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An ergonomic and systemic evaluation of the effect of sleep quality and lifestyle behaviors on academic performance among industrial engineering students

Mira Rahayu[1*], Ni Nyoman Prema Mega[2], Yusuf Nugroho Doyo Yekti[2]

[1]Center of Excellence for Human Centric Engineering, Institute of Sustainable Society, Department of Industrial Engineering, Telkom University, Jl. Telekomunikasi no. 1, Bandung, West Java 40257, Indonesia

[2]Department of of Industrial Engineering, Telkom University, Jl. Telekomunikasi no. 1, Bandung, West Java 40257, Indonesia

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ABSTRACT

University life is a demanding transitional period in which academic workload, social change, and financial pressure often disrupt students' sleep and daily health habits, with direct implications for learning and academic outcomes. This research examines how sleep quality and lifestyle habits affect the academic success of undergraduate students in industrial engineering, using a human factors and ergonomics framework. Utilizing the Pittsburgh Sleep Quality Index (PSQI) alongside the health-Promoting Lifestyle Profile II (HPLP-II), data from 293 students were paired with institutional cumulative Grade Point Average (GPA) records. The results indicate that 58% of the participants suffered from poor sleep quality (PSQI > 5). A significant negative correlation was observed between PSQI metrics and cumulative GPA ($r=-0.312$, $p<0.01$). Conversely, stress management ($r=0.267$, $p<0.01$) and health responsibility ($r=0.231$, $p<0.01$) positively correlated with GPA. Overall, sleep quality and lifestyle behaviors explained 29.6% of the GPA variance (adjusted $R2 =0.296$, $p<0.001$), with all predictors meeting multicollinearity thresholds (VIF < 3.0). No significant gender disparities were observed for sleep quality ($p = 0.339$) or GPA ($p = 0.066$), although males scored higher in overall lifestyle habits ($p = 0.008$). These findings demonstrate that lifestyle and sleep are critical determinants of the performance of industrial engineering students, suggesting that universities should deploy data-driven strategies, including schedule revisions and wellness initiatives, prior to longitudinal causal validation.

*Corresponding Author

Mira Rahayu
E-mail:
mirarahayu@telkomuniversity.ac.id

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1. INTRODUCTION

The primary objective of industrial engineering is to evaluate how human performance varies under shifting systemic parameters, with the goal of designing workflows that optimize rather than hinder capabilities [1]. The undergraduate engineering cohort offers an academic environment where cognitive performance, captured through cumulative GPA, can be evaluated using human factors and ergonomics frameworks applied to professional work settings. Both contexts require prolonged mental fatigue under strict operational demands, and both are fundamentally influenced by lifestyle factors such as sleep quality and stress coping mechanisms [1], [2]. The analysis of academic GPA as a key output metric reflects the goals of HFE and work systems engineering: identifying adjustable individual and environmental variables that drive output quality [3], [4]. Therefore, when students experience sleep deprivation or chronic stress, the issue extends beyond individual shortcomings [5], [6], [7]. This raises a critical macroeconomic question regarding whether the educational system itself creates

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systemic friction that renders healthy behaviors unsustainable. This study draws upon three complementary frameworks to model the underlying cognitive and behavioral mechanisms. First, the multiple resource theory [A88] frames cognitive bandwidth and working memory as finite resources that are vulnerable to sleep depletion. Second, the JD-R model [9] classifies excessive academic loads as environmental stressors that deplete internal coping resources. Third, the two-process model of sleep regulation [10] identifies how institutional constraints, such as early-morning classes, structurally induce circadian misalignment.

Higher education constitutes a transitional lifecycle stage characterized by heightened socio-academic and financial burdens. Globally, these conditions frequently precipitate unhealthy behavioral phenotypes, namely, irregular sleep cycles, physical inactivity, dietary imbalances, and high screen dependency among undergraduates [11], [12], [13]. Growing evidence demonstrates that these lifestyle habits are not merely peripheral health indicators but fundamental determinants of academic success [2], [5], [14], with prospective studies linking a single-hour increase in average nightly sleep to a 0.07-point gain in final GPA [15]. This global decline in sleep quality is widespread; a cross-national synthesis indicates a 63% pooled prevalence of poor sleep among African undergraduates [11], matching elevated baseline metrics found across Europe [12]. The Health Promoting Lifestyle Profile II (HPLP-II), a cross-culturally validated metric covering six distinct behavioral dimensions, demonstrates excellent psychometric reliability to quantify these behaviors holistically [13].

These lifestyle vulnerabilities are the downstream consequences of institutional configurations. Inflexible class blocks, clustered deadlines, and deficient campus wellness facilities drastically reduce a student's ability to practice healthy habits [12], [16], [17]. This reflects macro-ergonomic theory [1], which examines how macro-level organizational structures govern microlevel human behaviors. Thus, poor sleep hygiene and lifestyle degradation in students are viewed not as personal psychological failures but as systemic failures of an environment that imposes extreme operational demands without matching structural assets [4], [18]. However, this perspective serves as a guiding theoretical framework rather than a validated empirical mechanism because institutional variables were not explicitly operationalized in this study.

A notable limitation of the current literature is that sleep and lifestyle profiles are typically analyzed in silos by researchers. No prior study has deployed the PSQI and HPLP-II concurrently within a multivariate regression model to assess their joint effect on GPA, particularly within the cohort of Indonesian Industrial Engineering students. This investigation directly resolves this empirical void by: (1) evaluating the individual and combined explanatory power of sleep quality and lifestyle profiles on academic performance, (2) isolating the specific behavioral domains that most heavily dictate GPA variance, and (3) exploring gender as a potential moderating factor. The resulting data seek to inform university administrative design and student support strategies, although it does not constitute prescriptive causal evidence. To address these academic gaps, this study introduces the following novel contributions:

1) Adequate sample size: With 293 participants proportionally distributed across three academic years, the sample size exceeds that of most previous studies in this field (e.g., n = 126 in Rathakrishnan *et al*. [19]; n = 201 in Suardiaz-Muro *et al*. [20]; single-institution medical-student samples in Almalki *et al*. [15]) and allows for more reliable statistical estimates.
2) Domain-level behavioral analysis: This study investigates all six HPLP-II subscales individually instead of considering lifestyle as one combined variable. This approach enables us to determine which specific behaviors (e.g., stress management, health responsibility, and physical activity) have the strongest correlations with GPA and which areas (e.g., nutrition, spiritual growth, and interpersonal relations) fail to achieve significance in the multivariate framework.
3) Transparent statistical reporting: Alongside correlation and regression evaluations, we present diagnostics for multicollinearity (VIF < 3.0) and checks for residual assumptions, clearly outlining the model's limitations and constraints.
4) Contextually grounded findings: We provide data from a Southeast Asian perspective that is often overlooked in this literature by positioning the study within an Indonesian engineering curriculum. Scholars and institutions in comparable educational settings may discover the patterns to be more applicable than those derived from Western or medical education studies

2. RELATED WORK

Over the past decade, the influence of sleep quality, lifestyle behaviors, and academic performance has been extensively studied; however, the majority of studies have focused on these variables in isolation rather than in an integrated framework. Empirical evidence derived from the PSQI underscores that poor sleep hygiene is widespread within higher education ecosystems and significantly undermines GPA outcomes among students. Correspondingly, research tracking the HPLP-II underscores that holistic health behaviors are essential for maintaining physical and psychological equilibrium, which indirectly supports cumulative academic achievement [2], [21]. As noted

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Table 1. Comparison of related studies on sleep quality, lifestyle, and academic performance

Author(s)	Year	Sample	Instrument	Key Findings	Lifestyle Measured	Strengths	Limitations / Research Gap Addressed by the Present Study
Rathakrishnan *et al*. [19]	2021	n = 126; undergrad, Sabah University, Malaysia	PSQI + CGPA	r = 0.342, p < 0.05 between the sleep quality and CGPA scores	No	Validated PSQI and direct GPA correlation	No lifestyle assessment; small n; no regression model
Almalki *et al*. [15]	2025	Medical students in Saudi Arabia	PSQI + academic records	Poor sleepers showed lower academic performance; scheduling affects sleep	No	Institutional Factor Analysis: Recent Longitudinal Data	Single discipline (medicine); limited generalizability; no lifestyle assessment
Nakie *et al*. [11]	2024	35 studies in 11 African countries	PSQI (meta-analysis)	63% prevalence of poor sleep; stress and device use as risk factors	Partial	Large evidence base and cross-country synthesis	No GPA link; aggregated data only; no lifestyle regression
Chao [21]	2023	University students; Taiwan; n = 1,002	HPLP-II + self-rated health status	HPLP-II domains associated with self-rated health: suboptimal physical activity	Yes (HPLP-II)	Large n, validated HPLP-II, domain-level analysis	No PSQI; no GPA outcome; sleep not modeled
Hashim *et al*. [22]	2023	Dental students in Malaysia	PSQI + GPA records	Sleep deprivation is a significant predictor of lower academic achievement among dental student cohorts	No	Objective GPA; validated PSQI; single institution	No lifestyle measure, single discipline, and no gender sub analysis
Suardiaz-Muro *et al*. [20]	2023	University students; Spain, n = 201	PSQI + actigraphy + GPA	Sleep deprivation correlates with lower GPA during the examination period	No	Multi-method (objective + subjective); focus on the exam period	No HPLP-II; no lifestyle regression; limited to the examination context
Present Study		n = 293; Industrial Engineering, Indonesia	PSQI + HPLP-II + GPA + gender analysis	Integrated model: sleep + lifestyle predicts 29.6% of GPA variance	Yes (HPLP-II, all 6 domains)	First integrated PSQI + HPLP-II + GPA model; gender analysis; large n; SE framework	Cross-sectional design; self-reported data; single department; need for future longitudinal study

above, no prior study has combined both instruments in a single regression model for Indonesian industrial engineering students, a population that demographically and culturally differs from the Western and medical education samples that dominate this literature. Table 1 summarizes key prior studies, highlighting their methodological characteristics and the specific gaps addressed in this study.

3. RESEARCH METHODS

3.1. Study Design and participants

This study adopted a quantitative, cross-sectional design grounded in human factors and ergonomics, treating academic performance as an observable outcome associated with behavioral and environmental factors. Every inference is based on associations; this design does not support causal statements. A total of 293 undergraduate students enrolled in the Industrial Engineering Department of Telkom University, Indonesia, took part voluntarily in this study across the 2022 and 2023 academic years.

Inclusion criteria required that participants: (1) were actively enrolled as undergraduate students in the Industrial Engineering Department at the time of data collection; (2) had completed at least one full academic semester, ensuring a valid cumulative GPA record was available; and (3) provided voluntary informed consent. Exclusion criteria were applied to students who: (1) sent incomplete questionnaire responses on either the PSQI or HPLP-II; (2) were on academic leave or enrolled under a non-standard track; or (3) could not be matched with an official GPA record.

Participants were recruited proportionally across academic years. The final sample comprised students from the second year (n = 89, 30.4%), third year (n = 112, 38.2%), and fourth year (n = 92, 31.4%), reflecting active study cohorts at the time of data collection. Freshman students were omitted from the study due to the absence of completed semester records at the time of data collection to ensure data consistency. Data were collected using a structured Google Form distributed through official institutional channels. The sample composition pertains exclusively to Industrial Engineering students at one particular university in Indonesia; generalizing to other disciplines, institutions, and cultural settings must be done carefully.

3.2. Instrument

The Pittsburgh Sleep Quality Index (PSQI), a validated 19-item self-report scale that generates seven component metrics: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, usage of sleep medication, and daytime dysfunction, was used to measure sleep architecture. Global PSQI scores exceeding 5 serve as the clinical cutoff score for poor sleep quality [23]. Lifestyle profiles were assessed using the Health-Promoting Lifestyle Profile II (HPLP-II), a 52-item Likert-type instrument covering six dimensions: health responsibility, physical activity, nutrition, spiritual growth, interpersonal relations, and stress management. This scale has been validated psychometrically across multiple languages and university student cohorts [13]. Academic performance was operationalized as cumulative GPA obtained from institutional records, providing an objective outcome measure independent of self-report.

3.3. Statistical analysis

Preliminary descriptive statistical analyses were executed to summarize the sample demographics and map foundational variable distributions. Independent samples t-tests were conducted to compare the sleep quality, lifestyle scores, and GPA according to gender. Pearson correlation analyses were performed to assess the associations linking global PSQI scores, HPLP-II behavioral domains, and student GPA. Multiple linear regression was employed to model these relationships and examine the extent to which sleep quality and lifestyle variables were associated with academic performance while controlling for gender. The regression model is designed to clarify relationships among variables; interpretation is limited to the direction, magnitude, and statistical relevance of the connections rather than causal processes. The threshold for statistical significance was established at $\alpha = 0.05$.

Distributional assumptions were assessed before inferential analysis. The Shapiro-Wilk test was applied to the GPA, PSQI global scores, and HPLP-II domain scores. The GPA approximated normality ($W = 0.971$, $p = 0.082$) and HPLP-II total scores were similarly distributed ($W = 0.968$, $p = 0.063$). The PSQI global scores showed a mild positive skew ($W = 0.941$, $p = 0.031$), consistent with the known distributional patterns in the sleep data of students [11]. Note that the assumptions of normality in multiple regression primarily apply to the residuals of the model instead of the original predictors [24]. Residual diagnostics, including standardized residual plots and Q-Q plots, confirmed the absence of assumption violations. Multicollinearity was assessed using variance inflation factor (VIF) metrics; every predictor displayed a VIF < 3.0, that collinearity levels were within an acceptable range. Given the sample size (n = 293), the regression framework is robust to moderate nonnormality in predictor distributions [24].

4. RESULTS AND DISCUSSION

4.1. Participant characteristics

The final sample consisted of 293 undergraduate industrial engineering students with a mean age of 20.4 ± 1.6 years. The cohort comprised 182 female participants (62.1%) and 111 male participants (37.9%). Table 2 presents the baseline descriptive

Table 2. Descriptive statistics for study variables by gender

Variable	Total Mean (SD)	Female Mean (SD)	Male Mean (SD)	T-statistic	p-value
GPA	3.32 (0.36)	3.35 (0.34)	3.29 (0.38)	1.85	0.066
PSQI Global Score	6.41 (2.18)	6.53 (2.21)	6.22 (2.13)	−0.97	0.339
HPLP-II Total Score	2.63 (0.38)	2.59 (0.37)	2.71 (0.39)	2.68	0.008*
- Health Responsibility	2.71 (0.41)	2.80 (0.39)	2.58 (0.44)	4.42	< 0.001*
- Physical Activity	2.38 (0.52)	2.28 (0.50)	2.56 (0.54)	−4.47	< 0.001*
- Nutrition	2.61 (0.45)	2.62 (0.44)	2.59 (0.47)	0.54	0.592
- Spiritual Growth	2.89 (0.46)	2.97 (0.42)	2.75 (0.50)	3.90	< 0.001*
- Interpersonal Relations	2.82 (0.44)	2.88 (0.41)	2.72 (0.47)	2.96	0.003*
- Stress Management	2.34 (0.49)	2.34 (0.49)	2.35 (0.50)	−0.09	0.931

**p < 0.05 (statistically significant); SD = Standard Deviation*

statistics delineating the distribution of the primary study variables

4.2. Prevalence of poor sleep quality

Descriptive analysis of the PSQI global metrics revealed that 170 out of 293 respondents (58.0%) were categorized as poor sleepers (PSQI > 5), with a cohort mean global score of 6.41 (SD = 2.18). The highest PSQI component scores were observed for sleep latency (mean = 1.24) and daytime dysfunction (mean = 1.19), indicating that the student population faced substantial difficulties with sleep initiation and subsequent daytime functional impairment (Fig. 1). Only 17.7% of participants reported a habitual sleep duration reaching or exceeding the recommended 7 h, reinforcing the existing literature regarding widespread sleep deprivation among Asian undergraduate cohorts [11]. Female students showed marginally higher PSQI scores (M = 6.53 vs. M = 6.22), though this difference did not reach statistical significance (p = 0.339).

The prevalence rate of 58% aligns closely with broader regional and international trends. Nakie *et al*. [11] reported a pooled prevalence of 63% across African university populations, whereas Angelillo *et al*. [12] observed comparable elevations within Italian higher education settings. These figures exceed general adult population estimates of approximately 33%, suggesting that the atmosphere of higher education is linked to situations that make it difficult to sleep, a pattern consistent with academic institutions' ergonomic framing as demand-heavy human performance systems [1], [21].

4.3. Sleep quality and academic performance

The bivariate Pearson correlation analysis indicated a significant inverse association between global PSQI metrics and cumulative sleep quality (r = −0.312, p < 0.01), confirming that elevated PSQI scores reflecting poorer sleep quality coincided with diminished academic outcomes (Fig. 2). This trend strongly aligns with the established global literature. For instance, Rathakrishnan *et al*. [19] identified a positive correlation between sleep quality and CGPA (r = 0.342) within a Malaysian undergraduate cohort. Suardiaz-Muro *et al*. [20] demonstrated that sleep deprivation was associated with lower GPA during examination periods. Almalki *et al*. [15] found similar patterns among medical students, with the relationship being sensitive to class scheduling.

Sleep is associated with memory consolidation, synaptic homeostasis, and executive function from a neurocognitive perspective [14], [20]. Students with

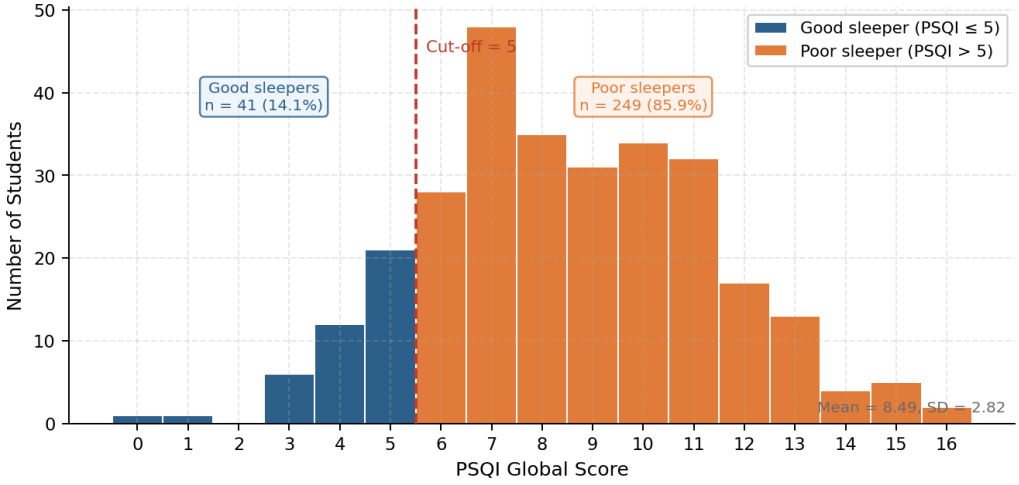
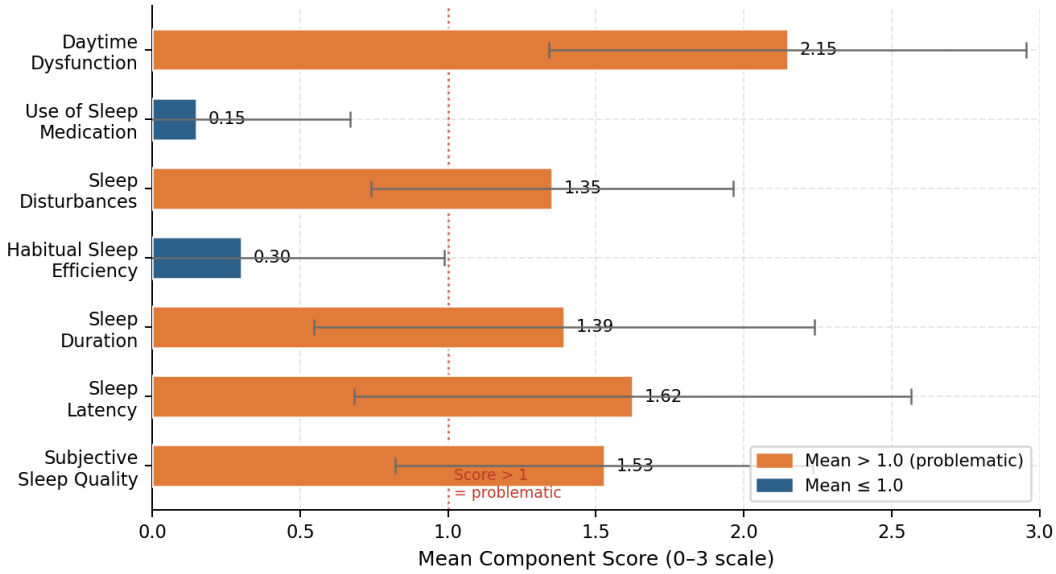


Fig. 1. Distribution of PSQI global scores among industrial engineering students (n = 290)
Orange bars =-poor sleepers (PSQI > 5, n = 249, 85.9%); blue bars = good sleepers. The dashed red line indicates a cut-off score of 5

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Fig, 2. Mean PSQI Component Scores (0–3 scale) Among Students in Industrial Engineering (n = 290)
Error bars represent ±1 SD. Components with mean > 1.0 (orange) indicate clinically meaningful sleep disruption. C7 (daytime dysfunction) and C2 (sleep latency) were the most problematic components.

PSQI scores above 5 may experience impairments in attention, working memory, and analytical reasoning capacities, which are particularly relevant in engineering curricula. The correlation coefficient of r = −0.312 falls within the moderate range reported in meta-analytic estimates (typically r = 0.15–0.35) [11]. Some prior studies have found no statistically significant association between sleep quality and GPA, particularly in Saudi Arabian [18], [25], India [26], Malaysia [27], Egypt [28], and Indonesian student samples. These inconsistencies may reflect moderating variables, such as academic motivation, self-efficacy, and institutional support structures, which were not controlled for in this study.

4.4. Association between health-promoting lifestyle behaviors and academic performance

Among the six HPLP-II domains, stress management (r = 0.267, p < 0.01) and health responsibility (r = 0.231, p < 0.01) showed the strongest positive correlations with GPA. Physical activity also demonstrated a significant positive association (r = 0.187, p < 0.01), whereas spiritual growth (r = 0.143, p < 0.05) and interpersonal relations (r = 0.121, p < 0.05) showed weaker but significant associations. Nutrition demonstrated the weakest and non-significant correlation (r = 0.089, p = 0.132), suggesting that dietary behaviors may have a more distal or mediated relationship with academic performance than stress regulation and health responsibility.

These results are consistent with those of Chao [21], who observed that health responsibility and physical activity were among the strongest lifestyle determinants of health in a Taiwanese sample. A similar consensus is reflected in the findings of Heller *et al*. [2], who found that stress-related behaviors moderated health-academic associations among German university students. Notably, stress management was simultaneously the most strongly associated HPLP-II domain (r = 0.267) and the lowest-scoring domain in the present sample (M = 2.34, SD = 0.49), suggesting that it represents both a high-impact and high-deficit area for this population. The significant positive association of physical activity with GPA, combined with significantly higher physical activity scores among male students (M = 2.56 vs. M = 2.28, p < 0.001), partially accounts for the higher total HPLP-II scores observed in male students, despite the absence of a significant gender difference in GPA.

4.5. Gender-based sleep, lifestyle, and academic performance differences

Independent samples t-tests indicated that cumulative GPA (t = 1.85, p = 0.066) did not vary significantly by gender, although female students tended to have marginally higher GPA (M = 3.35 vs. M = 3.29). Sleep quality did not significantly differ between the sexes (t = −0.97, p = 0.339). Conversely, statistically significant gender-based variations emerged across multiple HPLP-II subscales: female students scored higher in health responsibility (p < 0.001), spiritual growth (p < 0.001), and interpersonal relations (p = 0.003), whereas male students scored significantly higher in physical activity (p < 0.001). The

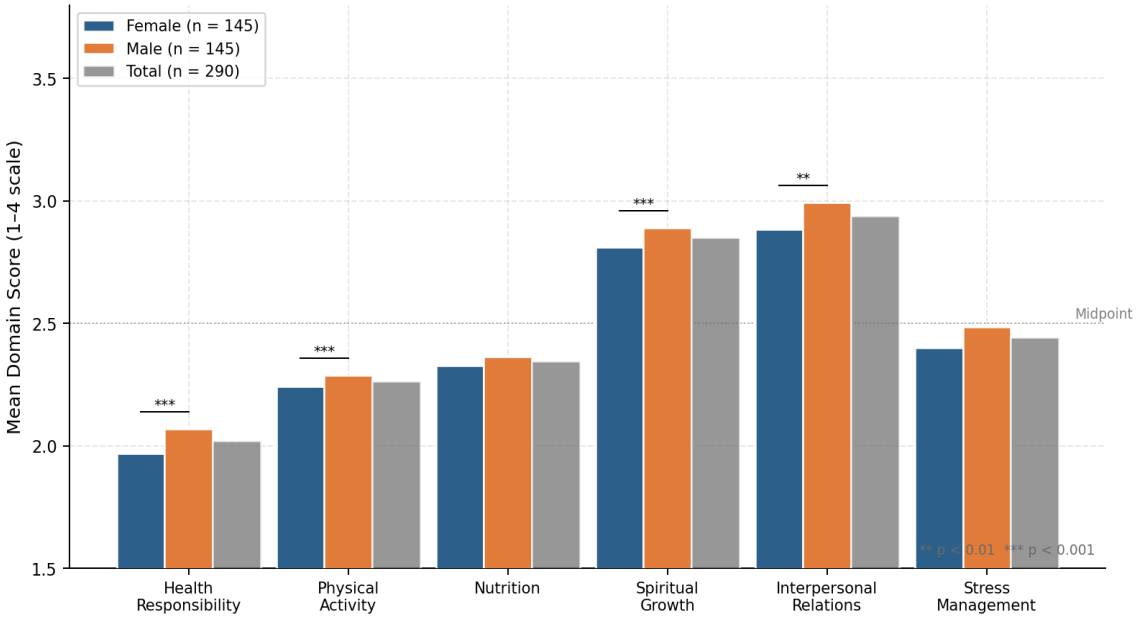


Fig. 3. Mean HPLP-II domain scores by gender (1–4 scale; female n = 145, male n = 145)
*Asterisks indicate statistically significant gender differences (** p < 0.01; *** p < 0.001). Stress management was the domain with the lowest scoring overall*

overall HPLP-II total score was significantly higher for male students (p = 0.008), driven primarily by the physical activity domain (Fig. 3).

These gender patterns are broadly consistent with the literature. Previous literature from Jordan indicates that female undergraduates are more vulnerable to sleep disturbances, which are primarily mediated by psychological stress and rumination [29]. Studies from Taiwan confirmed higher health responsibility but lower physical activity scores among female students [21]. The present findings corroborate these patterns in a Southeast Asian industrial engineering student, cross-cultural consistency in gender-differentiated lifestyle profiles. Despite these lifestyle differences, the absence of a significant gender difference in GPA supports the interpretation that the combined behavioral profile rather than gender is most meaningfully associated with academic outcomes.

4.6. Multiple regression analysis

Multiple regression analysis indicated that sleep quality and lifestyle behaviors together accounted for 29.6% of the GPA variance (Adjusted $R^2 = 0.296$, $F(7, 285) = 18.7$, $p < 0.001$). Table 3 summarizes the regression model. All VIF values were below 3.0, confirming the absence of multicollinearity.

Sleep quality index (PSQI) emerged as the strongest individual correlate of GPA ($\beta = -0.214$, $p < 0.001$), signifying that cumulative GPA decreased by 0.052 points for every unit increase in the global PSQI score. Stress management ($\beta = 0.173$, $p = 0.002$) and health responsibility ($\beta = 0.141$, $p = 0.010$) were the most significant HPLP-II predictors, followed by physical activity ($\beta = 0.103$, $p = 0.023$). When simultaneously evaluated in the multivariate model, the subscales of nutrition, spiritual growth, and interpersonal relations accounted for no unique statistically significant variance. Gender was not a significant predictor when behavioral variables were included ($\beta = -0.031$, $p = 0.437$), suggesting that observed gender differences in lifestyle behaviors do not independently translate into differential GPA outcomes once behavioral variables are controlled (Fig. 4).

The explained variance of 29.6% is higher than

Table 3. Multiple linear regression: GPA predictors

Predictor	B (Unstandardized)	SE	β (Standardized)	t	p-value
(Constant)	2.811	0.187	—	15.03	< 0.001
PSQI Global Score	−0.052	0.009	−0.214	−5.78	< 0.001*
Stress Management (HPLP-II)	0.128	0.042	0.173	3.05	0.002*
Health Responsibility (HPLP-II)	0.098	0.038	0.141	2.58	0.010*
Physical Activity (HPLP-II)	0.071	0.031	0.103	2.29	0.023*
Gender (male = 1)	−0.031	0.040	−0.031	−0.78	0.437

*Note: Adjusted $R^2 = 0.296$; $F(7, 285) = 18.7$; $p < 0.001$. *$p < 0.05$ (statistically significant). SE = Standard Error.*

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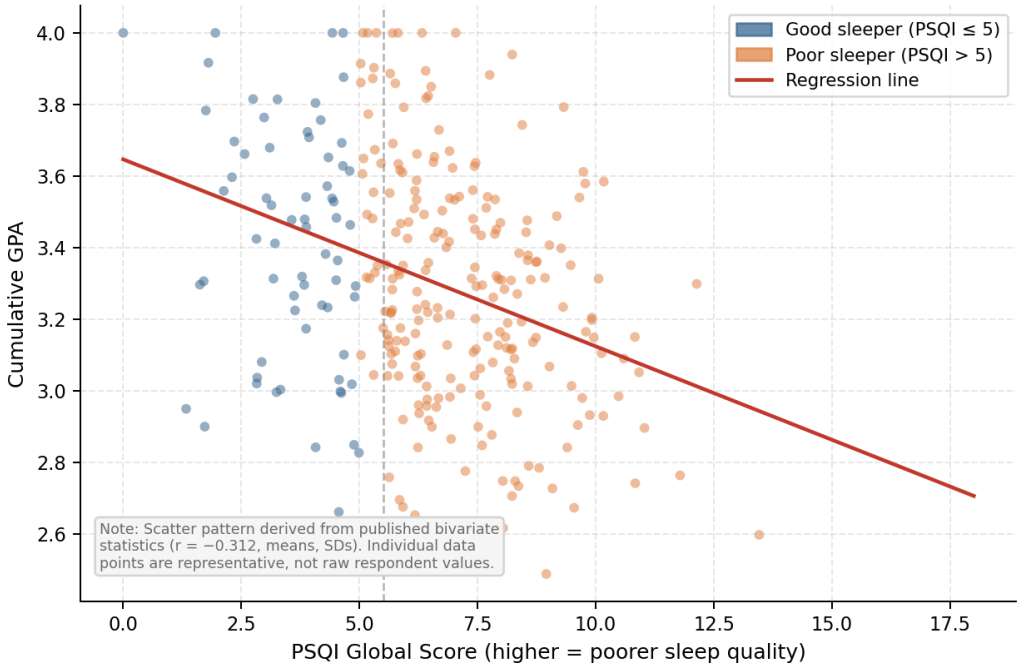


Fig. 4. Scatter Plot Illustrating the Association between the PSQI Global Score and Cumulative GPA ($r = -0.312$, $p < 0.01$; $n = 293$). Orange = poor sleepers (PSQI > 5); blue = good sleepers. Red line = regression line ($\beta = -0.214$)

Note: Scatter patterns were derived from published bivariate statistics; individual GPA values were obtained from institutional records.

that reported in single-domain studies. Models using only PSQI to predict GPA have typically explained 8%–15% of variance [19], [20], whereas lifestyle-only models have yielded comparable but partial results [21]. The integration of both measurement frameworks in this study provides broader explanatory coverage, consistent with the theoretical argument that academic performance reflects multiple interacting behavioral inputs rather than a single domain. However, it should be noted that the direct statistical comparison of R^2 values across studies must be approached with caution, as models differ in sample characteristics, study context, and variable composition. Formal model comparison, such as hierarchical regression or incremental R^2 testing within the same dataset is required to make definitive claims about each behavioral domain's unique contribution.

4.7. Discussion: Contextual and theoretical interpretation

The present findings are interpreted through the lens of HFE and established behavioral frameworks, rather than as direct causal evidence. The Multiple Resource Theory [8] suggests that students operating under chronic sleep deficiency face depletion of attentional and working memory resources when academic tasks demand sustained cognitive engagement. The JD-R model [9] further frames stress management deficits and physical inactivity as indicators of reduced personal resources under a configuration of high academic demand that is theoretically associated with performance impairment. The two-process model of sleep regulation [10] contextualizes the observed sleep latency and daytime dysfunction scores as physiologically plausible consequences of early morning class schedules imposed by circadian misalignment.

From a macro-ergonomic perspective, the high prevalence of poor sleep and low stress management scores in this sample may reflect, in part, the academic environment's structural features, such as early start times, dense scheduling, and limited recovery infrastructure. However, because these environmental factors were not directly measured or included as variables in the present study, any attribution of student outcomes to institutional design must remain speculative. Future studies incorporating system-level variables (e.g., scheduled course load, campus facility access hours, and commuting time) are needed to empirically test such claims.

Table 4 presents the present regression outcomes alongside comparable published studies. Direct numerical comparisons of Adjusted R^2 across these studies are indicative rather than definitive, given differences in sample characteristics, study context, instrument combinations, and model specifications.

Rathakrishnan *et al.* [19] established a baseline using the PSQI as the sole predictor, which explained 11.7% of the GPA variance among Malaysian undergraduates. Suardiaz-Muro *et al.* [20] augmented

Table 4. Comparison of regression outcomes with those of prior studies

Study	Predictors	Adj. R^2	Significant Predictors	Context
Rathakrishnan *et al*. [19]	PSQI only	0.117	Sleep quality	Malaysia; undergrad
Suardiaz-Muro *et al*. [20]	PSQI + actigraphy	0.142	Sleep deprivation	Spain; multi-faculty
Chao [21]	HPLP-II domains	0.183	Physical activity and nutrition	Taiwan; university
Heller *et al*. [2]	Health behaviors + mindfulness	0.228	Physical activity and sleep	Germany; university
Present Study	PSQI + HPLP-II + Gender	**0.296**	Keywords: PSQI, stress management, health responsibility, physical activity	Indonesia; engineering

Note. Direct comparison of the Adj. R^2 values across studies is limited by differences in sample composition, study context, variable selection, and model specifications. Values are presented for reference only

this by adding actigraphy, yielding 14.2%. Chao [21], focused entirely on HPLP-II, explaining 18.3%, but omitted sleep as a predictor. Heller et al. achieved 22.8% by integrating health behaviors with mindfulness. By incorporating both PSQI and all six HPLP-II domains, the present study reached 29.6%. This pattern is consistent with the theoretical expectation that a broader behavioral measurement framework captures more of the variance in academic outcomes, consistent with the incremental validity principle that combining measures from distinct behavioral domains tends to explain more outcome variance than any single domain alone [2], [21]. However, given the heterogeneity across studies, the progressive increase across Table 4 should not be interpreted as direct evidence of model superiority.

Practical considerations implied by these associations include the potential value of institutional attention to the following: (1) academic schedule design that accommodates students' biological sleep needs; (2) accessible stress management resources rather than optional; and (3) physical activity infrastructure that reduces participation barriers. These suggestions are consistent with the evidence from Tadros *et al*. [30], who found that psychological interventions significantly improved sleep quality in university students. However, direct longitudinal testing is required to confirm translation to GPA improvement.

4.8. Research implications

The results reinforce the usefulness of applying the HFE framework, specifically the MRT [8], and the JD-R model [9] to academic performance contexts. Notably, it is not simply that sleep and lifestyle matter for GPA, which prior work has already suggested, but that they matter in combination: the two-domain model accounts for 29.6% of GPA variance, compared to 8%–15% in sleep-only models [19], [20], and 18.3% in lifestyle-only models [21]. This gap suggests that behavioral resources for academic performance operate simultaneously across multiple domains, not in isolation. The finding that stress management is simultaneously the strongest lifestyle predictor and the lowest-scoring domain in this sample is particularly telling it points to a specific behavioral bottleneck worth targeting in both research and practice.

The pattern of results has some concrete, if preliminary, relevance for university program design. Because the cross-sectional design does not allow causal conclusions, we do not claim that changing sleep quality will directly increase GPA. However, the data suggest that students with poorer sleep and lower stress management scores consistently appear in the lower GPA range in this sample, a pattern worth taking seriously when designing student support programs. Specifically, universities may wish to: (1) review whether early morning class schedules create structural sleep deficits that cannot be resolved by individual effort alone; (2) make stress management training such as cognitive behavioral therapy (CBT)-I components or structured mindfulness sessions a standard part of the student support offer rather than an optional extra; (3) evaluate whether physical activity facilities are genuinely accessible given students' timetable loads; and (4) consider using the PSQI and HPLP-II as periodic screening tools to identify at-risk students early in the semester. These are not prescriptions; they are data-informed questions that administrators and curriculum designers may find valuable. Any policy changes in these areas should be piloted and evaluated prospectively, not assumed to produce GPA gains based on this cross-sectional evidence alone [30].

The dual-instrument framework's performance suggests a practical benchmark for future work in this area. Studies that use only the PSQI or HPLP-II are likely to leave a substantial proportion of behavioral variance unexplained. Future studies should at minimum combine both instruments and where resources allow extend toward: actigraphy-based sleep measurement for objective comparison; longitudinal tracking of GPA across multiple semesters to establish temporal ordering; and samples spanning multiple departments and institutions to test whether these patterns hold beyond IE students at a single Indonesian university. Importantly, measuring system-level

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variables, such as course load density, facility access hours, and commuting time [1], [31], alongside individual behavioral measures would allow researchers to empirically test, rather than merely invoke, the macro-ergonomic hypothesis that institutional design shapes student behavioral resources.

5. CONCLUSION

This study examined the associations between sleep quality (PSQI) and health-promoting lifestyle behaviors (HPLP-II) and academic performance (GPA) among 293 industrial engineering students at Telkom University, Indonesia, a population and context underrepresented in the literature on integrated sleep-lifestyle-academic performance. In cross-sectional correlation and multiple regression analyses, both behavioral domains showed significant independent associations with GPA, with sleep quality emerging as the strongest individual correlate and stress management and health responsibility as the most significant lifestyle predictors. The integrated behavioral model explained a greater proportion of GPA variance than prior single-domain models, although contextual and methodological heterogeneity limited direct cross-study comparisons. Gender was not independently associated with GPA when the behavioral covariates were controlled, despite significant differences in the specific lifestyle domain scores. These findings are consistent with HFE frameworks that conceptualize academic performance as a behavioral system output shaped by multiple interacting inputs and extend the application of such frameworks to the context of Indonesian industrial engineering students.

The limitations of the current study should be noted. Due to the cross-sectional design, directional causality cannot be inferred, and the identified relationships should be interpreted with caution. The dependence on self-reported data for both the PSQI and HPLP-II inventories exposes the findings to inherent subjective response biases. The sample is limited to one department at a single Indonesian university, restricting generalizability across disciplines, institutions, and cultural contexts. Unmeasured confounders, including socioeconomic status, mental health status, academic motivation, and family support, may have influenced both the predictor and outcome variables. The absence of system-level variables (e.g., schedule design, facility access hours) limits the capacity to empirically evaluate the proposed macro-ergonomic interpretations.

To establish temporal directionality, future research should employ longitudinal designs with objective sleep measurement (e.g., actigraphy) and semester-by-semester GPA tracking. Multi-institutional, cross-disciplinary, and international studies would enhance the generalizability of the findings. Randomized controlled trials targeting the behavioral domains identified here, particularly stress management and sleep quality, would provide the causal evidence needed to translate these associations into evidence-based institutional policy.

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