI ($B\text{-}PSQI_{T1}=4.8$, and $B\text{-}PSQI_{T2}=4.1$) compared with adolescents with monthly alcohol use ($B\text{-}PSQI_{T1}=5.9$, and $B\text{-}PSQI_{T2}=5.3$) suggesting poorer sleep quality.

Prospective association of sleep quality on alcohol use

To test if sleep quality may be associated with alcohol use over time a GLMM analysis was conducted. Among adolescents who drank monthly (n=91), good sleep quality was not significantly associated with the number of SDUs (p=0.814), the number of episodes of BD in the last month (p=0.430), or the AUDIT scores (p=0.549).

However, the fixed effects presented in Table 2, indicated a significant interaction effect related to changes over time in SDUs and sleep quality. The interaction between B-PSQI and time showed that experiencing good sleep quality among adolescents who used alcohol was associated with a steeper negative slope for SDUs (OR=0.68; 95%CI= 0.55–0.85; p=0.001) and episodes of BD over time (OR=0.29; 95%CI=0.10–0.87; p=0.028). The odds of using more SDUs and engaging in BD episodes decreased by 32% and 71%, respectively, in adolescents with good sleep quality compared to those with poor sleep. This interaction showed no significant impact on the AUDIT scores (p=0.424).

Among non-drinking adolescents (n=106), a significant increase in SDUs (OR=2.64; p<0.001) was observed as well as in AUDIT scores (OR=6.26; p=0.001). However, no significant associations were found between the quality of sleep and the number of SDUs, the BD episodes in the last month, or the AUDIT scores (p>0.05).

Analyses conducted in reverse order did not reveal any significant effects of SDUs, binge drinking, or AUDIT scores on the prediction of sleep quality (p>0.05).

Predictive probability of reducing alcohol use through sleep changes

Given that good sleep was significantly associated with a lower probability of using alcohol among those who drank monthly, a GLMM analysis was conducted to analyze the predictive probability of reducing alcohol use by changes in sleep. As shown in Table 3, a decrease in B-PSQI scores among drinking adolescents was significantly associated with a reduction of BD episodes after 6 months (OR=2.25; 95%CI=1.08–4.67; p=0.031), but not with reducing SDUs (p=0.419) or AUDIT scores (p=0.169). This effect was consistent regardless of the initial quality of sleep which showed no interaction effects (p>0.05). As illustrated in Figure 1, the ED75 corresponded to a -0.5 unit change in the B-PSQI, indicating the change associated with a reduction in at least one BD episode in 75% of the drinking adolescents.

The effects of improving other sleep parameters were also examined (Table 3). For those who drink monthly, several significant effects were observed in a dose-response relationship, as represented in Figure 1. Reducing sleep latency was linked to a higher probability of reducing BD (OR=1.08; 95%CI=1.01–1.15; p=0.026) with ED75 at -7.7 minutes. Similarly, reducing the frequency of nighttime awakenings tripled

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the likelihood of lowering AUDIT scores (OR=3.03; 95%CI=1.51–6.06), with the ED75 at -0.6. Regarding hours of sleep or sleep efficiency, no significant association was found with a decrease in alcohol use or related problems.

Regarding non-drinking adolescents, no significant associations were observed between changes in sleep and alcohol use (see Table 3).

To test if the improvement in sleep could be due to a lower alcohol intake, analyses were conducted in reverse order, with sleep as the outcome variable and alcohol changes as the predictor. These secondary analyses indicated that changes in BD did not significantly predict changes in B-PSQI scores (p=0.893), or sleep latency (p=0.296). Likewise, no significant differences were found for changes in AUDIT scores on the frequency of night awakenings (p=0.115).

Discussion

This study aimed to explore the prospective association between sleep quality and alcohol use among adolescents, as well as to investigate the effect of sleep changes on alcohol consumption over time. In our study, the prevalence of alcohol use and sleep problems aligns with trends observed in previous research in similar contexts (ESPAD, 2020; Kocevska et al., 2021), with those who drink regularly experiencing poorer sleep quality (Kwon et al., 2019). Consistent with previous research (Kwon et al., 2019; Miller, Janssen, et al., 2017; Pielech et al., 2023), our results support the notion that good sleep quality predicts decreased alcohol use among drinking adolescents. In particular, adolescents exhibiting good sleep quality demonstrated a decreased likelihood of reporting alcohol consumption and binge drinking over time, with no sex effects, contrary to findings from prior studies (Bootzin et al., 2013; Pielech et al., 2023).

Interestingly, good sleep alone did not significantly predict alcohol use but there were significant time-dependent effects. This indicates that the relationship between sleep quality and alcohol-related outcomes varies over time, and therefore, future studies should consider the temporal aspect when examining the impact of sleep on alcohol use. By contrast, the results of reverse analyses contradict that alcohol serves as a predictor of poor sleep, as previously observed in longitudinal studies with regular drinking adolescents (Pielech et al., 2023). This disagreement with previous studies may be attributed to the likelihood of sleep problems developing more prominently during early adulthood and subsequent years (Helaakoski et al., 2022). Nevertheless, the findings of our study align with the idea that sleep disturbances may contribute to the maintenance of substance use behaviors (Hasler et al., 2017, 2022; Hasler & Pedersen, 2020; Miller, DiBello, et al., 2017).

Evidence of this study suggests a potential protective effect of improvement of sleep on alcohol use. Adolescents who decreased their B-PSQI scores after six months, regardless of their initial sleep quality, were twice as likely to reduce episodes of binge drinking over time. Specifically, we found a dose-response association where greater improvements in overall sleep quality led to a lower probability of binge drinking. This effect was characterized by declines in sleep latency and frequency of night awakenings, which is coherent with findings from recent longitudinal studies (Troxel et al., 2021). However, increases in sleep efficiency or sleep duration showed no association with binge drinking, contrary to studies where sleeping more hours was associated with fewer substance use problems and health benefits (Britton et al., 2010; Hamilton et al., 2023; Scott et al., 2021). This may be attributed to consistent sleep hours observed at both time points, possibly influenced by the stable school schedule (Afolabi-Brown et al., 2022). Besides this, our results are similar to previous research highlighting the beneficial effects of improving sleep on various health outcomes (Asarnow et al., 2023; Bootzin et al., 2013; Scott et al., 2021).

Regarding non-drinking adolescents, no significant effect was observed between the increase in alcohol use and reported sleep quality. This suggests that in non-drinking adolescents, improved sleep does not seem to be associated with abstaining from drinking alcohol. Therefore, future studies should investigate whether implementing sleep interventions at an earlier age could affect the onset of drinking during early adolescence. In this regard, our findings underscore the importance of initiating studies to analyze the efficacy of incorporating sleep-focused interventions into substance use prevention programs for adolescents, as recently suggested (Hasler et al., 2024). Particularly, studies focus on improving overall sleep rather than only increasing sleep duration, paying attention to pre-sleep factors that can disturb sleep onset latency (e.g., rumination) or sleep continuity during the night (Harvey & Buysse, 2018; Jansson-Fröjmark et al., 2023).

Some limitations should be taken into consideration. Firstly, the use of self-reported measures for both sleep and alcohol use may introduce bias and measurement error. Future studies could benefit from incorporating objective measures of sleep, such as actigraphy, and biomarkers of alcohol consumption to provide a more comprehensive assessment. Furthermore, the longitudinal data were collected at two time points, potentially limiting the identification of other temporal associations between changes in sleep and alcohol use. In this regard, adolescents who never consume alcohol may tend to respond with zero, leading to overdispersion in the count data. This overdispersion can affect the precision of estimators and potentially impact their statistical significance. Future research should aim to corroborate these findings across larger sample sizes and with more longitudinal assessments.

In conclusion, these findings add to the growing body of research on the prospective association between sleep and substance use in adolescence. Good sleep could act as a protective factor against alcohol use, while improvements in various sleep dimensions may help reduce alcohol use among adolescents with regular alcohol use. These results expand the basis for future studies to analyze how interventions targeting sleep issues can mitigate alcohol use, and improve the efficacy of prevention programs for substance use.

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Table 1. Alcohol and sleep differences at Time 1 and 2

	T1 (N=197) *mean (SD)*	T2 (N=197) *mean (SD)*	*Z* (*p*)	OR (95%CI)
Alcohol past month *%(n)*	42.1 (83)	53.8 (106)	**2.8 (.005)**	**2.12 (1.3-2.6)**
SDUs	6.7 (14.8)	6.5 (14.1)	1.2 (.224)	0.95 (0.9-1.1)
BD episodes	0.7 (1.7)	0.7 (1.5)	0.3 (.766)	0.96 (0.8-1.2)
AUDIT	3.1 (4.6)	4.0 (4.4)	**4.2 (<.001)**	**1.28 (1.1-1.4)**
B-PSQI	5.2 (2.9)	4.6 (3.2)	**2.6 (.008)**	**0.88 (0.8-0.9)**
Hours	7.0 (1.3)	6.9 (1.3)	0.5 (.580)	0.98 (0.9-1.1)
Efficiency (%)	90.2 (13.9)	90.4 (12.3)	0.7 (.455)	0.99 (0.9-1.0)
Latency (min)	22.2 (28.4)	25.6 (37.6)	**7.1 (<.001)**	**1.17 (1.1-1.2)**
Awakenings %(n)	38.1 (75)	32.5 (64)	0.1 (.954)	1.02 (0.6-1.7)

Note. *p*: p-value; B-PSQI: Brief Pittsburgh Sleep Quality Index; AUDIT: Alcohol Use Disorders Identification Test; SDU: Standard Drinking Unit; BD: Binge Drinking. Bold typing indicates significant effects ($p<0.05$).

Table 2. Generalized Linear Mixed Model (GLMM) for good sleep as a predictor of Standard Drinking Units (SDUs), episodes of Binge Drinking (BD), and AUDIT scores.

	SDUs		BD episodes		AUDIT scores	
Fixed effects	*OR (95% CI)*	*p*	*OR (95% CI)*	*p*	*OR (95% CI)*	*p*
Regular drinkers (n=91)						
BPSQI (good)	0.89 (0.36–2.22)	.814	1.59 (0.50–5.06)	.430	0.92 (0.71–1.20)	.549
Time	0.93 (0.81–1.07)	.315	1.71 (0.74–3.95)	.205	1.10 (0.90–1.35)	.337
BPSQI x Time	**0.68 (0.55–0.85)**	**.001**	**0.29 (0.10–0.87)**	**.028**	0.88 (0.66–1.19)	.424
Sex	0.55 (0.23–1.31)	.177	1.55 (0.54–4.42)	.205	0.94 (0.69–1.29)	.713
Anxiety	**1.04 (1.02–1.07)**	**.001**	1.02 (0.96–1.09)	.465	1.01 (0.98–1.04)	.665
Depression	1.00 (0.98–1.02)	.963	1.01 (0.96–1.07)	.611	1.01 (0.98–1.03)	.634
Non-drinkers (n=106)						
BPSQI (good)	0.92 (0.58–1.45)	.718	0.97 (0.64–1.46)	.868	1.44 (0.67–3.10)	.356
Time	**2.64 (1.60–4.36)**	**<.001**	1.16 (0.68–1.97)	.586	**6.26 (2.36–16.6)**	**.001**
BPSQI x Time	1.05 (0.57–1.91)	.880	1.04 (0.56–1.94)	.901	0.59 (0.19–1.80)	.356
Sex	1.09 (0.78–1.52)	.632	1.04 (0.78–1.37)	.901	0.83 (0.29–2.40)	.728
Anxiety	0.97 (0.93–1.02)	.190	0.99 (0.95–1.04)	.804	0.99 (0.90–1.09)	.840
Depression	0.98 (0.94–1.02)	.280	0.99 (0.96–1.93)	.745	1.06 (0.96–1.17)	.267

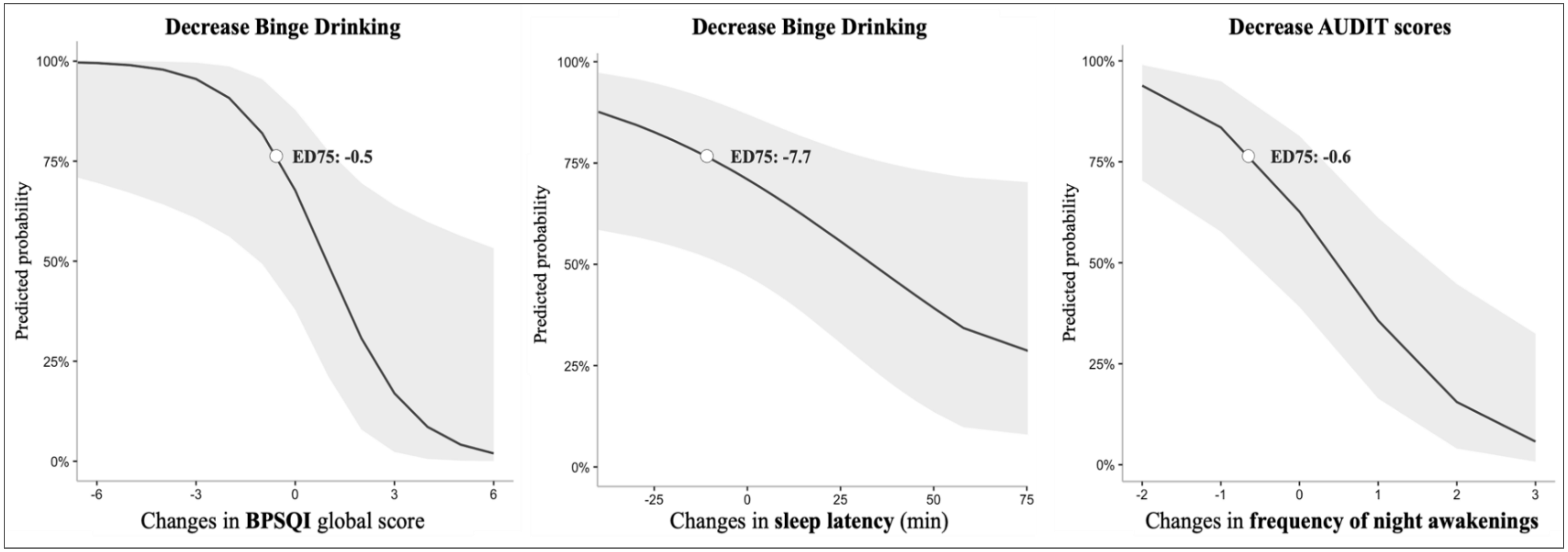
Note. The GLMM were adjusted by sex, anxiety, and depression. OR: Odd Ratio; 95%CI: 95% Confidence Interval; *p*: p-value; BPSQI: Brief Pittsburgh Sleep Quality Index; SDU: Standard Drinking Unit; BD: Binge Drinking; AUDIT: Alcohol Use Disorders Identification Test. Bold typing indicates significant effects (p<0.05).

Table 3. Generalized Linear Mixed Model (GLMM) for changes in sleep over time as predictor of reducing or preventing alcohol use

	Decrease SDUs or abstain from drinking		Decrease BD episodes or abstain from BD		Decrease AUDIT scores or maintain at zero	
	OR (95% CI)	*p*	*OR (95% CI)*	*p*	*OR (95% CI)*	*p*
Regular drinkers (n=91)						
ΔBPSQI	1.10 (0.71–1.71)	.429	**2.25 (1.08–4.67)**	**.031**	0.74 (0.48–1.14)	.169
Δ*Hours*	0.97 (0.61–1.53)	.885	1.32 (0.75–2.34)	.339	0.85 (0.53–1.35)	.485
Δ*Efficiency*	1.01 (0.98–1.03)	.523	1.03 (0.99–1.06)	.113	1.01 (0.99–1.04)	.282
Δ*Latency*	1.02 (0.98–1.07)	.296	**1.08 (1.01–1.15)**	**.026**	1.01 (0.99–1.04)	.292
Δ*Awakenings*	1.38 (0.66–2.87)	.387	1.55 (0.65–3.68)	.313	**3.03 (1.51–6.06)**	**.002**
Non-drinkers (n=106)						
ΔBPSQI	0.84 (0.66–1.07)	.150	0.82 (0.59–1.12)	.206	1.00 (0.80–1.26)	.967
Δ*Hours*	1.02 (0.51–2.03)	.962	1.66 (0.63–4.38)	.308	1.65 (0.71–3.78)	.251
Δ*Efficiency*	1.00 (0.96–1.04)	.981	0.96 (0.90–1.02)	.155	1.00 (0.96–1.05)	.849
Δ*Latency*	1.00 (0.94–1.06)	.979	0.96 (0.86–1.08)	.487	0.98 (0.92–1.05)	.613
Δ*Awakenings*	0.62 (0.33–1.15)	.130	1.04 (0.46–2.35)	.926	0.60 (0.32–1.12)	.110

Note. The GLMMs were adjusted by sex, the initial sleep status, anxiety, and depression. OR: Odd Ratio; 95%CI: 95% Confidence Interval; *p*: p-value; Δ: the change in the scores between T1 and T2 (6 months interval) with higher scores suggesting enhancing sleep quality or its dimension; BPSQI: Brief Pittsburgh Sleep Quality Index; SDU: Standard Drinking Unit; BD: Binge Drinking; AUDIT: Alcohol Use Disorders Identification Test. Bold typing indicates significant effects (p<0.05).

Figure 1. Predictive probability of reducing alcohol use among drinkers according to changes in sleep over time.



Note Fig 1. Only statistically significant associations are shown in the figure. The x-axis represents the changes in the sleep parameters over time, with negative values representing a decrease in the sleep parameter, and positive values an increase. The y-axis represents the predictive probability of reducing at least one episode of Binge Drinking (BD) or reducing at least one unit in AUDIT scores after 6 months.

SLEEP QUALITY AND SUBSTANCE USE IN ADOLESCENTS

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