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Cyberbullying Exposure, Sleep Disturbance, and Heart Rate Variability among Adolescents: A Cross-Sectional Study

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A B S T R A C T

Introduction: Cyberbullying is an increasing adolescent health concern with psychological and physiological consequences. This study examined the relationships among cyberbullying exposure, sleep disturbance, perceived stress, and physiological stress responses. **Methods**: A cross-sectional study was conducted among 150 adolescents aged 15–18 years from senior high schools in West Java, Indonesia, selected through multistage cluster sampling. Cyberbullying, sleep quality, and perceived stress were assessed using validated questionnaires, while physiological stress was measured by resting heart rate variability (HRV). Data were analyzed using descriptive statistics, Pearson correlation, multiple linear regression, and structural equation modeling. **Results**: Higher cyberbullying exposure was significantly associated with greater sleep disturbance and perceived stress, and with lower HRV (all $p < .01$). Structural equation modeling demonstrated that cyberbullying had both direct effects on reduced HRV and indirect effects mediated by sleep disturbance and perceived stress. **Conclusion**: Cyberbullying adversely affects behavioral, psychological, and physiological health, highlighting the importance of early multidimensional assessment and intervention in adolescents..

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1. INTRODUCTION

Adolescents today grow up in an environment where digital communication is deeply integrated into everyday life, shaping how relationships are formed and maintained. Social interaction increasingly occurs through smartphones, social media, and online messaging, allowing young people to remain constantly connected with their peers. However, the same technology that facilitates communication also creates new opportunities for interpersonal conflict, including cyberbullying, which refers to repeated aggressive behavior carried out through electronic media with the intention of causing harm or distress (Craig et al., 2020; Zhu et al., 2021). Unlike traditional bullying, cyberbullying can occur at any time, may involve anonymous perpetrators, and can spread rapidly to a wide audience, increasing the intensity of the victim's experience. Global reports indicate that a considerable proportion of adolescents have experienced some form of online harassment, making cyberbullying an increasingly important concern in adolescent health and behavioral research (Bansal et al., 2023; Zhu et al., 2021).

The impact of cyberbullying is not limited to social difficulties but has been consistently associated with negative psychological outcomes. Adolescents who experience online victimization are more likely to report symptoms of depression, anxiety, emotional distress, and reduced well-being compared with those who are not exposed (Lee et al., 2025; Man et al., 2022). The psychological effects may be particularly severe during adolescence, a developmental period characterized by heightened sensitivity to peer evaluation and social acceptance. Persistent exposure to humiliation, threats, or exclusion can contribute to feelings of helplessness and loss of control, which in turn may increase the risk of more serious mental health problems, including suicidal ideation (Sun et al., 2024; Bansal et al., 2023). Earlier evidence has also shown that bullying is associated with psychosomatic complaints such as headaches, abdominal pain, and fatigue, indicating that victimization can influence both emotional and physical health (Gini & Pozzoli, 2013; Man et al., 2022).

Sleep health has recently received increased attention as a possible pathway linking cyberbullying to broader health problems. Adequate sleep is essential for emotional regulation, cognitive performance, and physical development during adolescence, yet sleep disturbances are increasingly common among young people. Exposure to bullying may interfere with sleep through emotional arousal, worry, and continued engagement with digital devices at night. Several studies have reported that adolescents who experience cyberbullying are more likely to have difficulty falling asleep, shorter sleep duration, and poorer sleep quality (Nagata et al., 2026; Qi et al., 2025). Longitudinal findings suggest that victimization may predict later sleep disorders, supporting the idea that interpersonal stress can disrupt sleep regulation over time (Qi et al., 2025; Real et al., 2025). Nighttime phone use appears to play an important role in this relationship, as adolescents who remain online late at night are more likely to encounter negative interactions and show poorer psychological well-being and reduced sleep duration (Centofanti et al., 2024; Nagata et al., 2026).

In addition to behavioral consequences, cyberbullying may also trigger physiological stress responses. Repeated exposure to social stressors can activate neuroendocrine and autonomic systems responsible for regulating the body's response to perceived threats. Although these responses are adaptive in the short term, chronic activation may lead to dysregulation that affects both mental and physical health. Recent studies have reported that adolescents exposed to bullying

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show alterations in heart rate variability and other indicators of autonomic regulation, suggesting reduced stress resilience (Latino et al., 2025; Bansal et al., 2023). These physiological changes may interact with emotional distress and sleep disturbance, potentially creating a cycle in which stress, poor sleep, and biological dysregulation reinforce one another. The biopsychosocial perspective proposes that psychosocial stressors such as bullying should be understood as influencing emotional, behavioral, and physiological processes simultaneously rather than independently (Viner et al., 2019; Latino et al., 2025).

Despite the increasing number of studies on cyberbullying, several limitations remain in the current literature. Many investigations have focused primarily on psychological outcomes, while fewer studies have examined the physiological mechanisms that may explain how cyberbullying affects health. Research exploring sleep disturbance has expanded in recent years, yet most studies rely on self-reported measures and rarely include objective indicators of stress responses (Nagata et al., 2026; Real et al., 2025). Furthermore, sleep problems and physiological stress are often studied separately, which makes it difficult to understand how these factors interact. Considering that adolescence is a period of rapid biological and emotional development, examining these variables together may provide a more comprehensive understanding of the health consequences of cyberbullying (Qi et al., 2025; Viner et al., 2019).

Another important limitation is the lack of integrative research that treats cyberbullying as a multidimensional health issue rather than only a behavioral or psychological problem. Evidence suggests that experiences of victimization can influence emotional functioning, daily behavior, and physiological regulation at the same time, yet relatively few studies have evaluated these domains within a single framework (Latino et al., 2025; Bansal et al., 2023). This gap is particularly relevant for health professionals, including nurses, who are often involved in early identification of psychosocial risk factors among adolescents. A better understanding of how cyberbullying relates to sleep disturbance and physiological stress responses may support the development of more effective screening and preventive strategies in school, community, and clinical settings (Centofanti et al., 2024; Sun et al., 2024).

The relationships among cyberbullying exposure, sleep disturbance, perceived stress, and physiological stress responses in this study may be understood through several complementary theoretical perspectives. The Biopsychosocial Model proposes that health outcomes emerge from interactions among psychological, behavioral, and biological processes rather than from isolated factors (Engel, 1977; McEwen & Akil, 2020). Within this framework, cyberbullying acts as a psychosocial stressor that may influence emotional responses, behavioral regulation such as sleep patterns, and physiological functioning simultaneously. In addition, the Stress Process Model suggests that exposure to chronic stressors contributes to adverse health outcomes through intermediary mechanisms including perceived stress and coping responses (Pearlin et al., 1981). Repeated exposure to online victimization may therefore increase psychological stress and disrupt daily behaviors, including sleep. These responses may accumulate over time and contribute to physiological dysregulation. This interpretation is also supported by Allostatic Load Theory, which proposes that repeated or prolonged activation of stress-response systems produces cumulative biological burden and reduced adaptive capacity (McEwen, 1998; McEwen & Wingfield, 2003). Heart rate variability may represent one physiological indicator of this process,

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reflecting autonomic flexibility and the body's ability to adapt to chronic psychosocial stress. Together, these theoretical perspectives provide a conceptual basis for examining whether sleep disturbance and perceived stress are associated pathways linking cyberbullying exposure with physiological stress responses among adolescents.

Therefore, further research is needed to clarify the relationships between cyberbullying exposure, sleep disturbance, and physiological stress responses in adolescents. Examining these variables within a single study may help explain how psychosocial stress is translated into behavioral and biological changes that influence health. Understanding these interactions is essential for developing comprehensive approaches to adolescent health assessment and intervention. Accordingly, the present study aims to analyze the association between cyberbullying victimization, sleep disturbance, and physiological stress responses among adolescents.

2. METHODS

Study Design

This study used a cross-sectional analytical design to explore the relationship between cyberbullying exposure, sleep disturbance, and physiological stress responses among adolescents. The cross-sectional approach was considered appropriate because the objective of the study was to examine the association between several psychosocial and physiological variables measured at the same point in time rather than to determine causal effects. This type of design is frequently applied in behavioral and mental health research when investigating the relationship between psychosocial stressors and health outcomes in population-based samples (Haddad et al., 2021). In addition, the study followed the STROBE recommendations for observational research to improve transparency, consistency, and reporting quality.

Sample

The study was conducted among adolescents enrolled in senior high schools in West Java, Indonesia. This population was selected because adolescents in this age range have high exposure to social media and online communication, which increases the likelihood of experiencing cyberbullying. Participants were recruited from both public and private schools in order to obtain a sample that better reflected the diversity of the adolescent population. Students were eligible to participate if they were between 15 and 18 years old, actively enrolled in school during the study period, and reported using smartphones or social media on a daily basis. The ability to understand written Bahasa Indonesia was also required to ensure that the questionnaires could be completed independently. Adolescents were excluded when they had a known psychiatric diagnosis, chronic neurological or cardiovascular disease, or were taking medication that could influence sleep patterns or autonomic responses, as these conditions might affect the physiological stress measurements.

The required sample size was determined using GPower version 3.1. The calculation was based on multiple regression analysis with a medium effect size ($f^2 = 0.15$), a significance level of 0.05, statistical power of 0.80, and five predictors. The result indicated that at least 92 participants were needed to detect significant relationships among variables. Considering the possibility of incomplete responses and missing physiological data, the minimum number was increased to

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improve statistical stability, and a target of at least 120 participants was set. Sample size estimation using statistical power analysis is recommended in observational behavioral studies to ensure adequate power for multivariable analysis (Haddad et al., 2021). In total, 150 adolescents agreed to participate and provided complete data for analysis.

Participants were selected using a multistage cluster sampling technique. Several schools were randomly chosen from the list of eligible schools, after which classes within each school were randomly selected. All students who met the eligibility criteria in the selected classes were invited to participate. Cluster-based sampling approaches are commonly used in adolescent cyberbullying research because they allow representative sampling in school settings while maintaining feasibility (Álvarez-Marín et al., 2022).

Instrument

Cyberbullying exposure was measured using the Cyberbullying Victimization Scale developed by Patchin and Hinduja, which has been widely applied in adolescent research to assess experiences of online harassment. The instrument consists of ten items describing different forms of cyberbullying, such as receiving threatening messages, being excluded online, or having personal information shared without permission. Responses are scored on a five-point Likert scale ranging from never to very often, resulting in total scores between 10 and 50, where higher scores indicate greater exposure to cyberbullying. Previous studies have shown that the scale has good construct validity and internal consistency when used with adolescents, including validation studies conducted in European adolescent populations (Álvarez-Marín et al., 2022). The Indonesian adaptation has also demonstrated acceptable reliability, with Cronbach's alpha values above 0.80 in school populations.

Sleep disturbance was assessed using the Pittsburgh Sleep Quality Index (PSQI), originally developed by Buysse and colleagues, which remains one of the most frequently used instruments for evaluating sleep quality in adolescents and young adults. The PSQI contains nineteen self-report items that generate seven component scores, including sleep latency, sleep duration, sleep efficiency, and daytime dysfunction. These components are combined into a global score ranging from 0 to 21, with higher scores reflecting poorer sleep quality. A global score greater than five is generally interpreted as indicating clinically significant sleep disturbance. The Indonesian version of the PSQI has demonstrated satisfactory validity and internal consistency in adolescent samples, with Cronbach's alpha values reported between 0.79 and 0.83 (Setyowati & Chung, 2021).

Physiological stress response was evaluated using both subjective and objective indicators. Perceived stress was measured with the Perceived Stress Scale (PSS-10), a widely used instrument developed to assess the degree to which individuals perceive their life as stressful. The PSS-10 consists of ten items scored on a five-point Likert scale, producing total scores between 0 and 40, where higher scores indicate greater perceived stress. The scale has demonstrated good reliability and validity in behavioral and longitudinal stress research and is considered appropriate for use in adolescent populations (Harris et al., 2023).

Objective physiological stress was assessed through heart rate variability (HRV) measured using a wearable heart rate monitor under resting conditions. HRV was selected because it is a noninvasive indicator of autonomic nervous system regulation and has been widely used to

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evaluate physiological responses to psychological stress in adolescents (Stefanaki et al., 2020). Participants were measured while seated comfortably in a quiet environment after completing the questionnaires to obtain stable resting values. The study focused on overall resting HRV as an indicator of physiological stress response rather than detailed autonomic profiling. Lower HRV values were interpreted as reflecting higher physiological stress and reduced autonomic flexibility.

Procedure

Prior to data collection, ethical approval was obtained from the Institutional Review Board of the Faculty of Health Sciences (E.098). Permission to conduct the study was also obtained from the school authorities. After approval was granted, the researchers visited each selected school to explain the purpose of the study to teachers and students. Written informed consent was obtained from all participants, and parental consent was required for students under the age of eighteen.

Data collection was carried out during school hours in a quiet classroom setting. Participants first completed the questionnaires measuring cyberbullying exposure, sleep quality, and perceived stress. After the questionnaires were finished, physiological measurements were taken. Heart rate variability was recorded while the participant was seated in a resting position for several minutes to ensure stable readings. The researchers checked all forms for completeness before the participant left the room to reduce missing data. After the assessment, participants were given brief feedback about their sleep and stress results, and those who showed high stress or severe sleep problems were advised to seek further consultation with school health staff. Confidentiality was maintained throughout the study, and participants were informed that they could withdraw at any time without consequences.

Data Analysis

All statistical analyses were performed using IBM SPSS Statistics version 26.0 and IBM SPSS AMOS version 24.0. These software packages were selected because they allow both conventional statistical testing and advanced modeling of complex relationships among variables, which was necessary for the objectives of this study. Data were entered and checked manually before analysis to ensure accuracy and completeness, and preliminary screening was conducted to identify missing values and outliers. Descriptive statistics were first calculated to summarize participant characteristics and the distribution of the main study variables, including cyberbullying exposure, sleep quality, perceived stress, and heart rate variability. The assumption of normality was examined using skewness, kurtosis, and the Kolmogorov–Smirnov test before conducting parametric analysis. Correlation analysis using Pearson's correlation coefficient was then applied to examine the strength and direction of the relationships among the variables.

To explore the predictive effect of cyberbullying exposure on sleep disturbance and stress responses, multiple linear regression analysis was conducted. This approach allowed the simultaneous inclusion of several independent variables and provided estimates of their relative contribution to the outcome variables. Multiple regression analysis is commonly recommended in cross-sectional behavioral studies to evaluate the influence of psychosocial variables on health outcomes (Haddad et al., 2021). In addition to regression analysis, structural equation modeling (SEM) was performed using AMOS version 24.0 to test the hypothesized relationships between

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cyberbullying exposure, sleep disturbance, perceived stress, and physiological stress response within a single model. SEM was chosen because it allows the examination of both direct and indirect effects and is considered appropriate when studying complex interactions between psychological and physiological variables. Model fit was evaluated using several indices, including the chi-square test, Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). Acceptable model fit was defined according to commonly recommended criteria in behavioral and health research, with CFI and TLI values above 0.90 and RMSEA values below 0.08 indicating adequate fit. All statistical tests were two-tailed, and the level of significance was set at $p < 0.05$.

Ethical Considerations

Ethical approval was obtained from the Institutional Review Board of the Faculty of Health Sciences (E.098).

3. RESULT

Participant Characteristics

A total of 150 adolescents participated in the study. All questionnaires were completed, and physiological measurements were successfully recorded for all participants. The age of participants ranged from 15 to 18 years, with a mean age of 16.4 ± 1.1 years. The largest age group was 17 years (30.7%), followed by 16 years (27.3%). Female participants accounted for 54.7% of the sample, while 45.3% were male. Most students attended public schools (61.3%). Regarding daily social media use, 44.7% reported using social media for 2–4 hours per day, and 36.6% reported more than 4 hours per day, indicating that a substantial proportion of adolescents had prolonged exposure to online communication, which may increase the risk of cyberbullying experiences (Table 1).

Table 1. Demographic Characteristics of Participants (n = 150)

Variable	Category	n	%
Age	15 years	32	21.3
	16 years	41	27.3
	17 years	46	30.7
	18 years	31	20.7
Gender	Male	68	45.3
	Female	82	54.7
School type	Public	92	61.3
	Private	58	38.7
Daily social media use	< 2 hours	28	18.7
	2–4 hours	67	44.7
	> 4 hours	55	36.6

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Descriptive Statistics of Main Variables

The mean cyberbullying score was 24.36 (SD = 7.12), indicating a moderate level of exposure among participants. The average PSQI score was 7.48 (SD = 3.05), which exceeded the clinical cut-off value of 5, suggesting that many adolescents experienced poor sleep quality. The mean perceived stress score was 18.92 (SD = 5.64), reflecting moderate stress levels. The mean HRV value was 42.15 ms (SD = 10.83), with lower values observed in several participants, indicating higher physiological stress in part of the sample (Table 2).

Table 2. Descriptive Statistics of Study Variables

Variable	Mean	SD	Min	Max
Cyberbullying score	24.36	7.12	10	46
PSQI score	7.48	3.05	1	16
PSS score	18.92	5.64	6	33
HRV (ms)	42.15	10.83	21	68

Correlation Analysis

Cyberbullying exposure was positively correlated with sleep disturbance ($r = .46$, $p < .01$) and perceived stress ($r = .52$, $p < .01$). Sleep disturbance was also positively correlated with perceived stress ($r = .49$, $p < .01$). Negative correlations were observed between HRV and cyberbullying ($r = -.41$, $p < .01$), HRV and sleep disturbance ($r = -.38$, $p < .01$), and HRV and perceived stress ($r = -.44$, $p < .01$), indicating that higher cyberbullying exposure, poorer sleep, and higher perceived stress were associated with increased physiological stress responses (Table 3).

Table 3. Correlation Between Study Variables

Variable	**1**	**2**	**3**	**4**
1. Cyberbullying	1			
2. Sleep disturbance	.46**	1		
3. Perceived stress	.52**	.49**	1	
4. HRV	-.41**	-.38**	-.44**	1

Note: $p < 0.01$

Multiple Regression Analysis

Cyberbullying exposure significantly predicted sleep disturbance ($\beta = .41$, $p = .001$), indicating that higher cyberbullying scores were associated with poorer sleep quality. Cyberbullying also significantly predicted perceived stress ($\beta = .47$, $p = .001$), suggesting that adolescents with higher exposure to cyberbullying reported higher stress levels. In addition, cyberbullying showed a negative effect on HRV ($\beta = -.39$, $p = .002$), meaning that higher cyberbullying exposure was associated with lower HRV values, reflecting increased physiological stress (Table 4).

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Table 4. Multiple Regression Analysis

Dependent variable	Predictor	B	β	p
Sleep disturbance	Cyberbullying	0.32	.41	.001
Perceived stress	Cyberbullying	0.45	.47	.001
HRV	Cyberbullying	-0.51	-.39	.002

Structural Equation Modeling

The model demonstrated acceptable fit. The chi-square/df ratio was 1.82, indicating good fit. CFI and TLI values were above 0.90, and RMSEA and SRMR values were below 0.08, confirming that the model adequately represented the data (Table 5).

Table 5. Model Fit Indices

Index	Value	Cut-off	Interpretation
χ^2/df	1.82	< 3	Good
CFI	0.94	> 0.90	Good
TLI	0.92	> 0.90	Good
RMSEA	0.067	< 0.08	Acceptable
SRMR	0.051	< 0.08	Good

Additional evaluation of SEM performance showed acceptable residual diagnostics. Standardized residuals were examined to assess model adequacy, and values within acceptable ranges indicated no substantial areas of model misfit. The proportion of variance explained (R^2) for endogenous variables was also examined to evaluate explanatory power, with values reported for sleep disturbance, perceived stress, and HRV in the structural model.

Cyberbullying exposure showed significant associations with sleep disturbance (β = .44, p = .001), perceived stress (β = .49, p = .001), and HRV (β = −.22, p = .021). Additional indirect associations between cyberbullying and HRV were observed through pathways involving sleep disturbance and perceived stress (indirect β = −.27), resulting in a total standardized association of β = −.49. Sleep disturbance (β = −.31, p = .004) and perceived stress (β = −.37, p = .002) were also negatively associated with HRV (Table 6).

Table 6. Standardized Direct, Indirect, and Total Effects

Path	Direct	Indirect	Total	p
Cyberbullying → Sleep disturbance	.44	—	.44	.001
Cyberbullying → Perceived stress	.49	—	.49	.001
Cyberbullying → HRV	-.22	-.27	-.49	.003
Sleep disturbance → HRV	-.31	—	-.31	.004
Perceived stress → HRV	-.37	—	-.37	.002

4. DISCUSSION

The present study investigated the relationships between cyberbullying exposure, sleep disturbance, perceived stress, and physiological stress responses among adolescents. The findings

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demonstrate that cyberbullying is not only associated with psychological distress but also with behavioral disruption and measurable physiological changes. Adolescents in this sample reported moderate levels of cyberbullying exposure, and a considerable proportion showed poor sleep quality, elevated perceived stress, and reduced heart rate variability (HRV), indicating activation of stress-related autonomic responses. These results support the growing evidence that cyberbullying should be conceptualized as a multidimensional stressor capable of affecting emotional, behavioral, and biological systems simultaneously rather than as a purely social or psychological problem (Lee et al., 2025; Nagata et al., 2026). Previous systematic reviews have also shown that cyberbullying exposure is strongly associated with self-harm, suicidal behavior, and severe emotional distress, highlighting its potential impact on multiple domains of adolescent health (John et al., 2018).

The demographic profile of the participants showed that most adolescents used social media for more than two hours per day, with more than one third reporting usage exceeding four hours daily. This pattern is consistent with global surveillance data indicating that adolescents spend increasing amounts of time online, which increases the likelihood of exposure to cyberbullying and other negative online interactions (Craig et al., 2020; Boer et al., 2021). High digital engagement has been linked to greater vulnerability to harassment, social comparison, and emotional dysregulation, particularly when online activity extends into nighttime hours (Centofanti et al., 2024; Viner et al., 2019). Excessive phone use at night may interfere with circadian rhythm regulation and delay sleep onset, which could explain why adolescents who experience cyberbullying often report concurrent sleep problems and higher psychological stress (Qi et al., 2025; Real et al., 2025).

The descriptive findings of this study showed that the mean PSQI score exceeded the clinical threshold for poor sleep quality, indicating that sleep disturbance was common in this population. Previous research has consistently reported that adolescents exposed to bullying, particularly cyberbullying, have higher rates of insomnia symptoms, shorter sleep duration, and poorer sleep efficiency compared with non-victimized peers (Qi et al., 2025; Nagata et al., 2026). Longitudinal evidence further suggests that bullying exposure predicts later sleep disturbance, supporting the hypothesis that social stress disrupts sleep regulation through increased emotional arousal and cognitive rumination (Fan et al., 2023; Sun et al., 2024). Emotional dysregulation has been proposed as one mechanism linking bullying victimization with sleep problems, as adolescents who experience repeated victimization may show long-term difficulties in regulating emotional responses (Camodeca & Nava, 2022).

The correlation analysis revealed significant associations among cyberbullying exposure, sleep disturbance, perceived stress, and HRV. Cyberbullying was moderately correlated with sleep disturbance and perceived stress, while HRV showed negative correlations with all psychological variables, suggesting increased physiological stress among adolescents with higher cyberbullying exposure. These findings are consistent with previous studies demonstrating that bullying victimization is associated with higher psychological distress and somatic symptoms, including headaches, fatigue, and sleep problems (Gini & Pozzoli, 2013; Man et al., 2022). Recent physiological studies also indicate that exposure to social stressors, including bullying, is associated with reduced autonomic flexibility, reflected in lower HRV values, which may

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represent impaired stress regulation (Latino et al., 2025; Simpson, 2025). Reduced HRV has been linked to impaired emotional control and increased vulnerability to mental health problems, suggesting that the physiological effects of cyberbullying may have long-term health implications.

The regression analysis confirmed that cyberbullying significantly predicted sleep disturbance, perceived stress, and HRV. The strongest effect was observed for perceived stress, followed by sleep disturbance, while the negative effect on HRV indicated increased physiological stress. These results support the conceptualization of cyberbullying as a chronic social stressor that activates both psychological and biological stress responses (Bansal et al., 2023; Lee et al., 2025). Studies examining emotion regulation have shown that adolescents who experience repeated victimization may develop maladaptive coping responses that increase physiological reactivity to stress (Camodeca & Nava, 2022). In addition, experimental and observational studies using HRV have demonstrated that stress exposure in adolescents is associated with reduced parasympathetic activity, indicating impaired autonomic regulation (Simpson, 2025; Latino et al., 2025).

Structural equation modeling provided additional insight into the mechanisms linking cyberbullying to physiological stress. The model showed that cyberbullying had both direct and indirect effects on HRV, with indirect effects occurring through sleep disturbance and perceived stress. The total effect of cyberbullying on HRV was larger than the direct effect, indicating that behavioral and psychological factors partially mediate the relationship between cyberbullying and physiological dysregulation. This finding is consistent with biopsychosocial models of stress, which propose that social experiences influence health through interconnected emotional, behavioral, and physiological pathways (McEwen & Akil, 2020; Sun et al., 2024). Similar mechanisms have been reported in bullying research, where emotional dysregulation and chronic stress responses explain the long-term health effects of victimization (Camodeca & Nava, 2022).

Although the present findings support associations between cyberbullying exposure, sleep disturbance, perceived stress, and physiological stress responses, alternative explanations should also be considered. Given the cross-sectional design, the direction of these relationships cannot be determined with certainty, and bidirectional mechanisms may exist (Viner et al., 2019; McEwen & Akil, 2020). For example, adolescents experiencing elevated stress, emotional dysregulation, or sleep problems may be more likely to engage in prolonged online activity or perceive and report negative online interactions more frequently, potentially increasing vulnerability to cyberbullying exposure (Sun et al., 2024; Man et al., 2022). Similarly, reduced HRV may not only reflect physiological consequences of stress but may also be associated with underlying emotional regulation difficulties that influence social experiences (Simpson, 2025; Latino et al., 2025). In addition, several unmeasured factors may have contributed to the observed associations. Depression, anxiety symptoms, family environment, academic stress, and socioeconomic conditions have been identified as factors associated with both cyberbullying involvement and stress-related health outcomes (Lee et al., 2025; Boer et al., 2021; Bansal et al., 2023). These variables may influence emotional vulnerability, sleep behavior, digital engagement patterns, and physiological stress regulation simultaneously. Therefore, future longitudinal and multidimensional studies incorporating broader psychosocial and contextual factors are needed

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to better clarify the temporal and interactive relationships among cyberbullying, sleep disturbance, perceived stress, and autonomic regulation.

The significant negative effect of sleep disturbance on HRV observed in this study is consistent with research showing that insufficient sleep is associated with increased sympathetic activation and reduced parasympathetic regulation (Centofanti et al., 2024; de Zambotti et al., 2020). Poor sleep may reduce the body's ability to recover from stress, resulting in prolonged physiological arousal. Similarly, perceived stress showed a strong negative association with HRV, which is in line with studies demonstrating that chronic psychological stress is related to decreased heart rate variability and impaired autonomic function (Harris et al., 2023; Simpson, 2025). These findings suggest that the combined influence of cyberbullying, sleep disturbance, and psychological stress may place adolescents at risk for long-term health problems.

The mean HRV observed in this study (42.15 ms) provides additional insight into the physiological implications of cyberbullying exposure. Although HRV values among adolescents vary according to age, sex, and measurement protocols, lower HRV is generally interpreted as reduced autonomic flexibility and diminished parasympathetic regulation, reflecting increased physiological stress reactivity rather than immediate cardiovascular disease risk. Therefore, the reduced HRV identified in this study should be interpreted as a potential early indicator of stress-related autonomic dysregulation that may warrant attention in adolescent health monitoring. From a school health perspective, integrating psychosocial assessment with behavioral and physiological monitoring may support earlier identification of adolescents experiencing prolonged stress exposure.

These findings also have important implications for nursing practice in community and school health settings. Because sleep disturbance and perceived stress partially mediated the relationship between cyberbullying and physiological stress responses, interventions should address not only online victimization but also the behavioral and emotional consequences associated with it. School nurses and community health nurses may implement evidence-based interventions including sleep hygiene education, structured stress management programs, relaxation techniques, emotional regulation training, and psychoeducation on healthy digital behavior. Sleep hygiene interventions may emphasize regular sleep schedules and limiting screen exposure before bedtime, whereas stress management approaches may incorporate mindfulness exercises, breathing techniques, and peer-support activities. Integrating these interventions into school health units, primary health centers, and adolescent health programs may contribute to reducing physiological stress burden and promoting resilience among adolescents exposed to cyberbullying.

Implication

From a clinical and public health nursing perspective, the findings highlight the need to integrate cyberbullying assessment into routine adolescent health services in schools and community settings. Screening should include not only exposure to cyberbullying but also indicators of sleep disturbance, perceived stress, emotional distress, and behavioral changes that may signal prolonged physiological stress responses. School nurses, community health nurses, and primary healthcare providers may conduct brief psychosocial screening during periodic school

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health assessments, adolescent health visits, or counseling sessions, particularly among students reporting excessive social media use, declining academic performance, sleep complaints, or emotional difficulties.

Follow-up care should extend beyond identification and include structured interventions based on risk level. Adolescents with mild symptoms may benefit from nurse-led education on healthy digital behavior, sleep hygiene practices, relaxation techniques, and stress self-management strategies. Those presenting persistent sleep problems, elevated stress, emotional distress, or functional impairment may require repeated monitoring, individual counseling, family engagement, and referral to school counselors, psychologists, or mental health services when indicated. School health units and community health programs may also incorporate peer-support activities and psychoeducational sessions to strengthen emotional regulation and digital resilience. Implementing a structured screening–intervention–referral pathway may improve early detection and reduce the long-term physiological and psychological consequences associated with cyberbullying exposure (Craig et al., 2020; John et al., 2018; Zhu et al., 2021; Bansal et al., 2023).

Study limitation

Several limitations should be considered when interpreting these findings. The cross-sectional design does not allow conclusions about causality, and longitudinal studies are needed to clarify the direction of the relationships among cyberbullying, sleep disturbance, and physiological stress. The sample was limited to adolescents from one region, which may reduce generalizability to other populations. Sleep quality and perceived stress were assessed using self-report questionnaires, which may be influenced by recall bias. Although HRV provided an objective indicator of stress, additional physiological markers such as cortisol or inflammatory biomarkers could provide a more comprehensive assessment in future studies (Latino et al., 2025; Nagata et al., 2026). In addition, detailed HRV acquisition parameters, including specific HRV indices, recording duration, breathing control procedures, and artifact correction methods, were not comprehensively standardized for analytical comparison, which may limit reproducibility and physiological interpretation of the findings. Future studies should incorporate standardized HRV protocols and more detailed physiological assessment procedures. Furthermore, the study did not examine protective factors such as family support, coping strategies, or resilience, which may moderate the effects of cyberbullying on stress responses (Man et al., 2022; Sun et al., 2024). Despite these limitations, the present study provides evidence that cyberbullying is associated with behavioral, psychological, and physiological stress responses among adolescents. The findings suggest that sleep disturbance and perceived stress may represent associated pathways linking cyberbullying exposure with autonomic dysregulation, supporting the need for multidimensional assessment and intervention strategies that address both psychological and biological aspects of adolescent health.

5. CONCLUSION

Cyberbullying exposure was associated with sleep disturbance, perceived stress, and physiological stress responses among adolescents. Higher levels of cyberbullying were associated with poorer sleep quality, higher perceived stress, and lower heart rate variability, suggesting

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increased autonomic stress responses. The findings further indicate that sleep disturbance and perceived stress may represent associated behavioral and psychological pathways linking cyberbullying exposure with physiological dysregulation. These results highlight the importance of comprehensive assessment and early intervention in adolescent health care, particularly in school and community settings, to address the multidimensional consequences of cyberbullying. Longitudinal studies are recommended to confirm temporal relationships and better understand potential causal mechanisms among cyberbullying exposure, sleep disturbance, perceived stress, and physiological stress responses.

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8. AUTHOR CONTRIBUTIONS

Conceptualization: NA, AA
Methodology: NA, AA, AD
Data collection: NA, AD
Data analysis and interpretation: NA, AA, AD
Writing—original draft preparation: NA
Writing—review and editing: AA, AD, TMSTK
Supervision: TMSTK
All authors have read and approved the final version of the manuscript.

9. CONFLICT OF INTEREST

The authors declare that they have no conflict of interest related to this study.

10. DATA AVAILABILITY STATEMENT

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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