ПСИХОЛОГИЧЕСКИЕ ИССЛЕДОВАНИЯ В ОБРАЗОВАНИИ

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THE ASSOCIATION OF CIRCADIAN RHYTHMS WITH ACADEMIC, PHYSICAL, AND COGNITIVE PERFORMANCE: A SYSTEMATIC REVIEW

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Abstract. *Introduction.* Biological cycles exist across diverse time spans. Circadian rhythms are the most thoroughly examined and significantly influence individuals. These rhythms in physiological measures are affected by cyclical variations in human actions and surroundings over a 24-hour duration.

Aim. The present research *aims* to analyse the association of biorhythm factors with performance in students considering research in the field of chronobiology in relation to the educational field.

Research methodology and methods. The present systematic review summarises 34 records treating sleep quality, lifestyle, and circadian preferences in their association with the academic, physical, and cognitive performance of students during their daily life; using a PRISMA model.

Results. The current review paper has cited numerous studies that confirm the significant impact of sleep and circadian preference on a student's academic, psychomotor, and cognitive performance. These two factors play a crucial role in the rhythmicity of a student's life.

Scientific novelty. This study introduces a novel interdisciplinary method that applies findings from the study of biological rhythms to education, revealing how these rhythms affect student learning and performance. By merging chronobiology with educational theory, it opens new research paths and enhances our understanding of the relationship between students' circadian rhythms and their academic, cognitive and physical results, representing a significant progression in how the field of education is linked with chronopsychology.

Practical significance. Educational professionals can use the results obtained to gain a deeper insight into how chronobiological factors may affect student performance, thereby enhancing their comprehension of student productivity and potentially identifying more efficient ways to improve it.

Keywords: circadian rhythm, sleep, chronotype, performance, PRISMA.

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СВЯЗЬ ЦИРКАДНЫХ РИТМОВ С АКАДЕМИЧЕСКОЙ, ФИЗИЧЕСКОЙ И КОГНИТИВНОЙ РАБОТОСПОСОБНОСТЬЮ: СИСТЕМАТИЧЕСКИЙ ОБЗОР

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Аннотация. *Введение.* Биологические циклы существуют на протяжении различных временных интервалов. Циркадные ритмы являются наиболее полно изученными и оказывают значительное влияние на индивидов. Эти ритмы в физиологических показателях подвержены циклическим изменениям в действиях человека и окружающей среде в течение 24 часов.

Цель. Цель данной статьи – проанализировать связь факторов биоритма с результативностью учащихся, учитывая исследования в области хронобиологии в отношении образовательной сферы.

Методология, методы и методики. Настоящий систематический обзор обобщает 34 работы, посвященные качеству сна, образу жизни и циркадным предпочтениям в их связи с академической, физической и когнитивной работоспособностью студентов в их повседневной жизни, с использованием модели PRISMA.

Результаты. В нашем обзоре привдено множество исследований, подтверждающих значительное влияние сна и циркадных предпочтений на академическую, психомоторную и когнитивную работоспособность студента. Эти два фактора играют ключевую роль в ритмичности жизни студента.

Научная новизна. Это исследование представляет новый междисциплинарный метод, который применяет результаты изучения биологических ритмов к образованию, показывая, как они влияют на обучение и работоспособность студентов. Соединяя хронобиологию с образовательной теорией, он открывает новые пути для исследований и расширяет наше понимание связи между циркадными ритмами студентов и их академическими, когнитивными и физическими результатами, представляя значительный прогресс в том, как образовательная сфера связана с хронопсихологией.

Практическая значимость. Педагогические специалисты могут использовать полученные результаты для более глубокого понимания того, как хронобиологические факторы могут влиять на успеваемость учащихся, тем самым повышая их осведомленность о продуктивности студентов и потенциально выявляя более эффективные способы ее улучшения.

Ключевые слова: циркадные ритмы, сон, хронотип, работоспособность, PRISMA.

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LOS RITMOS CIRCADIANOS Y SU RELACIÓN CON EL RENDIMIENTO ACADÉMICO, FÍSICO Y COGNITIVO: REVISIÓN SISTEMÁTICA

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Abstracto*. Introducción.* Los ciclos biológicos existen a lo largo de diversos intervalos de tiempo. Los ritmos circadianos son los más estudiados y tienen un impacto significativo en los individuos. Estos ritmos en términos fisiológicos están sujetos a los cambios cíclicos en las actividades de los seres humanos y el medio ambiente durante las de 24 horas del día.

Objetivo. El propósito de este artículo es analizar la relación de los factores biorritmicos con el rendimiento de los estudiantes, teniendo en cuenta las investigaciones en el campo de la cronobiología en relación al ámbito educativo.

Metodología, métodos y procesos de investigación. La presente revisión sistemática se ha llevado a cabo mediante el uso del modelo PRISMA, y resume 34 estudios que examinan la calidad del sueño, el estilo de vida y las preferencias circadianas en relación con el rendimiento académico, físico y cognitivo de los estudiantes universitarios en su vida diaria.

Resultados. En nuestra revisión se proporcionan numerosos estudios que confirman la influencia significativa del sueño y las preferencias circadianas en cuanto al rendimiento académico, psicomotor y cognitivo del estudiante. Estos dos factores juegan un papel crucial en el ritmo de vida del estudiante.

Novedad científica. Este estudio presenta un nuevo método interdisciplinario que aplica los hallazgos del estudio de los ritmos biológicos a la educación, mostrando cómo influyen en el aprendizaje y el desempeño de los estudiantes. Al fusionar la cronobiología con la teoría educativa, abre nuevas puertas para la investigación y amplía nuestra comprensión de la relación existente entre los ritmos circadianos de los estudiantes universitarios y sus resultados académicos, cognitivos y físicos, lo que representa avances significativos en cómo el campo educativo está relacionado con la cronopsicología.

Significado práctico. Los profesionales de la educación pueden utilizar los hallazgos para tener una comprensión más profunda de cómo los factores cronobiológicos pueden incidir en el rendimiento de los estudiantes, aumentando así su conciencia en lo que respecta a la productividad de los estudiantes y de manera potencial, identificar mecanismos más efectivos para mejorarla.

Palabras claves: ritmos circadianos, sueño, cronotipo, rendimiento, PRISMA.

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Introduction

Academic, cognitive, or physical performance has always been the focus of the learning act. In the last few years, there has been a growing interest in students' academic achievement and its relation to cognitive and psychomotor performance. Previous research has demonstrated that school performance is not the result of a single parameter but of a multitude of interacting variables. It is obvious that the student's environment has an implicit influence on his/her performance, whether at school or at home. However, it is crucial to remember that the student's lifestyle, routines, and habits as well as numerous psychophysiological aspects like sleep and chronotype, affect how well he/she does at school. Growing research indicates that, regardless of country or culture, teenagers often fail to achieve the suggested sleep duration.

Literature Review

Many studies have shown that human performance during the day is constantly changing [1]. Initial studies primarily aimed to identify the best time of day for instruction to enhance school schedules. N. Kleitman, a leader in the fields of sleep and circadian rhythms, was the first to establish a connection between cognitive abilities, sleep, and chronobiology. He observed daily fluctuations in cognitive efficiency, noting peak performance in the afternoon and declines during early morning and late evening [2].

In a meta-analysis of children and adolescents, sleep length was found to be strongly associated with performance, although considerably less than sleep quality [3]. Several studies have been conducted to investigate how physical exercise impacts sleep [4–6]; however, little research has been conducted to investigate how sleep affects physical activity. Yet, sleep deprivation has been demonstrated to severely influence university students' reaction times and vascular responses to exercise [7]. Sleep has been demonstrated to influence cognitive abilities. A continuous drop in sustained attention, working memory, and executive functioning, as well as an increase in subjective sleepiness, were demonstrated in research studying the relationship between sleep and cognitive processes in students [8]. The latter, strengthened during the day, deteriorated at night and in the early morning. Sleep deprivation impairs these cognitive processes even more throughout the day [9]. In view of current findings, a direct effect of sleep disturbance on cognitive performance cannot be dismissed [10, 11]. Other research indicates that sleep length is unrelated to cognitive performance [12]. On the other hand, many studies that evaluated total hours of sleep as a predictor of grade point average (GPA) found that it was the most important predictor of GPA among the characteristics analysed [13–15]. In contrast, chronotype is another aspect that influences performance. Morningness and academic achievement were found to be positively related. In a previous study, students with higher GPAs scored higher on the chronotype. Morning and middle chronotypes performed better academically [16, 17].

Prior studies have delineated the intricate interplay between diurnal preferences, cognitive capabilities, and scholastic performance [18–21]. Moreover, the pedagogical implications of students' lifestyle determinants, especially reduced screen exposure and dietary choices, have been recognised as potential influencers on their academic outcomes [22]. Stemming from this empirical backdrop, our study posits the overarching question: "To what extent do circadian rhythms, modulated by both internal and external factors, influence students' academic, cognitive, and physical performance outcomes?". Anchored by this inquiry, our hypothesis suggests that students' circadian rhythms have a pronounced effect on their scholastic achievements, cognitive processes, and physical capabilities. This review endeavours to systematically examine the multifaceted dynamics between students' circadian rhythms and their performance across these dimensions.

Conceptual Framework

An individual academic journey can have its ups and downs, determined by various factors and the tools available within each person's unique environment. It is clear that academic, cognitive, and physical performance varies from person to person due to differences in determinants such as chronotype (morning or evening), sleep patterns (awake during the day or night), and other factors. Initially, the effects of circadian rhythms on daily performance were studied more in the field of sports, where research showed significant individual differences in athletes' sleep-wake habits, sometimes misconstrued as laziness by coaches. Although an optimal chronotype for sports performance is yet to be identified, a training programme that does not align with an athlete's biological clock may be difficult to adhere to [1]. E. Teng et al. highlight that enhancing sleep qualities, especially an athlete's view of sleep, can significantly impact sports outcomes [23]. This is because psychological aspects are connected to both cognitive and physical abilities. However, the influence of sleep on performance is not limited to the sports field but extends to other domains as well.

Sleep, circadian preferences, school schedules, lifestyle habits, and other factors remain critical determinants that impact attention, memory, and learning levels. These determinants can be classified into two groups: primary and secondary, each having a significant percentage of influence.

Rhythms in school schedules can be defined in two ways: either as timetables and academic calendars or as periodic variations in physiological (biological rhythms) and psychological (behavioural rhythms) processes. The challenge with school rhythms is reconciling the natural and artificial socio-economic environment with that of the students.

Thus, this conceptual framework integrates foundational theories and empirical research on circadian rhythms – the biological cycles that govern physiological and cognitive functions across a 24-hour period – and their implications for performance. Within this context, performance is dissected into three primary dimensions: physical performance, reflecting the capacity for bodily activities and tasks; cognitive performance, pertaining to mental processes such as attention, memory, and problem-solving; and academic performance, indicating the level of success in educational endeavours.

To enhance the precision and relevance of the systematic review, this framework necessitates a meticulous identification of key concepts, variables, and their interconnections pertinent to the research question. Consequently, it encompasses the development of a conceptual model or diagram, meticulously illustrating these relationships. The model underscores how circadian rhythms can significantly influence physical, cognitive, and academic performance, providing a robust basis for interpreting the results of the included studies. This approach ensures a comprehensive understanding of the multifaceted nature of performance and its intricate relationship with biological rhythms, which is paramount in the educational field for devising evidence-based strategies and interventions.

Biological Rhythm

A biological rhythm is described as a series of events that, when stable, recur in a consistent sequence and timeframe [24]. Each biological rhythm is characterised by its period, amplitude, and phase. The period signifies the length of a full cycle of rhythmic change, and it is standard to categorise these rhythms into three primary durations: rhythms of about 24 hours (24 ± 4 hours) called circadian, that are believed to impact various facets of a person's life. Areas such as study, physical activity, dietary patterns, and the capacity to adapt to shift jobs are among the sectors influenced by these roughly 24-hour cycles [25–29]. The fast or ultradian rhythms, for which the period is less than 20 hours, and the slow infradian rhythm, are longer than 28 hours.

Circadian Rhythm

Physiological structure

Circadian rhythms originate in the suprachiasmatic nuclei (SCN), a group of neurons located in the hypothalamus, just above the optic crossroads. The oscillating neurons within the SCN, often called the primary or central timekeeper, produce cycles slightly longer than 24 hours. These circadian patterns in the SCN arise from the repetitive expression of certain genes, commonly known as clock-controlled genes (CCG). This process uses a feedback loop that manages both transcriptional and posttranscriptional stages. Some notable CCGs are period (per) and cryptochrome (cry) [30].

Endogenous and exogenous factors

Circadian rhythms are not fully dependent upon exogenous factors, but also have an "endogenous component". Numerous physiological circadian rhythms are endogenously regulated during rest and continue while a person is shielded from external changes [1]. A synchroniser or "time donor" is a factor of the exogenous environment, a living organism whose periodic variations can modulate the biological rhythms of this organism. The synchroniser does not generate rhythm, it modifies it. It may be natural, like the alternation of day and night, the succession of seasons, temperature connected with the preceding factors, etc., or artificial, created by man [31]. Two interacting processes drive temporal fluctuations in neurophysiological parameters: the homeostatic sleep drive grows the longer one remains awake, while the circadian regulator promotes an intrinsic cycle that is close to 24 hours [32].

Performance

Human performance, in contrast to physiological factors, cannot be constantly tracked to determine circadian patterns. Research studies, exploring the influence of circadian rhythms on performance, need meticulous planning to account for the effects of consecutive fatigue and to reduce sleep disruptions. The degree of test-retest repeatability of the measuring apparatus has a significant impact on rhythmicity identification in performance variables [1].

Cognitive performance

Evidence suggests that the interaction between homeostatic and circadian elements can influence numerous neurobehavioural activities, and this relationship is not consistent throughout the day. Yet, the potential effects of these daily fluctuations on brain functions and cognitive abilities are often overlooked in both cognitive psychology and neuropsychology [21].

Academic performance

Students' academic performance is measured by their reporting of their previous semester cumulative grade point average (CGPA) or GPA, as well as their projected GPA for the current semester. Most postsecondary institutions currently utilise the GPA as a useful summary indicator of their students' academic success. The GPA is a more accurate indicator since it gives more information about the relative levels of achievement of individuals and various groups of students [33].

Physical performance

Alertness peaks in the afternoon, leading to enhanced pattern identification, quicker response times, and increased muscular strength. Reduced perceived effort, reduced weariness, and improved tolerance for all-out exertion is all benefits. Laboratory results could not show any genuine competitive performance advantage because worldwide competition is already stimulating. The body reaches its highest temperature in the late afternoon. While this can be likened to a "warm-up" in some ways, it does not affect heat regulation during exercise. Due to the heart rate aligning with alertness and core temperature in the afternoon, PWC170 and estimated maximum oxygen uptake are at their minimal levels. Respiratory reactions to exertion are also reduced during this time. Metabolic efficiency remains fairly consistent when accounting for daily body mass fluctuations. There is minimal change in maximum oxygen intake throughout the day, and its trend is not universally agreed upon. However, many researchers agree that peak competitive performance occurs in the late afternoon [34].

Methodology

In this systematic investigation, we upheld a stringent and unbiased approach, underpinned by a descriptive quantitative strategy involving a methodical content analysis. By adhering to the well-established PRISMA framework, we ensured a transparent and equitable evaluation of the 34 included studies, thereby affirming the integrity of our findings. This study structure was further refined in accordance with the frequency of methodological techniques employed and the specific subjects under scrutiny. Our specific emphasis on circadian rhythms and their intricate relations with students' academic, physical, and cognitive capacities underlines the study relevance. Anchoring our analysis within the realm of chronobiology, we provide a significant contribution to the ongoing discourse in educational sciences, offering insights into contemporary challenges and expanding the body of knowledge in this pivotal domain.

Data Source and Search Strategies

The current study was based on data collected from published articles through a search for relevant studies in the following databases: Scopus, Web of Science, PubMed, PsycINFO, and ScienceDirect; published between 2010 and 2019. The following elements were all included in the search terms: "sleep", "chronotype", "morningness-eveningness ","academic performance", "cognitive performance", "physical performance", "lifestyle", "student", "school", and "university", either in the title, abstract or keywords. A search for the pertinent literature included in this systematic review was conducted from May to August 2022. From the pertinent online sources, we were able to gather 310 research publications. After removing duplicates, a total of 171 articles were gathered from the databases and manual backtracking. When criteria were set to only consider articles in English and from peer-reviewed journals, 143 articles remained for screening. During the title and abstract evaluation, we sought articles that: (1) described academic (GPA), cognitive, or physical performance; (2) compared three distinct chronotypes (morning-type, neither-type, and evening-type); and (3) involved student participants from elementary, middle, high school, or university from any nation. This led to the exclusion of 99 articles. Upon evaluating the full content of the remaining articles, 10 more were discarded for various common reasons: (1) the study was not conducted between 2010 and 2019; and (2) the students in the sample had some health issues. This search method produced 34 records in the end (Figure 1).

Data Collection Instrument

The studies that we have been able to address are those that originated from different search engines, notably Google Scholar, Semantic Scholar, and RefSeek. The authors of those studies based their research on many validated materials, such as Pittsburgh Sleep Quality and the Epworth Sleepiness Scale, for more reliable measurements of biological variables, which impact is reflected in academic, cognitive, or physical performance.

The study employed a paper classification form as a data collection tool, made by the second author of this paper. It contains twenty-one items that organise the research content. These items are generally related to descriptive information, area of application, research components, research design and methodologies, data gathering tools and their authors, sample size, data analysis techniques, and mean findings.

Table 1 includes all tools that researchers have used in their studies to learn about the relationship between academic, cognitive, or physical performance and different biological rhythms, namely, sleep and chronotype, as with lifestyle.

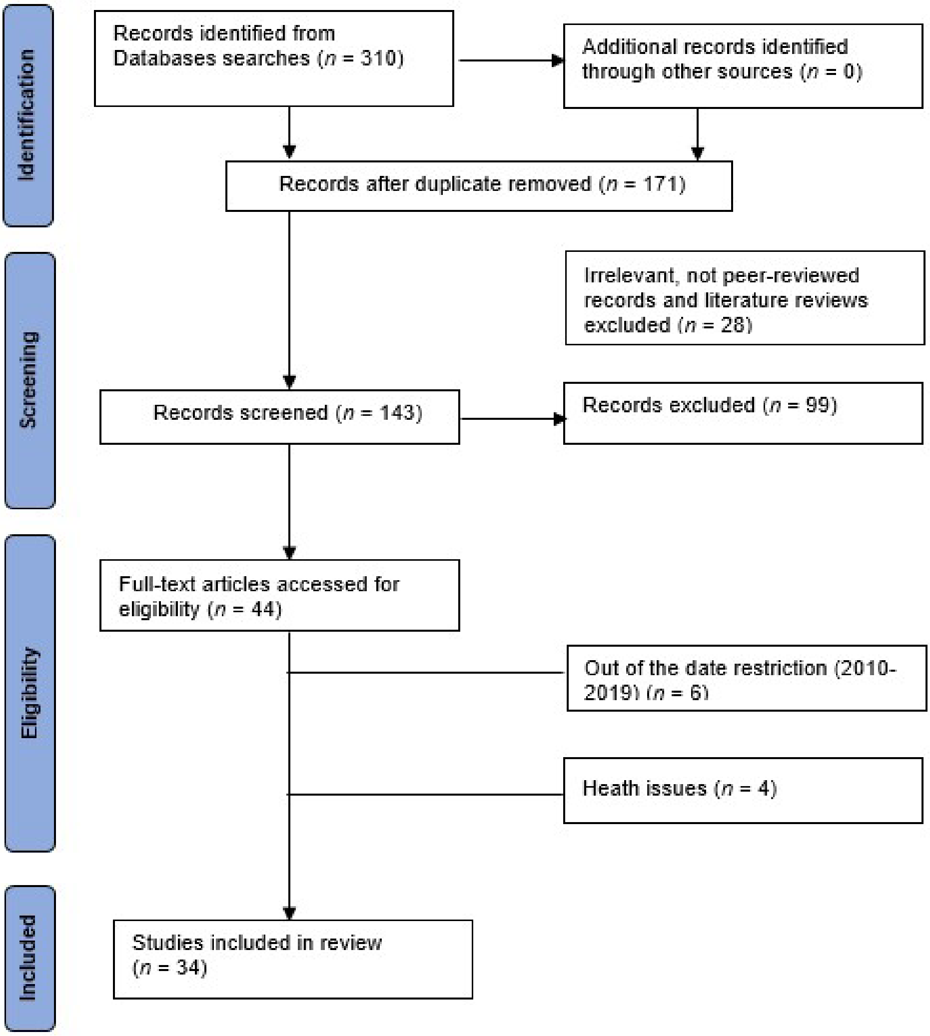
Identification
Records identified from Databases searches (n = 310)
Additional records identified through other sources (n = 0)
Records after duplicate removed (n = 171)
Screening
Irrelevant, not peer-reviewed records and literature reviews excluded (n = 28)
Records screened (n = 143)
Records excluded (n = 99)
Eligibility
Full-text articles accessed for eligibility (n = 44)
Out of the date restriction (2010-2019) (n = 6)
Heath issues (n = 4)
Included
Studies included in review (n = 34)

Fig. 1. PRISMA

Table 1

Frequently used tools to measure the selected study variables (2010–2019)

Variables	Material	Author, year	*n*	*f*
Sleep features	Pittsburgh Sleep Quality lndex (PSQI)	D. J. Buysse et al. (1989) [36]	8	23,5%
	Actigraphy	---	4	11,7%
	Sleep Disturbance Scale for Children (SDSC) questionnaires	O. Bruni et al. (1996) [37]	2	5,9%
	Chronic Sleep Reduction Questionnaire (CSRQ)	J. F. Dewald et al. (2012) [38]	1	2,9%
	Sleep diary	---	4	11,7%
	The Pediatric Daytime Sleepiness Scale	C. Drake et al. (2003) [39]	1	2,9%
	The Italian version of the Mini Sleep Questionnaire (MSQ)	J. Zomer et al. (1985) [40]	1	2,9%
	The Chinese version of the adolescent sleep disturbance questionnaire (ASDQ)	Y. Yang (2016) [41]	1	2,9%
	Self-report sleep measures	---	6	17,6%
	Epworth Sleepiness Scale (ESS)	M. Johns (1991) [42]	1	2,9%
Chronotype	Morningness-Eveningness Questionnaire (MEQ)	J. A. Horne & O. Ostberg (1976) [43]	4	11,7%
	Morningness-Eveningness Scale for Children (MESC)	M. A. Carskadon, C. Vieira & C. Acebo (1993) [44]	2	5,9%
	The Composite Morningness Questionnaire (CMQ)	C. S. Smith et al. (1989) [45]	1	2,9%
Academic performance	School data-base (GPA or CGPA)	---	4	11,7%
	Academic Motivation Scale (AMS-C)	R. J.Vallerand et al. (1992) [46]	1	2,9%
	Nationwide standardised, compulsory assessment: The National Assessment Programme-Literacy and Numeracy (NAPLAN).	---	3	8,8%
	Self-report academic performance	---	4	11,7%
	Assessment based on items	---	1	2,9%
	Amsterdam Neuropsychological Tasks programme	L. M. J. De Sonneville (1999) [47]	1	2,9%
	Operation span task (working memory)	M. L. Turner & R. W. Engle (1989) [48]	1	2,9%
	Digit span (working memory)	D. Wechsler (2003) [49]	1	2,9%
Cognitive performance	Letter number sequencing (working memory)		1	2,9%
	Digit-symbol substitution (processing speed)		1	2,9%
	Primary Mental abilities (PMA-R), notably Inductive reasoning	L. L. Thurstone (1938) [50]	1	2,9%
	Stroop Colour and Word Test	J. R. Stroop (1935) [51]	1	2,9%
Physical performance	Cardiopulmonary exercise testing (CPET)	---	1	2,9%
	PANIC Physical Activity Questionnaire	J. Väistö et al. (2014) [52]	1	2,9%
	7 day, 24 h accelerometry (the Actigraph GT3X+ accelerometer)	---	1	2,9%
Lifestyle	Self-reported sedentary time or physical activity time	---	2	5,9%

Data Analysis

The data was evaluated and exported into an excel sheet for descriptive statistical analysis by the authors after they double-classified the selected research articles to guarantee validity and reliability. Descriptive statistics, such as frequency, percentage tables, and charts, are used to present the results.

Results

Numerous abstracts were analysed, resulting in the selection of 34 relevant articles for evaluation. The research was categorised based on various factors that either directly or indirectly influenced student outcomes.

Descriptive Information of the Reviewed Papers

Table 2 shows that the studies included in our review are from 17 different countries, with Australia (*n* = 5), the United States (*n* = 4), and Finland (*n* = 3) in the lead. While the rest of the studies are dispersed across the 14 remaining countries, namely: Norway, Turkey, Italy, Spain, Brazil, Portugal, Germany, UK, Japan, Switzerland, Canada, China, Malaysia, and Netherlands.

Table 2

International frequency of featured research reports (2010–2019)

Country (18)	Research reports
Australia	5
USA	4
Finland	3
Norway	2
Turkey	2
Italy	2
Spain	2
Brazil	2
Portugal	2
Germany	2
UK	2
Japan	1
Switzerland	1
Canada	1
China	1
Malaysia	1
Netherland	1
Total	34

From 2010 to 2019, several studies examined the relationship between students' performance and sleep, chronotype, or lifestyle. In the meantime, our research selection criteria had identified the publications that were relevant to our aim in each of the years from 2010 to 2019. The majority of research reports included in our review were completed in 2013 (*n* = 8), in 2014 (*n* = 6), and in 2017 (*n* = 6). More details are provided in Table 3.

Table 3

Yearly breakdown of reviewed research reports' numbers (2010–2019)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Research reports	0	2	2	8	6	2	1	4	3	6	34

In 85.3% of the publications, academic performance was discussed in connection with one of the independent variables. Few studies in our review incorporated cognitive (n = 2) and physical performance (n = 2), while only one dealt with two mixed categories of performance (academic and cognitive). Regarding the dependent variables, sleep was correlated with performance in 52.9% of cases and in 23.5% of other cases when associated with the chronotype, as shown in Table 4. This indicates the significance that the scientific community accords with sleep because of its close correlation with performance, directly or indirectly using other associated variables (i.e. chronotype and lifestyle).

Table 4

Frequently studied variables in the selected research records (2010–2019)

Studied variables		***n***	***f***
Performance	Academic	29	85,3%
	Cognitive	2	5,9%
	Physical	2	5,9%
	Mixed: Academic and cognitive	1	2,9
Total		34	100%
Sleep		18	52,9%
Chronotype		2	5,9%
Lifestyle		4	11,8%
Mixed: Sleep and chronotype		8	23,5%
Mixed: Sleep and lifestyle		2	5,9%
Total		34	100%

The majority of research publications in the current research review (38.2%) address the impact of independent variables on the performance of university students, whereas only three papers analyse the relationship between these factors in high school students. As for the elementary (17.7%) and middle schools (26.5%), researchers have demonstrated a substantial interest in the category of students enrolled in these institutions. Furthermore, 8.8% of published reports investigated students' performance in different application fields (elementary school, middle school, high school, and university), as shown in Table 5.

Table 5

Frequently used application areas to assess the studied variables (2010–2019)

Application field	***n***	***f***
Elementary school	6	17,7%
Middle school	9	26,5%
High school	3	8,8%
University	13	38,2%
Mixed	3	8,8%
Total	34	100%

Among the 34 selected reports, 33 were quantitative studies; one was qualitative; and none of them was mixed. All reports in the review were experimental, including 52.9% of correlative studies, 44.2% of comparative studies, and only 2.9% representing one case study (Table 6).

Table 6

Analysis methods and category of studies frequently used (2010–2019)

Data analysis method		***n***	***f***
Quantitative		33	97,1%
Qualitative		1	2,9%
Mixed		0	0%
Total		34	100%
Category of studies		***n***	***f***
Experimental re-searches	Correlative	18	52,9%
	Comparative	15	44,2%
	Case study	1	2,9%
Total		34	100%

Mean Research Findings

While much research has delved into sleep impact on academic achievement, several additional insights stand out. Table 7 presents twenty-two articles exploring the influence of sleep factors on academic outcomes. One particular study found no correlation between hours of sleep and cumulative grade point average (CGPA) [35]. Research that looked into various sleep habits revealed that students, who experienced subpar sleep, heightened sleep disruption, later sleeping times, and early risings, often displayed reduced academic and neurobehavioural performance [12]. Another article highlighted the detrimental effects of poor sleep quality on academic results [53]. Similarly, the presence of Delayed Sleep-Wake Phase Disorder was linked to a decline in the CGPA as an indicator of academic success [54]. A rise in the sleep regularity index (SRI) corresponded with an uptick in average GPA [55]. The bulk of studies focusing on sleep and academic performance revealed that teenagers with superior sleep quality attained better grades [56], while those with evening-oriented tendencies had lower GPAs [57]. A comprehensive breakdown of key conclusions regarding sleep characteristics and their relation to academic achievements can be found in Table 7.

Table 7

The association of academic performance with sleep features: daytime sleepiness, insomnia, sleep quality, efficiency, regularity, and length/duration, sleep disorders, and sleep habits (2010–2019)

Authors, year	**Country**	***n* (n of females)**	**Age**	**Academic performance**	**Sleep variables**	**Findings**
M. Nihayah et al. (2011) [35]	Malaysia	104 biomedical science students (77.9 %)	19–24	The academic performance of students is denoted by their Cumulative Grade Point Average (CGPA)	Sleeping hours	There was no correlation between sleep duration and CGPA ($p > 0.05$), nor between study habits and CGPA ($p > 0.05$).

A. A. Gomes, J. Tavares & M. H. P. de Azevedo (2011) [53]	Portugal	1,654 full-time students (55%)	17–25	Prior GPA and underperformance in the majority of subjects during the last academic year	Sleep quantity; Sleep quality; Sleep irregularity	There was a rise in average values regarding the belief that sleep adversely affected academic performance in the university.
B. Sivertsen, N. Glozier, A. G. Harvey & M. Hysing (2015) [54]	Norway	8,347 high-school students (54%)	16–19	GPA	DSP	Adolescents with DSP displayed notably lower academic performance, having a GPA of 3.5, in contrast to 3.9 in the group without DSP ($p < .001$).
A. J. K. Phillips et al. (2017) [55]	USA	61 undergraduates (47.5%)	18–24	GPAs	Sleep regularity; Sleep duration; Delayed sleep timing	Overall, there was a positive linear relationship between SRI and Grade Point Average (GPA).
M. Adelantado-Renau, A. Diez-Fernandez, M. R. Beltran-Valls, A. Soriano-Maldonado & D. Moliner-Urdiales (2019) [56]	Spain	269 adolescents (48%)	14	The final grades; A mean score of the fundamental subjects; GPA score	Sleep quality	Adolescents with superior sleep quality (*PSQI* < 5) had elevated grades (all $p < 0.05$). However, these findings indicated no variances in cognitive performance.
J. F. Díaz-Morales & C. Escribano (2013) [57]	Spain	887 adolescents	12–16	Grade Point Average (GPA)	Sleep length	Evening adolescents obtained lower GPA.
I. Önder, Ş. Beşoluk, M. İskender, E. Masal & E. Demirhan (2014) [58]	Turkey	1343 university students (62,8%)	18–34	CGPA	Sleep Quality (poor/good)	The majority of the sample exhibited poor sleep quality.
L. Tonetti, M. Fabbri, M. Filardi, M. Martoni & V. Natale (2015) [59]	Italy	36 Italian students (33.3%)	18.14 ± 0.49	From school records	Sleep efficiency	Multiple regression analysis revealed a significant relationship between SE and the final grade. Only the actigraphic measure of sleep quality had a notable impact on academic performance.

I. Merikanto, T. Lahti, R. Puusniekka & T. Partonen (2013) [60]	Finland	384,076 students (50.9%)	14–20	Absence from school	General bedtime during school nights	Adolescents with later bedtimes tend to have reduced school performance and motivation.
N. Perkinson-Gloor, S. Lemola & A. Grob (2013) [61]	Switzerland	2716 adolescents (48,6%)	15.4 ± 0.8	End-of-year grades in math and the German language.	Sleep duration	Students who sleep for less than 8 hours, resulting in insufficient sleep duration, achieve lower academic grades in mathematics and the German language compared to their peers who get more sleep.
S. Blunden et al. (2018) [62]	Australia	513 children (48%)	7–9	NAPLAN performance: Reading,writing,spelling, grammar, numeracy	Early Risers; Long Sleep; Normative Sleep; Variable Bedtimes; Short Sleep	The highest performance was observed among individuals who slept for an extended duration, while those who experienced reduced sleep (such as short sleepers and early risers) exhibited lower performance in grammar, numeracy, and writing skills.
J. Duarte et al. (2014) [63]	Portugal	2094 adolescent students (55.3%)	16–23	Academic grades of Portuguese (Port), and Mathematics (Math)	Daytime sleepiness Sleep quality	Slight drowsiness, enhanced sleep efficiency, increased subjective sleep satisfaction, reduced sleep disturbance, decreased daytime dysfunction – all these factors are linked to improved academic performance.
L. B. C. De Carvalho et al. (2013) [64]	Brazil	2384 children (51%)	7–10	Academic grades of Portuguese (Port), and Mathematics (Math)	Symptoms of sleep disorders (SSD); Sleep breathing disorders (SBD)	Children diagnosed with SSD or sleep breathing disorders (SBD) exhibited lower Mean Port and Math grades compared to their counterparts without SSD.

L. D. Asarnow, E. McGlinchey & A. G. Harvey (2014) [65]	USA	2,700 adolescents (42%)		GPA	School year bedtime; Total sleep time	Having a later bedtime during the school year in Wave I (1994–1995) was linked to poorer educational results, while shorter overall sleep duration did not show a longitudinal association with academic performance.
K. Ahrberg, M. Dresler, S. Niedermaier, A. Steiger & L. Genzel (2012) [66]	Germany	144 medical students (66%)	19–31	German grade system.	Sleep quality Sleep habits	Before exams, there was a correlation between academic performance and both stress and sleep quality. It is important to note that poor performance was linked to low sleep quality and elevated stress levels.
K. Zhao et al. (2019) [67]	China	4966 adolescents (50.7%)	11–20	Academic achievement	Insomnia symptoms	Poorer academic performance was associated with the presence of multiple symptoms of insomnia.
L. Foulkes, D. McMillan & A. M. Gregory (2019) [68]	UK	15 undergraduate Students (80%)	18–20	Academic difficulties (falling asleep during a private study, concentration in class, missing the first contact hour, later revision)	Sleep quality	The social setting of noise issues and the temptation of peer socialising may cause a lack of quality sleep during university life. An unstructured academic lifestyle is the result of the widespread repercussions of low sleep quality.
R. Gruber et al. (2014) [69]	Canada	75 students (45.3%)	8.85 ±1.6	English, French, mathematics, science and technology, and art grades' from end-of-year report card.	Sleep duration Sleep efficiency, and sleep log	Apart from the influences of age, gender, and socioeconomic status, improved sleep efficiency (though not sleep duration) was connected to higher grades in Mathematics, English, and French as a second language.

M. A. Short, M. Gradisar, L. C. Lack & H. R. Wright (2013) [70]	Australia	385 adolescents (40%)	15.6 ± 1.0	Self-reported grades	Sleep quantity Sleep quality	Poor outcomes were substantially correlated with poor sleep quality, with teenagers reporting less sleep on school nights, less attentiveness throughout the day, and more negative mood.
D.S. Lewin et al. (2017) [71]	USA	32980 students (50.2%)	13–14	The grades were obtained from a school's publicly accessible dataset.	School start time Sleep duration	Students who started school before 7:45 a.m. were more likely to have lower sleep quality, academic effort, and performance.
K. Okano, J. R. Kaczmarzyk, N. Dave, J. D. E. Gabrieli & J. C. Grossman (2019) [72]	USA	100 university students (47%)	18.19	A quarter of the overall cumulative class grade consisted of the scores from the nine quizzes.	Sleep duration Sleep quality Sleep consistency	The results of this study showed that greater sleep consistency, higher sleep quality, and longer sleep duration were all related to improved academic achievement.
Ø. Vedaa, E. K. Erevik, M. Hysing, A. C. Hayley & B. Sivertsen (2019) [73]	Norway	50,054 university students (69%)	23.2 ± 3.3	Self-reported academic performance/ failure	Insomnia Sleep duration Sleep quality and sleep disorders	Insomnia was linked to a greater chance of exam failure and slower academic development. A curvilinear relationship between sleep duration and academic failure risk was observed. Sleeping less than 5 hours or more than 10 hours was associated with a higher likelihood of exam failure compared to sleeping between 7 and 9 hours.

Sleep holds a notable role in shaping not just academic achievements but also various other essential aspects in students' lives, including their cognitive abilities. Substantial evidence exists to propose that limited sleep, as a result of acute sleep deprivation, exerts an impact on the cognitive capabilities of adolescents [8, 74]. To underscore the significance of this element, we examined four research articles that delve into the connection between sleep and cognition. An Australian study exploring whether adolescents with delayed sleep patterns experience compromised cognitive performance found that these individuals performed notably worse than their well-rested counterparts across three out of four cognitive tasks – namely attention, concentration, and memory. This discrepancy might imply a pessimistic anticipation of the detrimental consequences stemming from insufficient sleep. Moreover, sleep-related parameters exhibit a correlation with one's chronotype, hinting at a pattern that influences cognitive performance [75]. Evening adolescents scored higher on their primary mental abilities [57]. The mean findings are shown in Table 8.

Table 8

The association of cognitive performance with sleep time, sleep length, sleep efficiency, and sleep deprivation (2010–2019)

Authors, year	Country	*n* (% of females)	Age	Cognitive performance	Sleep variables	Findings
Y. Patrick et al. (2017) [7]	UK	64 college students (42%)	22 ± 4	Selective attention; Automatic response; Inhibition; and Control of executive functions	Sleep deprivation	The impact of sleep deprivation on a student's cognitive capacity is negligible.
J. F. Díaz-Morales & C. Escribano (2013) [57]	Spain	887 adolescents	12–16	Primary Mental Abilities (PMA)	Sleep length	Evening adolescents scored higher on PMA.
C. Richardson et al. (2018) [75]	Australia	63 adolescents (100%)	13–24	Poor Attention/ Concentration/ Memory	School night total sleep time and daytime sleepiness	Youth experiencing delayed sleep-wake phase disorder reported markedly lower cognitive task performance compared to individuals with healthy sleep patterns.
J. F. Dewald-Kaufmann, F. J. Oort & A. M. Meijer (2013) [76]	The Netherlands	55 adolescents (85.5%)	12–19	Simple reaction time; Visuospatial processing; and Divided attention	Sleep onset latency; Wake time after sleep onset; and Sleep efficiency	Children who increased their sleep duration by a minimum of 30 minutes did not exhibit a noteworthy enhancement in the simple RT task.

Table 9 presents the outcomes derived from a pair of investigations regarding the impact of sleep insufficiency on the physical capabilities of both athletic individuals and university attendees. Numerous research studies have pointed out the adverse consequences of complete sleep deprivation on various exercise undertakings, such as walking and cycling [77]. An examination of the influence of partial sleep deprivation on weight-lifting prowess indicated that tasks involving submaximal lifting are more susceptible to the effects of sleep shortage compared to maximal exertions, particularly during the initial two consecutive nights of restricted sleep [61]. Nevertheless, Y. Patrick et al. concluded that, barring reaction time, no noteworthy distinctions were observed between sleep-deprived individuals and those who had sufficient sleep [7].

Table 9

The association of physical performance with sleep disorders and sleep deprivation (2010–2019)

Authors, year	Country	*n* (% of females)	Mean age	Physical performance	Sleep variables	Findings
Y. Patrick et al. (2017) [7]	UK	64 college students (42%)	22 ± 4	Physical function: intensity of exercise reaction time	Sleep deprivation	Apart from reaction time, there were no notable variances observed, except that individuals who were sleep deprived exhibited a notably higher average for reaction time (p = 0.03).
T. Monma et al. (2018) [78]	Japan	906 student athletes (29.9%)	19.1 ± 0.8	Sports time during, evening practices each day	sleep disorders	In relation to competitive activities, individuals who engaged in morning practice exhibited notably increased chances of developing sleep disorders.

Circadian preference is partly genetic [79]. Irrespective of a person's individual chronotype, ensuring synchronisation and consistency in the sleep-wake cycle is imperative. In the case of medical students, this rhythm can be altered by multiple factors, including the demands of their curriculum throughout the day, involvement in extracurricular pursuits, encounters with physical and emotional stress, the pressure to excel academically, and the impact of hospital requirements [80, 81].

In short, there is an association between circadian preferences and the delayed sleep phase. In the study by G. L. N. Rique et al., 221 students underwent evaluation through four distinct questionnaires: a demographic questionnaire, the Morningness-Eveningness Questionnaire (MEQ), the Pittsburgh Sleep Quality Index (PSQI), and the Epworth Sleepiness Scale (ESS) [82]. The results indicated a significant divergence among the groups concerning chronotypes and PSQI scores (p < .001), although no notable distinction was observed in terms of excessive daytime sleepiness. Notably, a robust negative correlation existed between MEQ and PSQI scores (*rho* < -0.3, p < 0.001), highlighting that increased nighttime hours were associated with diminished sleep quality. Additionally, 51.6% of the students were found to have an indifferent chronotype, 61.5% to have inadequate sleep, and 42.1% to have severe daytime sleepiness. Gender and season of birth exhibited no significant variations in relation to the different chronotypes [82]. In summary, these results indicate that the evening chronotype is linked to subpar sleep quality among medical students; however, it is not connected to heightened daytime sleepiness. This association could potentially hinder both their academic achievements and overall quality of life. Numerous other studies have reached analogous conclusions, with G. Rique's work reaffirming the notion that individuals with evening chronotypes experience more compromised sleep quality. It is important to note that various factors, such as age, gender, and a range of cultural, social, environmental, technological, and biological variables, can also influence one's chronotype [79, 83–86]. According to Table 10, the chronotype is significantly related to sleep quality [82, 87], daytime sleepiness [88], and age [87].

Table 10

The relationship between chronotype, sleep and age (2010–2019)

Authors, year	*n* (% of females)	Variables	Mean	*SD*	*p*
G. L. N. Rique, G. M. C. Fernandes Filho, A. D. C. Ferreira & R. L. de Sousa-Muñoz (2014) [82]	221 medical students (44.3%)	Chronotype	50.9	11.1	ns
		Age	22.3	3.8	
		Chronotype	50.9	11.1	< 0.001***
		Sleep quality	6.5	2.6	
		Chronotype	50.9	11.1	ns
		Diurnal sleepiness	9.12	3.2	
Y. Selvi et al. (2012) [87]	264 university students (48.1%)	Chronotype	---------	--------	< 0.05*
		Age	19.7	1.6	
		Chronotype	--------	-------	< 0.05*
		Sleep quality	--------	-------	
K. Roeser, A. A. Schlarb & A. Kübler (2013) [88]	273 adolescents (60.8%)	Chronotype	51.08	6.78	ns
		Age			
		Chronotype	51.08	6.78	*p* = .003**
		Daytime sleepiness			

In spite of the growing body of literature concerning chronotype and performance in young adolescents, limited investigations have so far delved into the comparative influence of circadian preference on academic performance. A notable research discovery suggests that the connections between chronotype and academic accomplishment, particularly in terms of grade point average (GPA) as well as performance in classroom tests and other markers of achievement, exhibit less incongruity. Multiple studies consistently underscore a significant negative correlation between eveningness and academic success indicators, whereas a positive correlation is observed between morningness and academic achievement. This pattern holds true for both children [89] and university students [90–92]. The findings presented in Table 11 encapsulate results from seven recent studies examining the link between chronotype and academic performance, aligning with the conclusions of F. Cortesi et al. [89]. A robust association emerges, connecting higher morningness with enhanced academic performance, the attainment of higher CGPA scores, and conversely, a connection with eveningness and lower performance. Morning-oriented individuals generally arise earlier than their evening-oriented counterparts. Furthermore, the cognitive and physical capacities of morning-oriented individuals reach their zenith before noon, whereas individuals with a pronounced evening orientation hit their peak around 12 hours later [93].

Table 11

The relationship between academic performance and chronotype (2010–2019)

Authors, year	Country	*n* (% of females)	Age	Academic performance items	Chronotype items	Findings
A. A. Gomes, J. Tavares & M. H. P. de Azevedo (2011) [53]	Portugal	1,654 full-time students (55%)	17–25	GPA	Diurnal type	University students with decreased morningness scores experienced an adverse effect on their academic performance.
J. F. Díaz-Morales & C. Escribano (2013) [57]	Spain	887 students	12–16	GPA	Morning type/Evening type	Higher scores on morning preference were significantly associated with higher school achievement.
I. Önder, Ş. Beşoluk, M. İskender, E. Masal & E. Demirhan (2014) [58]	Turkey	1343 university students (62.8%)	18–34	CGPA	Earlier/Later	Earlier chronotypes had higher CGPA scores than later chronotypes.
L. Tonetti, M. Fabbri, M. Filardi, M. Martoni & V. Natale (2015) [59]	Italy	36 Italian students (33.3%)	18.14 ± 0.49	School records	Morning type/ Evening type	Biorhythms of evening types do not align well with school schedules, affecting their final grades.
J. Duarte et al. (2014) [63]	Portugal	2094 adolescent students (55.3%)	16–23	School achievement.	Morningness/Eveningness type	Regarding morningness/eveningness, there is both a direct and indirect impact. Greater morningness leads to improved sleep quality.
K. Roeser, A. A. Schlarb & A. Kübler (2013) [88]	Germany	273 adolescents (60.8%)	15.18 ± 0.76	Grades of main subjects (German, English, and Mathematics)	M-type / N-type / E-type	Based on the Chronotype-Academic Performance Model (CAM), chronotype might not influence academic performance directly; instead, its effect could be channeled through daytime sleepiness and learning motivation.
A. Montaruli et al. (2019) [94]	Italy	423 university students (31.4%)	20.2 ± 1.5	Theoretical and practical subjects' mean grades	M-type / N-type / E-type	Morning type students did better academically overall, although neither type had poorer test marks for theoretical topics and the Evening type scored worse on practical examinations.

A recent research of D. Dumuid et al. sought to analyse academic outcomes among groups of children based on shared lifestyle habits. Participants from Australia, aged 9–11 (n = 284), were categorised into four distinct lifestyle behaviour patterns. These patterns were deduced from several factors: measurements from 24-hour accelerometry, which assessed sedentary behaviour, sleep, and varying intensities of physical activity, coupled with self-reported data on screen usage and dietary habits. Academic achievements varied among these groups. The group dubbed "Junk Food Screenies" (characterised by an unhealthy diet and elevated screen time) had the lowest academic scores, while the "Sitters" group (characterised by significant non-screen sedentary behaviour and minimal physical activity) boasted the highest. This evidence implies that decreasing screen time and enhancing dietary habits could positively affect academic success [22]. Furthermore, additional research, as summarised in Table 12, has supported these results.

Table 12

Effects of life style variables on child academic performance (2010–2019)

Authors, year	*n* (% of females)	Lifestyle variables	Findings
D. Dumuid et al. (2017) [22]	284 Australian children (53.9%)	Light; Moderate and vigorous physical activity; Sedentary behaviour; Sleep; Self-reported screen time and diet.	Lowest academic performance scores in the Junk Food Screenies cluster and highest in the Sitters cluster (high non-screen sedentary behaviour/low physical activity).
E. A. Haapala et al. (2014) [95]	186 children (42.5%)	Motor performance score, Total sedentary behaviour, Reading comprehension, Reading fluency, Arithmetic skills and others	Increased physical activity is linked to improved reading proficiency, while engagement in sports correlates with enhanced math skills. Additionally, sedentary behaviour tied to academic capabilities showed a connection to better reading proficiency.
H. J. Syväoja et al. (2013) [96]	277 children (56%)	Self-reported physical activity and screen time	Children who engaged in more physical activity tended to achieve higher GPAs. While there was a negative correlation between screen time and GPA ($p < 0.001$), there was not a noticeable link between GPA and measured moderate-to-vigorous physical activity (MVPA) or time spent being sedentary.
C. Maher et al. (2016) [97]	285 Australian children (55.1%)	Physical activity, sedentary behaviour patterns	Greater academic success was frequently and firmly associated with extended periods of sedentarity.

Discussion

The aim of this systematic review is to describe the relation between circadian preferences, sleep quality, and lifestyle on cognitive and physical performance from one side, and grade point average or any other measured variables of academic performance from the other side.

As already stated, several studies have dealt with these different variables characterising their relationship with academic performance that became the focus of many researchers today, given the importance that it covers in a student's academic life. A meta-analysis of multiple studies, including one long-term and 16 short-term ones, indicated that the length and quality of sleep, along with drowsiness, had negative impacts on the academic achievements of children and teenagers [3]. A primary factor for this decline in academic performance is the delayed sleep phase. Issues like tardiness to school, frequent absences, dropping out, and underachievement were all linked to the Delayed Sleep-Wake Phase Disorder. [3, 98–102]. Moreover, poorer academic performance, which is mostly attributable to attention problems in class, is frequently associated with more irregular bedtimes and, as a result, with much less sleep than with good sleepers who do not report attention issues [12].

In the study, involving 513 children between the ages of 7 and 9 from an Australian longitudinal research by S. Blunden and her team in 2018, five distinct sleep patterns were delineated: standard sleep, early waking, extended sleep, inconsistent sleep, and limited sleep. On the whole, those who slept for longer durations excelled in grammar, math, and writing compared to those with shorter sleep durations: those who slept less and woke up early [62]. Further analysis revealed that individuals with longer sleep durations had superior spelling and writing skills compared to both standard and short-duration sleepers [63].

In the investigation by N. Perkinson-Gloor et al., it was observed that students acquiring fewer than 8 hours of sleep manifested increased daytime lethargy, diminished behavioural resilience, a more pessimistic view of life, and subpar academic performance in mathematics and the German language. These observations corroborate prior scholarly evidence suggesting a relationship between sleep insufficiency during adolescence and consequent behavioural and emotional complications [103–109] and poor performance at school [3, 103, 109].

K. Roeser et al., and S. C. Link and his colleague noted that students exhibiting consistent sleep-wake patterns (characterised by brief sleep latencies, infrequent nocturnal disturbances, delayed school waking times, and earlier weekend waking times) tend to achieve higher GPAs [88, 103]. Conversely, students with diminished academic performance often experience heightened daytime drowsiness, frequently resulting from reduced nocturnal sleep durations [105, 110]. Furthermore, suboptimal college academic outcomes have been associated with factors like inconsistent sleep-wake rhythms [111] and compromised sleep quality [112–114], including complaints of onset and maintenance insomnia [115], excessive daytime sleepiness [116], and frequent [117].

Despite that, poor sleep is the most common factor impairing academic performance; it remains one of the many variables negatively affecting academic achievement. The research by K. Ahrberg et al. revealed that medical students and trainee doctors often face sleep shortages and increased stress during pivotal learning periods. In this study, 144 medical students were preparing for the preclinical board exam, they were assessed on their perceived sleep quality (using the Pittsburgh Sleep Quality Index, PSQI), academic grades, and self-reported stress at three stages: semester, pre-exam, and post-exam. A significant link emerged between academic performance and both stress and sleep quality right before the exam. During this pre-exam phase, 59% of participants exhibited notable sleep disturbances (*PSQI* > 5), in contrast to 29% during the semester and 8% post-exam. The data implies that among medical students, poorer sleep is not necessarily indicative of exam underperformance. However, those with anticipated lower scores tend to have increased anxiety and disrupted sleep [66]. Therefore, sleep irregularities might be a potential risk for subpar academic results during adolescence [118].

Additionally, most studies in this review presuppose a direct correlation between sleep length and performance. Yet, increased sleep does not invariably lead to enhanced outcomes [70, 119], indicating that nonlinear techniques should be considered [120]. Some studies have not found any significant results linking poor sleep with low academic performance. No significant link was found between students' sleep duration, stress levels, and study habits in relation to their CGPA [35]. Similarly, another study did not establish a noteworthy relationship between the amount of sleep and CGPA [121].

The meta-analysis examined 86 research papers, covering 35,936 children, marking the inaugural comprehensive assessment of relevant research on sleep and its relation to cognitive and behavioural aspects in healthy school-going children aged 5 – 12. A clear positive correlation was found between the length of sleep and cognitive capabilities (r = .08, CI = .06, .10). Specific links were noted between sleep duration and executive functions (r = .07, CI = .02, .13), performance in varied cognitive domain tests (r = .10, CI = .05, .16), and academic achievement (r = .09, CI = .06, .12), though not directly with intelligence [122].

Compelling research of A. Agostini et al. indicates that limited short-term sleep can hinder the cognitive abilities of teenagers [74]. In contrast, the long-term effects of sleep disturbances on their cognitive and academic capacities are not as well-understood [75]. Sleep loss also negatively influences some facets of working memory, including the ability to filter information effectively. Although scores on the Stroop test decline with sleep deprivation, these reductions are more related to slower response times rather than impaired processing capabilities [123–125].

E. J. Paavonen et al. conducted previously a research in Finland that showed the link between the amount of sleep and the cognitive abilities in children aged around 8 years based on specific neurocognitive tests. The study included 290 children ranging in age from 7.4 to 8.8 years. Tools like actigraphs and the Sleep Disturbance Scale for parents helped gauge sleep patterns and disturbances. Cognitive skills were assessed using selected tests from the Wechsler Intelligence Scale for Children III, the Beery Test for Visual-Motor Integration, and a specific memory test from the Developmental Neuropsychological Assessment for Children. After accounting for factors like age, gender, and maternal education, it was found that a reduced sleep duration negatively impacted visuospatial skills, but sleep quality did not have a similar impact. Also, neither sleep duration nor quality influenced verbal skills. Digging deeper into individual test outcomes, lack of adequate sleep was linked to subpar performance in Visual-Motor Integration, and in another test when children with elevated depression indicators were not considered. Furthermore, ineffective sleep was tied to poorer outcomes in a test measuring similarities [126].

The effect of experimentally manipulated sleep duration on cognition was examined in an Australian study; and only modest or no effects of sleep duration were found on several aspects of cognition [120]. Some studies, however, found no links between sleep quantity or quality and behavioural issues or cognitive outcomes like academic achievement [121, 127, 128].

The sleep influence does not stop at the academic or cognitive level but extends to a third plan: physical performance. Increasing sleep duration is accompanied by an increase in physical performance; conversely, an increase in sleep deprivation is associated with a decrease in physical performance. This is what some studies have concluded while examining strength and lifting performance impairments. P. Blumert et al.'s research examined 10 male collegiate weightlifters and found that a single night of sleep deprivation did not notably affect their weightlifting performance, even though they experienced heightened feelings of fatigue, negative emotions, and drowsiness [77]. Additionally, M. Taheri and E. Arabameri's study also determined that anaerobic capabilities, especially power, remained largely unchanged after one night without sleep [122]. However, broader research indicates that going without sleep for 50 hours has considerable negative impacts on students' motor skills, with significant declines in psychomotor capabilities manifesting after just 18 hours without sleep for tasks like reaction time. Other functions like endurance (assessed after 34 continuous waking hours), agility, balance, and power (assessed after 42 hours), as well as speed (measured after 50 hours), took longer periods of sleep deprivation before exhibiting detrimental effects [129].

Numerous studies highlight the advantages of extended sleep duration. Research on collegiate male basketball players, urged to maximise their nighttime sleep, revealed a notable increase in their mean sleep duration, from a typical 6.6 hours per night to 8.5 hours. Following this sleep augmentation, participants exhibited faster sprint times (from an initial average of 16.2 ± 0.61 seconds to 15.5 ± 0.54 seconds post-extension, $p < 0.001$). Furthermore, shooting proficiency improved, evidenced by a 9% rise in free throw accuracy and a 9.2% enhancement in 3-point field goal accuracy ($p < 0.001$). Additionally, there were marked improvements in the Psychomotor Vigilance Task (PVT) reaction time and reductions in the Epworth Sleepiness Scale scores after the sleep augmentation ($p < 0.01$). The Profile of Mood States (POMS) metrics also showed a boost in vitality and a decline in fatigue ($p < 0.001$). Players reported better overall physical and mental well-being during both practice sessions and actual games [130]. On the contrary, sleep deprivation adversely affects athletic performance through both physiological and psychological channels. From a physiological perspective, lack of sleep seems to correlate with diminished immune response, as seen in the reduction of natural killer cells and a decline in performance during prolonged submaximal exercise [131].

A study conducted by N. Goel et al. examined the repercussions of sleep deprivation on endurance running revealed that after a full night without sleep, participants covered reduced distances in timed tests. This suggests that sleep deprivation adversely affects endurance performance when preloaded conditions are considered [132].

Some research has been carried out on the impact of sleep quality on circadian preferences. There was a notable inverse relationship between the scores from the chronotype survey (MEQ) and sleep quality assessments (PSQI) with a coefficient of - 0.3 and a significance level of less than 0.0005. This suggests that those with a preference for evening activities – indicated by a lower MEQ score – tended to experience lower sleep quality, as marked by higher PQSI scores. However, there was no evident correlation between MEQ scores (indicating chronotype) and ESS scores (measuring daytime sleepiness). In this study from Brazil, those who preferred the evening had inferior sleep quality compared to their morning or neutral counterparts. This supports earlier studies, as referenced by G. L. N. Rique [82]. As mentioned previously, one's chronotype can indicate the quality of their sleep, with a greater inclination towards morning activities leading to better sleep quality. Additionally, chronotype serves as a determining factor for sleep quality, influencing academic outcomes [133].

More research supports the same findings about diurnal preference, which has a direct impact on sleep quality, particularly for the evening type, who has poorer sleep quality than the morning type. Evening types generally sleep and wake up later than intermediate sleepers, starting their sleep around 02:20 a.m. and waking up near 09:26 a.m., compared to 00:54 a.m. and 07:26 a.m. for the latter. Despite the difference in sleep timings, both groups spend roughly the same amount of time in bed. Evening types take longer to fall asleep and face more sleep disturbances, waking up more often than intermediate sleepers [134].

K. Roeser et al's research study has also identified a connection between one's circadian rhythm and their academic success. A study in Germany found that many teenagers have a mismatch between their natural inclination towards being night owls and the early start of school sessions. This so-called "social jet lag" means that, those who prefer evenings, tend to have poorer school performance. The Chronotype-Academic Performance Model (CAM) was developed to understand this relationship better, factoring in the influence of daytime tiredness and the motivation to achieve. This study included 273 participants aged between 14 and 16. The research collected data online regarding their sleep patterns, daily fatigue, motivation levels, and recent academic results. The findings indicated that one's circadian rhythm does not directly affect academic outcomes; instead, the impact is through factors like daytime fatigue and motivation to learn. Those inclined towards mornings exhibited lower daytime fatigue and higher motivation levels, leading to better academic results. Conversely, night owls showed a strong link between tiredness and a lack of motivation. The CAM proposes that while circadian rhythm does not directly impact grades, it does so indirectly through levels of daily tiredness and the drive to succeed academically. Night owls appear more vulnerable to daytime fatigue and may have unproductive attitudes toward academic efforts. Interventions that address these fatigue levels and reshape attitudes about academic success might help mitigate challenges faced by evening-oriented individuals due to social jetlag [88].

K. Roeser et al's findings support the notion that, under sleep deprivation, individuals need to exert more effort to maintain their behavioural effectiveness. Therefore, even with the same amount of effort, lack of sleep seems to hinder athletic performance. This could be linked to the noted decrease in muscle glycogen levels even before any athletic activity, following a single night without sleep [135].

In another study conducted by J. F. Díaz-Morales and C. Escribano, the same findings were demonstrated about circadian preferences and their effect on academic performance. After considering factors like age, gender, inductive reasoning, sleep duration, and more, the impact of circadian preference (morningness-eveningness or M-E) on academic success was studied. These two researchers comprised 887 teenagers aged between 12 and 16. Academic performance was gauged using the Grade Point Average (GPA), while inductive reasoning was assessed through the reasoning section of the Primary Mental Abilities test (PMA-R). Sleep duration was determined based on answers related to waking and sleeping times, and M-E was measured using the Morningness-Eveningness Scale for Children (MESC). It was observed that teenagers who leaned towards eveningness performed better on the PMA-R but had lower GPAs. Collectively, factors like inductive reasoning, age, gender, sleep duration, and M-E explained 19% of the variability in GPA. Even when considering traditional predictors, M-E still emerged as a subtle yet significant determinant of academic performance [57]. While most studies confirmed the negative correlation of the evening type with academic performance and inversely for the morning type, there were no significant differences between intermediate and morning types in the scores of all components of the PSQI. In the research by Y. Selvi et al., no significant differences between chronotypes in terms of sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, and use of sleeping medication were found ($p < 0.05$) [87].

In the research by D. Dumuid et al., initial predictions were based on earlier studies, anticipating that children underperforming academically would exhibit behaviours such us unhealthy eating habits, excessive screen time, minimal sleep, decreased physical activity, and extensive sedentary periods. However, the study did not identify a group that embodied all these traits. The closest group, termed "Junk Food Screenies", consumed the least healthy diets and spent the most time in front of screens, yet had average amounts of sleep, physical activity, and sedentary behaviour. Interestingly, no group in the study showcased both high levels of sedentary behaviour and physical activity. Instead, a pattern emerged where increased sedentary actions coupled with decreased physical activity were linked to superior academic performance. This suggests that among typical childhood habits, investing more time in stationary activities, such as reading or studying, and less in physical exertion correlates with better academic results [22].

In 2013, H. J. Syväoja et al. have conducted a study with 277 children from five schools in Jyvaskyla, Finland, representing 58% of the eligible 475 students. The average age of participants was 12.2 years, with girls comprising 56% of the sample. There was no observed correlation between Grade Point Average (GPA) and objectively measured Moderate-to-Vigorous Physical Activity (MVPA) (p = 0.955) or sedentary behaviour (p = 0.285). However, screen time was found to have a consistent negative relationship with GPA (p = 0.002). Moreover, after accounting for factors like gender, learning challenges, parental educational level, and sleep duration, self-reported MVPA showcased a unique inverse U-shaped correlation with GPA (p = 0.001) [96].

Furthermore, increased involvement in physical activities during break times, active commuting to school, engagement in organised sports, and sedentary activities linked to academic tasks were found to correlate with improved academic abilities in children during their initial school year. For boys, heightened total physical activity, active school commuting, computer usage, video gaming, and sedentary pursuits were connected with enhanced academic abilities in their first year. Conversely, for girls, elevated levels of overall sedentary activities, those related to music, arts, crafts, games, as well as increased total physical activity, were linked to lower academic performance. This underscores that the impacts of physical activity and various hobbies on academic abilities in the first school year differ between boys and girls [95].

The present discussion offers a thorough examination of empirical studies, highlighting the deep-seated connections between circadian rhythms, sleep quality, and student performance metrics. Through a systematic analysis of sleep patterns, physical activity, and lifestyle factors' impact on academic outcomes, these review findings robustly validate our initial hypothesis. This empirical evidence accentuates the central role of circadian rhythms in determining students' academic, cognitive, and physical outcomes. From pedagogical and psychological perspectives, it becomes evident that sleep parameters, circadian preferences, and lifestyle decisions are deeply interwoven with student performances. An understanding of students' sleep and circadian patterns can guide educators in pinpointing optimal learning periods, resulting in enhanced lesson design and curriculum formulation. Psychologically, consistent sleep and well-aligned circadian rhythms correlate with heightened cognitive abilities, emotional stability, and general well-being, all crucial for enduring educational engagement and success. Furthermore, lifestyle choices, encompassing dietary practices and screen exposure, can either augment or impede a student's capacity to concentrate, assimilate information, and sustain motivation. As the realm of educational development progresses, adapting to our expanding comprehension of comprehensive student health, the integration of these insights into pedagogical strategies becomes essential, championing a learning environment that resonates with the biological rhythms and preferences of students.

Conclusions and Recommendations

In response to our hypothesis suggesting the profound effects of circadian rhythms on students' academic, cognitive and physical performance dynamics, this systematic review sought to unpack the existing literature on the topic. Grounded in foundational studies exploring diurnal preferences, cognitive functions, and educational outcomes, our analysis confirmed that individual attributes like age, gender, habits, and lifestyle – along with sleep parameters and circadian inclinations – are intricately tied to students' academic, cognitive, and psychomotor achievements. By rigorously engaging with the literature, we have further elucidated the interconnected role of sleep patterns, circadian nuances, and academic results, underscoring the integral relevance of metacognitive [136] and neuroscientific dimensions [137] within this context.

In light of our findings concerning the influence of circadian rhythms on student performance, we advocate for several educational adjustments. Firstly, we suggest a reconsideration of school start times to align with peak human alertness, which typically emerges around 10 a.m. This change ensures students can optimise their cognitive capacities during learning. Moreover, given the increased propensity for sleepiness between noon and 2:00 p.m., it would be ideal to commence afternoon academic sessions post this interval, preferably after 3:00 p.m., when coordination is optimal. Lastly, considering the peak in cardiovascular efficiency and muscular strength post 5 p.m., scheduling physical education (PE) classes towards the end of the day could yield better outcomes. By harmonising these elements with the students' natural circadian patterns, educational institutions can foster an environment more attuned to maximising student success.

Limitations

While this systematic review provides a comprehensive analysis of the association between circadian rhythms and academic, physical, and cognitive performance, there are several limitations to note. Firstly, the review encompasses only 34 records, which might not capture the full spectrum of research in this domain. Variability in the methods, designs, and populations of the included studies might have introduced heterogeneity, making it challenging to draw consistent conclusions. Additionally, the reliance on the PRISMA model, while rigorous, could have potentially excluded relevant studies that did not meet specific criteria. It is also essential to acknowledge the potential for publication bias, as studies with negative or inconclusive results might be underrepresented. Lastly, while the focus on students provides a specific demographic, the findings might not be generalisable to other age groups or populations with different lifestyle factors.

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