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CUMULATIVE DIGITAL RISK EXPOSURE AND SELF-HARM BEHAVIOR AMONG INDONESIAN ADOLESCENTS

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Background: Self-harm behavior (SHB) among adolescents is a growing public health concern, particularly in the digital era. Exposure to digital risks such as online gaming addiction and cyberbullying victimization may increase vulnerability, especially when multiple risks co-occur. This study examined the association between cumulative digital risk exposure and SHB among Indonesian adolescents and identified associated psychosocial factors.

Methods: A cross-sectional study was conducted among 1,742 Indonesian adolescents recruited using a multistage school-based sampling approach. Data were collected using structured questionnaires assessing sociodemographic characteristics, online gaming addiction, cyberbullying victimization, and SHB. Instruments included the Indonesian Online Game Addiction Questionnaire, the Cyberbullying and Online Aggression Survey Instrument, and the Self-Harm Inventory. Bivariate analyses and multivariable binary logistic regression were performed.

Results: Overall, 33.1% of participants met the criteria for online gaming addiction, 57.5% reported cyberbullying victimization, and 55.0% reported SHB. Based on the cumulative digital risk index, 38.9% of participants had no digital risk, 31.7% had one digital risk, and 29.4% had two digital risks. SHB prevalence differed across digital risk groups (43.3%, 67.8%, and 56.7%, respectively). In multivariable analysis, one digital risk was associated with higher odds of SHB compared with no digital risk (AOR = 2.20, 95% CI: 1.71–2.82), whereas the association for two digital risks was attenuated after adjustment (AOR = 0.56, 95% CI: 0.40–0.78). No significant linear dose–response relationship was observed (p for trend = 0.411). A history of violence (AOR = 4.19, 95% CI: 2.50–7.02), low academic performance, lower parental income, having fewer than three close friends, and parental separation/divorce were independently associated with higher

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odds of SHB, whereas female sex was associated with lower odds (AOR = 0.57, 95% CI: 0.46–0.72).

Conclusion: Cumulative digital risk exposure was associated with SHB among Indonesian adolescents; however, the association did not demonstrate a linear dose–response pattern after adjustment for psychosocial factors. A history of violence emerged as the strongest correlate of SHB, highlighting the importance of addressing both digital and broader psychosocial vulnerabilities in adolescent self-harm prevention.

Keywords: adolescents; cyberbullying; digital risk; online gaming addiction; self-harm behavior

BACKGROUND

Adolescence is a developmental period characterized by significant biological, psychological, and social changes[1]. During this stage, adolescents experience increased vulnerability to stress alongside the development of coping strategies[2]. These conditions place adolescents at greater risk of developing both adaptive and maladaptive coping strategies. One maladaptive coping behavior that commonly emerges is self-harm behavior (SHB)[3]. Other terms frequently used to describe this behavior include self-injurious behavior (SIB), non-suicidal self-injury (NSSI), self-mutilation, self-inflicted injury, self-directed violence, self-destructive behaviour, and self-abuse.

SHB is a broad category of intentional self-injurious behaviors that may occur with or without suicidal intent, encompassing both suicide attempts, which involve intent to die, and NSSI, which is performed without such intent [4,5]. SHB serves multiple functions, predominantly intrapersonal purposes such as emotion regulation, while also fulfilling interpersonal functions [6].

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The most widely researched non-suicidal reasons for self-harm were dealing with distress and exerting interpersonal influence[7].

Globally, SHB has decreased since 1990, but trends are not uniform across countries, the burden is more concentrated in low-SDI countries[8], but previous studies have shown that the prevalence of SHB among adolescents is relatively high across various countries[9–11]. This behavior is associated with several psychological factors, including difficulties in emotion regulation, stress, depression, as well as negative social experiences or psychological distress [12–15]. In addition to psychological factors, the development of digital technology has increasingly been considered an environmental factor that may influence SHB. Among various forms of digital technology, social media is one of the most frequently used platforms by adolescents and has attracted considerable attention due to its potential influence on mental health and SHB. Social media has become a space for self-harm expression and the formation of online communities among adolescents and young adults[16,17]

One of the most widely studied digital risks is online gaming addiction, which is associated with various social and psychological problems among adolescents [18]. Its impacts include sleep disturbances, reduced quality of life, and decreased academic achievement[19]. Other studies have also reported increased expressions of anger and reduced social interaction among adolescents with online gaming addiction[20]. Furthermore, online gaming addiction is more frequently found among adolescents with SHB and is associated with mental health problems[21].

In addition to online gaming addiction, another common form of digital risk among adolescents is cyberbullying, which refers to aggressive behavior conducted through electronic media with the intention of harming others[22]. Engagement with social media and digital technology has also been linked to increased depression and psychological distress, which are important risk factors

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for SHB[23]. Compared with traditional bullying, cyberbullying has distinct characteristics because it can occur at any time, is often anonymous, and is difficult to detect[24].

These two forms of digital risk often do not occur independently but are interconnected within adolescents' digital experiences. Nevertheless, online gaming addiction and cyberbullying are still frequently studied as separate risk factors. In reality, adolescents often experience multiple risks simultaneously within digital environments. Victims of cyberbullying are known to have a higher tendency to experience online gaming addiction[25,26]. This condition indicates the interrelationship among various forms of digital risks experienced by adolescents.

Online gaming addiction and cyberbullying were selected as the primary components of cumulative digital risk exposure because both have been consistently associated with adverse mental health outcomes, including SHB among adolescents[21,27,28]. Furthermore, evidence suggests that these digital risks frequently co-occur within adolescents' online environments [25,26]. Consequently, examining them as cumulative rather than isolated exposures may provide a more comprehensive understanding of adolescents' vulnerability to SHB

Traditional research approaches generally analyze risk factors separately, potentially overlooking the cumulative effects of multiple risk exposures occurring simultaneously. The concept of cumulative risk emphasizes that exposure to several risk factors at the same time may produce greater impacts because these risks interact and accumulate, thereby increasing vulnerability to various psychological problems [29]. Recent studies have also demonstrated that the greater the number of risk factors experienced by adolescents, the higher the likelihood of mental health problems, indicating significant cumulative and gradient risk effects [30]. Although this theoretical framework has been widely applied, its applicability to co-occurring digital risks among adolescents remains insufficiently understood.

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However, most previous studies have examined individual digital risk factors separately, with limited attention to the cumulative effects of multiple co-occurring digital risks on adolescent development and mental health [31,32]. Such approaches may overlook the combined impact of multiple digital risks occurring simultaneously. Assessing SHB based solely on a single risk factor may not adequately capture adolescents' vulnerability in a more accurate and comprehensive manner[33]. Previous studies have reported associations between cyberbullying, online gaming addiction, and SHB among adolescents. Systematic reviews have demonstrated consistent associations between cyberbullying involvement and self-harm outcomes among children and adolescents[34,35]. In addition, the available evidence was derived from studies conducted in North America, Europe, and Australia[36]. However, most studies have examined these digital risk factors as individual exposures rather than considering the cumulative effects of multiple co-occurring digital risks. Furthermore, evidence regarding digital risks among adolescents in low- and middle-income countries remains limited [37], highlighting the need for further research in these setting.

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These knowledge gaps are particularly important in the Indonesian context because SHB, including non-suicidal self-injury, represents an important mental health concern among adolescents, and existing evidence highlights the need for early prevention and targeted interventions [38–40]. Although several psychosocial interventions have been evaluated, evidence regarding their effectiveness in adolescents remains limited, with only dialectical behaviour therapy for adolescents (DBT-A) showing promising results, while further evaluation of existing interventions is still needed[41]. Understanding the cumulative influence of multiple digital risks may provide a more comprehensive representation of adolescents' online experiences and help identify adolescents at greater risk of SHB. This evidence could contribute to the development of

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targeted prevention strategies and evidence-based mental health interventions for adolescents across school, family, and healthcare setting[42]

Indonesia represents an important setting for this research because more than 70% of the population has internet access, with adolescents comprising one of the largest groups of internet users [43], most internet users in Indonesia belong to younger generations, particularly Generation Z and millennials, potentially increasing exposure to various digital risks. Therefore, the primary objective of this study was to examine the association between cumulative digital risk exposure, comprising online gaming addiction and cyberbullying, and SHB among Indonesian adolescents. The secondary objective was to identify psychosocial and demographic correlates of SHB through multivariable analysis.

METHODOLOGY

Study Design

This study employed an analytical cross-sectional design to examine the association between cumulative digital risk exposure and SHB among adolescents. This approach was selected because it enables the efficient examination of associations between digital risk exposures and outcomes within a large population at a single point in time. The study data were part of a broader survey on adolescents' digital behavior and mental health in Indonesia, designed to capture the dynamics between psychosocial factors and digital environmental exposures.

The study was conducted in junior high schools across several regions in Indonesia to capture variations in adolescents' social environments and digital access. School settings were selected because they represent a primary environment for adolescent social interaction and provide a

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relevant context for examining digital risk exposure and mental health behaviors among school-aged adolescents.

Population and Sampling Technique

The target population consisted of junior high school adolescents in Indonesia. Junior high school students were targeted because early adolescence is a critical developmental period for the onset of SHB. Recent evidence indicates that although the age of onset of SHB ranges from 9 to 18 years, most studies report a mean onset age between 12 and 14 years, which closely corresponds to the junior high school age range [44]. Furthermore, adolescence represents a period of increasing engagement with digital environments and heightened vulnerability to psychosocial difficulties. Recent research has emphasized the importance of early identification and prevention of SHB during adolescence, considering their associations with multiple psychosocial contexts, including family, school, and broader social environments[45].

The present study analyzed all eligible participants from a broader survey on adolescent digital behavior and mental health conducted in Indonesia. Therefore, an a priori sample size calculation was not performed because the present study involved a secondary analysis of an existing dataset, and all respondents who met the eligibility criteria were included. The final analytical sample comprised 1,742 adolescents, which was considered adequate for the planned multivariable analyses based on the number of participants available and the observed distribution of SHB outcomes.

A multistage school-based sampling approach was used. In the first stage, five provinces representing different geographical regions of Indonesia were purposively selected based on research feasibility, accessibility, and collaboration with local stakeholders. The selected provinces

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were Jambi (Sumatra), West Kalimantan (Kalimantan), East Java (Java), North Sulawesi (Sulawesi), and Central Papua (Papua). This approach was intended to ensure geographical diversity rather than to achieve nationally representative random sampling.

In the second stage, junior high schools within the selected provinces were identified with assistance from local education authorities, located in selected cities and regencies. Schools recommended by the education offices were invited to participate and served as cluster units. A total of 26 junior high schools were invited, of which 22 agreed to participate. According to school enrollment records, the participating schools had a combined enrollment of approximately 16,135 students.

In the third stage, eligible students aged 10–19 years who were registered as active students were recruited from the participating schools. Adolescents with cognitive impairments or medical conditions that interfered with questionnaire completion were excluded. A total of 1,768 eligible adolescents were approached for participation. Of these, 26 declined to participate, resulting in a final analytical sample of 1,742 participants. Data were collected using both online and paper-based questionnaires. Because questionnaire distribution was coordinated through participating schools and the number of students who initially received or accessed the questionnaire was not systematically recorded, an exact participation rate could not be calculated.

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Research Instruments

All instruments used in this study underwent language adaptation as well as validity and reliability testing within the Indonesian population.

The Indonesian Online Game Addiction Questionnaire (IOGAQ), developed by Tjibeng Jap et al. (2013), The IOGAQ is a self-report questionnaire originally developed and validated among

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Indonesian junior and senior high school students, with a mean participant age of 14.2 years (approximately 12–18 years), consists of 7 items rated on a 5-point Likert scale, with total scores ranging from 7 to 35. The instrument demonstrated acceptable reliability (Cronbach's alpha = 0.73)[46]. Based on the original validation study, scores of 7–13 indicate no online gaming addiction, scores of 14–21 indicate mild online gaming addiction, whereas scores ≥22 indicate online gaming addiction. For the purpose of the present study, respondents with scores ≥22 were classified as having online gaming addiction (1), whereas those with scores <22 were classified as not having online gaming addiction (0).

Cyberbullying victimization was assessed using the Cyberbullying Victimization Scale, the victimization subscale of the Cyberbullying and Online Aggression Survey Instrument (COAS) developed by Patchin and Hinduja (2015) [47]. The subscale consists of nine items assessing experiences of cyberbullying victimization during the previous 30 days. Responses were rated on a four-point scale ranging from never (0) to many times (3). Following the scoring procedure recommended by Patchin and Hinduja, item scores were summed to obtain a summary score ranging from 0 to 27. The summary score was then dichotomized into not exposed to cyberbullying victimization (summary score = 0–1) and exposed to cyberbullying victimization (summary score ≥2). The resulting binary variable was included as the cyberbullying component of the cumulative digital risk index.

SHB was measured using the Self-Harm Inventory (SHI), developed by Sansone et al. (1998)[48]. The SHI is a 22-item self-report screening instrument designed to assess the lifetime occurrence of SHB using dichotomous (yes/no) responses. The instrument covers various forms of direct and indirect SHB and can be completed in approximately five minutes. Each "yes" response was scored as 1 and each "no" response as 0, with total scores ranging from 0 to 22, higher scores indicate a

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greater lifetime history of SHB.. Previous studies have demonstrated good psychometric properties of the SHI, with Cronbach's alpha values ranging from 0.80 to 0.90 across different populations. Although the SHI includes suicide attempt as one of the assessed behaviors, it is intended to screen for the lifetime occurrence of SHB rather than to distinguish suicidal from NSSI or to assess suicidal intent. In this study, SHI scores were dichotomized into no history of self-harm (score = 0) and presence of a history of self-harm (score ≥1), as a single affirmative response indicates previous engagement in SHB

Operationalization of Cumulative Digital Risk

To construct the cumulative digital risk variable, online gaming addiction and cyberbullying exposure were first dichotomized (0 = absent, 1 = present). The two variables were then summed to create a cumulative digital risk index ranging from 0 to 2. A score of 0 indicated no digital risk, a score of 1 indicated one digital risk, and a score of 2 indicated two co-occurring digital risks.

Data Collection Procedure

Data were collected between June and July 2025 using a mixed-mode approach to accommodate differences in internet accessibility across participating schools. In schools with reliable internet access, questionnaires were administered online under the coordination of school personnel and supervision of the research team. In schools with limited internet connectivity, paper-based questionnaires were completed in classroom settings under the supervision of trained research assistants. This approach was adopted to promote equitable participation across diverse settings and reduce the exclusion of adolescents from under-resourced areas. All questionnaires were completed anonymously following standardized data collection procedures.

Data Analysis

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Data analysis was conducted using IBM SPSS Statistics version 19. Descriptive statistics were used to summarize participant characteristics and study variables. Associations between categorical variables and SHB were examined using Pearson's chi-square test. Multivariable binary logistic regression was used to identify factors independently associated with SHB while controlling for potential confounders. To assess the linear trend across cumulative digital risk categories, cumulative digital risk exposure was modeled as an ordinal variable (0, 1, and 2), and the p-value for trend was obtained from the corresponding logistic regression model.

Results are presented as adjusted odds ratios (AORs) with 95% confidence intervals (CIs), and a two-sided $p < 0.05$ was considered statistically significant**.** Survey-weighted analyses were not performed because sampling weights were not assigned during recruitment. The multistage school-based sampling approach was intended to improve geographical representation rather than to produce nationally representative estimates. Therefore, conventional multivariable logistic regression was considered appropriate for examining associations between cumulative digital risk exposure and SHB.

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The dependent variable was SHB. The primary independent variable was cumulative digital risk exposure, comprising online gaming addiction and cyberbullying exposure. Covariates included age, sex, living arrangement, parental marital status, parental income, academic performance, close friends, and history of violence. **C**ovariates were selected a priori based on previous empirical evidence demonstrating their associations with adolescent SHB, their potential to confound the association between cumulative digital risk exposure and SHB [34,49–53]. The multivariable model was used to estimate the independent association between cumulative digital risk exposure and SHB while adjusting for potential confounding variables. Online gaming addiction and

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cyberbullying exposure were not entered separately into the multivariable model because both variables were incorporated into the cumulative digital risk index.

Ethical Considerations

This study received ethical approval from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Tanjungpura (Approval No. 4200/UN22.9/PT.0104/2025). All research procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki (2013) and the Council for International Organizations of Medical Sciences (CIOMS) Guidelines (2016).

Informed consent was obtained from all participants prior to their participation in the study. For participants under the age of 18 years, informed consent was obtained from parents or legal guardians, and assent was obtained directly from the adolescents. For the online survey component, consent and assent procedures were completed electronically before participants accessed the questionnaire

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RESULTS

A total of 1,742 participants were included in the study. The mean age was 13.8 ± 0.97 years, and 54.2% were female. Most participants resided in urban areas (73.9%) and lived with their parents (73.9%). More than half reported moderate academic performance (54.0%) and having three or more close friends (58.9%), while 15.7% reported a history of violence exposure (Table 1). Regarding digital risk exposure, 33.1% of adolescents reported online gaming addiction and 57.5% reported cyberbullying victimization. Based on the cumulative digital risk index, 38.9% of participants had no digital risk, 31.7% had one digital risk, and 29.4% had two digital risks (Table 2). Overall, 55.0% reported SHB. Among the 22 SHI items, the most frequently endorsed

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behaviors were hitting oneself (33.9%), failing to seek treatment for injuries (32.5%), and torturing oneself with self-defeating thoughts (24.5%). In bivariate analyses, SHB was significantly associated with cumulative digital risk exposure ($p < 0.001$), with prevalence increasing from 43.3% among adolescents with no digital risk to 67.8% among those with one digital risk and 56.7% among those with two digital risks (Table 3).

In multivariable logistic regression analyses (Table 4), female adolescents had lower odds of SHB than males (AOR = 0.58, 95% CI: 0.46–0.73). Higher odds of SHB were observed among adolescents with separated/divorced parents (AOR = 1.53, 95% CI: 1.10–2.13), lower parental income (AOR = 1.31, 95% CI: 1.04–1.65), fewer close friends, a history of violence (AOR = 4.21, 95% CI: 2.51–7.08), and lower academic performance (AOR = 9.56, 95% CI: 5.44–16.80). After adjustment for demographic and psychosocial factors, cumulative digital risk exposure remained associated with SHB. Compared with adolescents reporting no digital risk, those exposed to one digital risk had higher odds of SHB (AOR = 2.18, 95% CI: 1.70–2.80), whereas those exposed to two digital risks had lower adjusted odds (AOR = 0.54, 95% CI: 0.38–0.76). No significant linear dose–response relationship was observed when cumulative digital risk exposure was modeled as an ordinal variable (AOR = 0.94, p for trend = 0.411). Residential area and living arrangement were not significantly associated with SHB.

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DISCUSSION

This study examined the association between cumulative digital risk exposure, operationalized as online gaming addiction and cyberbullying victimization, and SHB. Cumulative digital risk exposure was independently associated with SHB. Adolescents exposed to one digital risk had significantly higher odds of SHB than those reporting no digital risk exposure. However, the association for adolescents exposed to two digital risks was attenuated after adjustment for

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potential confounders, and no significant linear dose-response relationship was observed. These findings suggest that cumulative digital risk may be better understood as part of a broader psychosocial risk profile rather than as an independent determinant that incrementally increases the likelihood of SHB.

The relatively high prevalence of cyberbullying victimization and SHB observed in this study should be interpreted in the context of methodological differences across studies, including variations in measurement instruments, operational definitions, recall periods, and cut-off scores, which may contribute to differences in reported prevalence estimates. Previous reviews have shown that methodological heterogeneity can substantially influence prevalence estimates for both cyberbullying victimization and self-harm among adolescents[54,55]. In the present study, both cyberbullying victimization and SHB were classified using validated instruments designed to identify the presence of these experiences rather than clinically significant severity [47,48]

The observed association is consistent with evidence linking adverse digital experiences to poorer adolescent mental health outcomes. Cyberbullying victimization has been associated with adverse psychological outcomes even after accounting for other psychosocial adversities[56], while problematic digital media engagement has been linked to depression, anxiety, and SHB among children and adolescents [57]. Digital risks have also been associated with impulsivity, attentional difficulties, and reduced psychological well-being [58]

The absence of a significant dose-response relationship warrants cautious interpretation. Cumulative digital risk may not operate through a simple additive mechanism but instead interact with broader psychosocial determinants of adolescent mental health. In this study, history of violence, lower academic achievement, limited peer support, and unfavorable family

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circumstances were independently associated with SHB, suggesting that digital risk exposure is embedded within a broader constellation of psychosocial vulnerabilities.

Sequential regression analyses further showed that the association between exposure to two digital risks and SHB progressively weakened after adjustment for demographic and psychosocial factors. This attenuation suggests that part of the observed association is explained by psychosocial characteristics that contribute both to digital risk exposure and vulnerability to SHB, consistent with evidence that SHB is shaped by interacting biological, psychological, social, and environmental determinants [53,59]. In addition, digital and psychosocial risks are likely interrelated, and adjustment for psychosocial variables may reduce the apparent independent contribution of digital risk because some variance is shared across these domains.

Residual confounding also cannot be excluded because potentially important protective factors were not assessed. Family, school, and community-level factors, including parental monitoring and school connectedness, have been shown to reduce vulnerability to mental health problems and SHB [60,61]. The inverse association observed after full adjustment may reflect residual confounding, differences in the composition of adolescents across digital risk groups, or other unmeasured characteristics that were not captured in the present study. Measurement or classification of cumulative digital risk may also have contributed to the observed pattern. Given the cross-sectional design, these possible explanations cannot be distinguished from the observed data**.** Rather, it may reflect overlapping influences between digital and psychosocial factors that jointly contribute to SHB.

The relationship between digital risk exposure and SHB is likely to be complex and potentially bidirectional. Experiences such as cyberbullying victimization, problematic internet use, and internet gaming disorder have been associated with an increased risk of SHB among

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adolescents[62]. These risks frequently co-occur; for example, cyberbullying victimization has been linked to problematic gaming behaviors, while both have been associated with increased stress, sleep disturbances, and poorer psychological well-being [63,64]. Cyberbullying victimization has also been associated with depression, anxiety, and non-suicidal self-injury through mechanisms involving emotion dysregulation, internalizing symptoms, stress, and limited social support[65]. Conversely, adolescents with pre-existing psychological vulnerabilities or a history of SHB may be more susceptible to adverse online experiences. Consistent with this interpretation, a systematic review of longitudinal studies suggests that the association between problematic internet use and adolescent mental health may be reciprocal, whereby emotional distress can both precede and be exacerbated by problematic online engagement[66]. Therefore, the observed associations should not be interpreted as evidence of a progressive increase in SHB risk with a greater number of digital risks.

Among the psychosocial variables examined, a history of violence emerged as the strongest independent correlate of SHB. Adolescents exposed to violence were substantially more likely to report SHB, consistent with meta-analytic evidence linking adverse childhood experiences, including emotional, physical, and sexual violence, to increased SHB risk [67,68]. Adjustment for violence exposure substantially attenuated the association between cumulative digital risk exposure and SHB, suggesting that online and offline adversities frequently co-occur and may jointly contribute to adolescent vulnerability.

Academic achievement was also independently associated with SHB. This finding is consistent with evidence showing that declining educational attainment and higher academic pressure are associated with an increased risk of SHB and poorer mental health outcomes during adolescence[69,70]. Family environment was likewise independently associated with SHB.

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Adolescents with separated or divorced parents had higher odds of SHB, consistent with evidence linking parental separation, negative parenting practices, and family dysfunction to self-harm among children and adolescents[51,71,72]. Nevertheless, family structure should not be interpreted as a direct cause of SHB but rather as part of a broader psychosocial context that shapes adolescents' exposure to stressors and mental health trajectories.

Peer relationships also appeared to play an important role. Adolescents who reported having fewer than three close friends were more likely to engage in SHB than those with larger friendship networks. This finding is consistent with evidence showing that friendships and peer relationships are closely associated with self-harm thoughts and behaviors among young people [73]. Social network research further indicates that social isolation is associated with increased SHB risk, whereas stronger integration within friendship networks is associated with lower risk[74].

In the present study, female adolescents had significantly lower adjusted odds of SHB than male adolescents. This finding differs from much of the existing literature, which generally reports higher rates of self-harm among adolescent girls. For example, a large meta-analysis of community-based studies from 41 countries found that girls were significantly more likely to engage in SHB than boys [75], while population-based evidence from the United Kingdom reported substantially higher SHB prevalence among girls [52]. However, sex differences in SHB are not consistent across settings; a large school-based study in Beijing found no significant gender differences in SHB prevalence[76]. Together, these findings suggest that gender differences in SHB may vary according to sociocultural and contextual factors. Therefore, the present finding should be interpreted cautiously and may reflect characteristics specific to the Indonesian adolescent population studied.

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This study has several strengths. To our knowledge, it is among the first studies to examine online gaming addiction and cyberbullying victimization as a cumulative digital risk index in relation to SHB among Indonesian adolescents. By considering multiple co-occurring digital risks within a single analytical framework, the study extends previous research that has largely examined these exposures separately. In addition, the large sample drawn from five major geographical regions of Indonesia and the inclusion of multiple demographic and psychosocial covariates strengthened the precision of the estimates and enabled a more comprehensive assessment of the independent association between cumulative digital risk exposure and SHB.

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inference and prevents determination of the temporal relationship between cumulative digital risk exposure and SHB, therefore, reverse causation cannot be excluded. Second, all variables were assessed using self-report measures for sensitive behaviors, which may be subject to underreporting, recall, reporting, and social desirability biases. Third, the cumulative digital risk index was limited to online gaming addiction and cyberbullying victimization and may not fully capture the broader range of adolescents' digital experiences, such as problematic social media use, exposure to harmful online content, or other forms of online victimization.

Fourth, the cut-off scores used for cyberbullying victimization (COAS) and SHB (SHI) were intended to identify the presence of these behaviors but may not reflect clinically significant thresholds or variations in frequency, duration, and severity, thereby limiting the clinical interpretation of the findings. Fifth, differences in survey administration modes (online and paper-based questionnaires) may have introduced potential selection bias. Adolescents with greater internet access may differ in their patterns of digital engagement and exposure to online risks compared with those completing paper-based questionnaires, which may have influenced the

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observed associations. Sixth, cyberbullying victimization was measured over a recent period, whereas SHB was assessed as a lifetime experience, creating a temporal mismatch between exposure and outcome. **Seventh, the regression analyses did not account for potential clustering of participants within schools. Because adolescents from the same school may share contextual and social characteristics, failure to account for school-level clustering may have resulted in underestimated standard errors and may have affected the precision of the estimated associations.**

Finally, participants were recruited exclusively from junior high schools located in selected cities and regencies across five provinces in Indonesia. Therefore, the findings may not be generalizable to out-of-school adolescents or to adolescents from other geographic, educational, and sociodemographic settings. Overall, the findings suggest that digital risk exposure should be interpreted within a broader psychosocial context rather than as an isolated determinant of adolescent SHB. Although exposure to at least one digital risk was independently associated with SHB, the absence of a clear dose-response relationship indicates that digital risks may interact with other vulnerabilities, including violence exposure, family adversity, academic functioning, and peer relationships. These findings underscore the importance of comprehensive prevention strategies that combine digital safety education with school-based mental health promotion, violence prevention, family engagement, and peer support. Future longitudinal studies incorporating a wider range of digital risk exposures are needed to clarify the temporal and causal pathways linking digital experiences and SHB among adolescents.

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CONCLUSION

Cumulative digital risk exposure was associated with SHB among Indonesian adolescents, although the association did not follow a clear linear dose–response pattern after adjustment for

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demographic and psychosocial factors. These findings suggest that digital risk exposure should be considered alongside broader demographic and psychosocial factors when understanding SHB among adolescents. Future longitudinal studies are needed to clarify the temporal relationship between digital risk exposure and SHB and to identify protective factors that may influence these associations.

Declarations

Abbreviations

AOR: Adjusted odds ratio; CI: Confidence interval; COAS: Cyberbullying and Online Aggression Survey Instrument; IOGAQ: Indonesian Online Game Addiction Questionnaire; SHB: Self-harm behavior; SHI: Self-Harm Inventory.

Ethics approval and consent to participate

This study received ethical approval from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Tanjungpura (Approval No. 4200/UN22.9/PT.0104/2025). Written informed consent was obtained from the parents or legal guardians of all participants, and written assent was obtained from all adolescents prior to participation.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to ethical restrictions involving minors but are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare that they have no competing interests.

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Authors' contributions

Triyana Harlia Putri: Conceptualization, methodology, formal analysis, writing-original draft preparation. Fitri Ariyanti Abidin: Supervision, methodology, writing-review and editing. Meita Dhamayanti: Methodology, supervision. Popy: Investigation, data curation. Fitri Fujiana:

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Investigation, data curation. Aprida Manurung: Validation, writing-review and editing. Suryani Suryani: Supervision, project administration, writing-review and editing.

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Table 1. Sociodemographic Characteristics of the Study Participants Overall and by Sex

Characteristics	**Total (N = 1,742)**	**Male (n = 797)**	**Female (n = 945)**
	n (%)	**n (%)**	**n (%)**
Age (years), mean ± SD	13.8 ± 0.97	13.7 ± 0.96	13.9 ± 0.98
Residential area			
Urban	1,287 (73.9)	616 (77.3)	671 (71.0)

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Rural	455 (26.1)	181 (22.7)	274 (29.0)
Living arrangement			
With parents	1,287 (73.9)	672 (84.3)	615 (65.1)
With Grandparents	398 (22.8)	108 (13.6)	290 (30.7)
With Extended family	54 (3.1)	15 (1.9)	39 (4.1)
With Adoptive family	3 (0.2)	2 (0.3)	1 (0.1)
Parental marital status			
Living together	1,284 (73.7)	644 (80.8)	640 (67.7)
Separated/Divorced	414 (23.8)	130 (16.3)	284 (30.1)
Deceased	44 (2.5)	23 (2.9)	21 (2.2)
Parental income			
≥5 million IDR/Month	973 (55.9)	460 (57.7)	513 (54.3)
<5 million IDR/Month	769 (44.1)	337 (42.3)	432 (45.7)
Academic performance			
Low	367 (21.1)	112 (14.1)	255 (27.0)
Moderate	941 (54.0)	413 (51.8)	528 (55.9)
High	434 (24.9)	272 (34.1)	162 (17.1)
Close friends			
≥3	1,026 (58.9)	506 (63.5)	520 (55.0)
<3	716 (41.1)	291 (36.5)	425 (45.0)
History of violence			
Yes	273 (15.7)	103 (12.9)	170 (18.0)
No	1,469 (84.3)	694 (87.1)	775 (82.0)

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Table 2. Distribution of Digital Risk Exposure Variables

Variable	**Category**	**N**	**%**
Online gaming addiction	No addiction	1,166	66.9
	Addiction	576	33.1
Cyberbullying victimization	Not exposed	740	42.5
	Exposed	1,002	57.5

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Cumulative digital risk exposure	No digital risk	677	38.9
	One digital risk	552	31.7
	Two digital risks	513	29.4

Table 3. Association Between Cumulative Digital Risk Exposure and Self-Harm Behavior Among Adolescents

Cumulative Digital Risk Exposure	**No SHB**	**SHB**	**Total**	**p-value**
	n (%)	**n (%)**	**n (%)**	
No digital risk	384 (56.7)	293 (43.3)	677 (100.0)	<0.001
One digital risk	178 (32.2)	374 (67.8)	552 (100.0)	
Two digital risks	222 (43.3)	291 (56.7)	513 (100.0)	
Total	784 (45.0)	958 (55.0)	1742 (100.0)	

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Table 4. Multivariable Logistic Regression Analysis of Factors Associated with Self-Harm Behavior

Variable	**AOR (95% CI)**	***p*-value**
Sex		
Female vs Male	0.57 (0.46–0.72)	<0.001
Living arrangement (reference = With parents)		0.524
Grandparents vs With parents	0.90 (0.64–1.26)	0.537
Extended family vs With parents	1.63 (0.73–3.65)	0.234
Adoptive family vs With parents	0.51 (0.04–6.74)	0.609
Parental marital status (reference = Living together)		0.013
Separated/Divorced vs Living together	1.55 (1.12–2.15)	0.009
Deceased vs Living together	1.79 (0.83–3.85)	0.136
Parental income (reference = >5 million IDR/month)		

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<5 million IDR/month vs >5 million IDR/month	1.32 (1.05–1.67)	0.017
Close friends (reference = ≥3 close friends)		
<3 vs ≥3	1.54 (1.20–1.98)	0.001
Residential area (reference = Urban)		
Rural vs Urban	0.98 (0.74–1.28)	0.854
Cumulative digital risk exposure (reference = No digital risk)		<0.001
One digital risk vs No digital risk	2.20 (1.71–2.82)	<0.001
Two digital risks vs No digital risk	0.56 (0.40–0.78)	0.001
History of violence (reference = No)		
Yes vs No	4.19 (2.50–7.02)	<0.001
Academic performance (reference = High)		<0.001
Low vs High	9.30 (5.34–16.21)	<0.001
Moderate vs High	0.75 (0.58–0.97)	0.027

All variables were simultaneously entered into the multivariable logistic regression model.

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