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Article

Behavioral and Psychosocial Determinants of Gender Differences in Adolescent Mental Health: A Population-Based Cross-Sectional Study in Northern Italy

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Abstract

Background: Gender differences in adolescent mental health are well documented; however, the extent to which modifiable behavioral and psychosocial factors account for the excess of mental health problems in females remains insufficiently quantified. Methods: Data from the 2025 Corona and Psyche South Tyrol (COP-S) survey comprised a base sample of 2,428 adolescents aged 11–19 years (51.4% males) with valid self-reported data. Multivariable regression analyses were conducted on 1,448–1,603 adolescents (depending on the outcome) who provided complete responses to the relevant predictor and outcome measures. Gender differences in depression scores (PHQ-2), anxiety scores (SCARED-GAD), and emotional/behavioral difficulties (SDQ) were examined using Mann-Whitney U and chi-square tests. Multivariable linear regression models were used to assess the associations between mental health outcomes and the ten predictors. Gender effects were quantified by comparing standardized regression coefficients from unadjusted and adjusted models. Results: Female adolescents reported higher anxiety (median 6 vs. 4; rank-biserial r = 0.24), depression (r = 0.13), and emotional/behavioral (r = 0.08) scores than male adolescents. School stress, problematic Internet use, and poor sleep quality were the strongest predictors of all three outcomes (all $p < 0.001$). After multivariable adjustment, gender remained a significant predictor of anxiety ($\beta = 0.18$) and depressive scores ($\beta = 0.09$) but no longer reached significance for emotional/behavioral scores ($\beta = 0.04$, $p = 0.078$). The attenuation of the gender effect ranged from 25.3% for anxiety to 37.1% for depression and 58.5% for emotional/behavioral difficulties. Conclusions: Gender differences in adolescent mental health are partially explained by modifiable behavioral and psychosocial factors, with the excess of females in emotional/behavioral scores fully accounted for by these covariates. Persistent gender disparities in anxiety indicate the need for anxiety-specific preventive strategies that target mechanisms beyond the measured behavioral correlates.

Keywords: adolescents; mental health; gender differences; depression; anxiety; school stress; problematic internet use; sleep; South Tyrol; COP-S

1. Introduction

Mental disorders are the leading cause of disability among children and adolescents globally. Meta-analyses estimate a 13.4% prevalence among this group (Polanczyk et al., 2015), supported by Global Burden of Disease data, which show an 11.6% prevalence for ages 5–24 (Kieling et al., 2024). Subthreshold psychological distress is more common and affects academic, social, and well-being aspects. Adolescent mental health issues often persist into adulthood, impacting education, work,

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health, and social outcomes (Kessler et al., 2005). Understanding the determinants of adolescent mental health is crucial for public health research and preventive interventions.

Gender differences in adolescent mental health have been documented. Girls report more depressive symptoms, anxiety, and psychosomatic complaints than boys, with disparities increasing from mid-adolescence (Barbieri et al., 2024, 2025). These differences appear during development, with internalizing symptoms diverging in early to mid-adolescence (Barch et al., 2021; Wade et al., 2002). Longitudinal data show that internalizing symptoms rise in girls but remain stable or decline in boys, with a female-to-male depressive symptom ratio of 2:1 to 3:1 by late adolescence (Breslau et al., 2017; Daly, 2022). Boys more often show externalizing difficulties, such as conduct disorder and hyperactivity/inattention, with male-to-female ratios of approximately 2:1 in community samples (Fairchild et al., 2019; Zahn-Waxler et al., 2008). In the Corona-and-Psyche South Tyrol (COP-S) survey series (2021-2025), 40% of female adolescents screened positive for a mental health problem compared to 27% of males, with higher female anxiety rates (Barbieri et al., 2026).

Gender-differentiated prevalence patterns are not fully understood, but cognitive and psychosocial factors play a role in this. Meta-analyses indicate that adolescent girls ruminate more than boys, mediating stress and depressive symptoms (Michl et al., 2013; Rood et al., 2009). Girls experience more interpersonal stress and use emotion-focused coping, which is linked to psychological symptoms (Hampel & Petermann, 2006). Restrictive gender norms partly mediate cultural differences in depression (Koenig et al., 2021), while self-reliant traits protect against depression (Lin et al., 2021). These findings suggest that female internalizing psychopathology results from cognitive vulnerabilities, gendered stress, and sociocultural constraints, not a single cause.

Several modifiable behavioral factors contribute to gender differences in adolescent mental health, with sleep disturbance being a key factor. Poor sleep quality is more strongly linked to depressive symptoms than sleep duration (O'Callaghan et al., 2021), and a shorter sleep duration raises mood problem risks by 55% (Short et al., 2020). Sleep disturbances predict later internalizing symptoms regardless of initial psychopathology (Scott et al., 2021). Girls report shorter weekday sleep and worse sleep quality than boys, with stronger links between sleep and depression in females (Goldstone et al., 2020; Lemke et al., 2023). Poorer sleep in girls may partly explain their higher depression and anxiety symptoms.

The use of digital media is relevant. Reviews show minimal links between ordinary social media use and youth depression and anxiety, with causation disputed (Odgers & Jensen, 2020). Problematic Internet use (PIU), marked by preoccupation, loss of control, and impairment, is moderately associated with depression, anxiety, and reduced well-being in adolescents (Cai et al., 2023). Gender differences are notable: girls engage more in social comparison and addictive networking, whereas boys have higher problematic gaming rates, affecting their mental health (Cai et al., 2023). Barbieri et al. found that PIU predicts mental health issues in both genders, with similar effect sizes (Barbieri, Piccoliori, Engl, & Wiedermann, 2026). These analyses did not explore whether PIU and other factors explain the gender gap in mental health outcomes.

Perceived social support is crucial for the mental health of adolescents. It predicts lower depression, anxiety, and suicidal ideation in young adulthood (Scardera et al., 2020). Family support and friendship quality in early adolescence predict fewer depressive symptoms in adolescents who have experienced prior adversity (van Harmelen et al., 2016). Peer relationship quality strongly determines depression risk, especially in girls (Letkiewicz et al., 2023). Social support reduces chronic stress and fosters adaptive coping, potentially buffering gender-differentiated stressors.

School-related stress is a key correlate of adolescent mental health, with links to depressive and anxiety symptoms (Högberg et al., 2020). Female adolescents report more school stress than males, suggesting that differential burden may affect gender disparities in internalizing symptoms. Physical activity protects adolescent mental health, with dose-response relationships for depression and anxiety (Ruiz-Ranz & Asín-Izquierdo, 2025). Boys engage in more physical activity than girls, possibly explaining the mental health difficulties in females. Health literacy, the capacity to access,

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understand, and apply health information, is linked to mental health outcomes in adolescents (Paakkari et al., 2020), although its role in gender differences is underexplored.

Despite extensive research on gender differences in adolescent mental health, there remains a critical gap. Most studies either examine predictors within each gender separately or document prevalence differences without addressing whether the gender gap is due to modifiable behavioral and psychosocial exposures. It is unclear to what extent factors such as sleep disturbance, digital media use, physical inactivity, school stress, perceived social support, and health literacy, which may vary across genders, contribute to the excess of mental health issues in females, and whether gender differences persist independently after adjusting for these factors. Most evidence comes from demographically limited samples, and studies focusing on a single predictor cannot assess the contributions of multiple factors or determine whether gender effects remain after joint adjustment. This question is relevant for intervention design: if gender differences in mental health are largely explained by modifiable factors, targeted interventions could reduce the mental health gap between male and female adolescents.

This study used data from a survey of adolescents aged 11–19 years in South Tyrol, Northern Italy, as part of the COP-S survey series (Barbieri et al., 2023, 2024; Barbieri, Piccoliori, Engl, & Wiedermann, 2026). This study aims to: 1) examine gender differences in mental health indicators such as depressive and anxiety symptoms and related behavioral and psychosocial factors; 2) investigate multivariable associations between these factors and mental health outcomes, identifying predictors; and 3) quantify the extent to which gender differences in mental health are explained by behavioral and psychosocial factors, comparing unadjusted and adjusted gender effects. This analysis, which has not been previously performed on this dataset, addresses whether the excess female adolescent mental health issues reflect gender effects or modifiable exposures that differ between genders.

2. Methods

2.1. Study Design and Setting

This cross-sectional study analyzed data from the fourth wave of the COP-S survey series, which was conducted between March 17 and April 13, 2025. The COP-S series is a repeated cross-sectional, population-based survey of children and adolescents in South Tyrol, a bilingual autonomous province in Northern Italy bordering Austria with approximately 530,000 inhabitants. Previous waves were conducted in 2021, 2022, and 2023 (Barbieri et al., 2023, 2024). Each wave recruited an independent sample, and participants were not followed across waves. The primary objective of the survey series was to monitor post-pandemic mental health trends among the youth population of South Tyrol and examine the associated behavioral, psychosocial, and sociodemographic factors. The survey was administered via the SoSci Survey platform (Version 3.2.46; SoSci Survey GmbH, Munich, Germany) and was available in German and Italian versions.

2.2. Participants and Recruitment

The questionnaire was distributed to families of schoolchildren across South Tyrol via personalized email links sent through school directorates to approximately 40,000 families in South Tyrol. A reminder was sent to all families two weeks after the initial invitation. Both parental proxy and adolescent self-report versions were included. Adolescents could complete the self-report form independently after their parents completed the proxy version; due to the anonymous online format, independent completion could not be verified. The overall response rate was approximately 23%, with approximately 80% of the returned questionnaires considered suitable for analysis after data cleaning.

The present analysis focused exclusively on adolescent self-reported data from participants aged 11–19 years. Adolescents were included if they confirmed their participation in the self-report questionnaire and attended lower secondary school, upper secondary school, a vocational track, or

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another formal educational setting. Adolescents who reported attendance at primary school (n = 122) were excluded to maintain consistency with the target age range, as were participants with missing school-type information. All remaining adolescents were retained as the base sample for descriptive analyses (n = 2,428), irrespective of the completeness of the behavioral and mental health modules. The present sample definition differs from that applied by Barbieri et al. (2026) in their gender-specific analysis of the same COP-S wave, which was restricted to adolescents with complete data on all three mental health instruments (n = 1,471). The broader inclusion criteria adopted in this study were chosen to retain the full range of sociodemographic variability and to enable the use of continuous mental health scores as outcomes. Regression models accommodate item-specific missingness through listwise deletion per model, resulting in analytic samples of approximately 1,400–1,600 adolescents for each outcome. A comparison of complete versus sparsely completed self-report subgroups drawn from the same COP-S 2025 wave is reported in Supplementary Material 1 of Barbieri et al. (2026), showing no substantive differences in demographic composition but modest differences in behavioral factors, such as elevated problematic Internet use, perceived school burden, and low social support.

2.3. Measures

2.3.1. Mental Health Outcomes

Three validated screening instruments were used to assess self-reported mental health. All instruments were available in validated German and Italian versions and were applied consistently across all COP-S waves.

Depressive symptoms were assessed using the Patient Health Questionnaire-2 (PHQ-2), a two-item instrument asking about the frequency of depressed mood and anhedonia over the past two weeks, rated on a four-point Likert scale from 0 (nearly never) to 3 (nearly every day), yielding a total score ranging from 0 to 6 (Löwe et al., 2005). The PHQ-2 is recommended for use in adolescents aged 12 years and older and has been validated in the relevant cultural context (D'Argenio et al., 2013; Schuler et al., 2018). A total score of ≥ 3 was applied as the threshold for elevated depressive symptoms, consistent with established cut-off recommendations and prior COP-S publications (Barbieri, Piccoliori, Engl, & Wiedermann, 2026).

Anxiety symptoms were assessed using the Generalized Anxiety Disorder subscale (GAD-9) of the Screen for Child Anxiety-Related Emotional Disorders (SCARED). This nine-item subscale asks adolescents to rate the frequency of anxiety-related cognitions and behaviors on a three-point scale from 0 (not or hardly true) to 2 (very or often true), yielding a total score of 0–18 (Birmaher et al., 1999). German and Italian validation studies confirmed adequate psychometric properties in adolescent community samples (Crocetti et al., 2009; Weitkamp et al., 2010). A total score of ≥ 9 was used as the threshold for elevated anxiety, consistent with prior COP-S applications. In the present study, this subscale is referred to as SCARED-GAD.

Emotional and behavioral difficulties were assessed using the Strengths and Difficulties Questionnaire (SDQ) (Goodman, 2001). The total difficulty score was computed from four subscales: emotional symptoms, conduct problems, hyperactivity/inattention, and peer relationship problems, each comprising five items rated on a three-point scale (0, 1, 2), yielding a total score of 0–40. Higher scores indicate greater difficulty. Scores were dichotomized according to established cut-offs, with borderline and abnormal range scores (≥ 17) classified as elevated, consistent with prior COP-S analyses (Barbieri, Piccoliori, Engl, & Wiedermann, 2026). The SDQ has been validated in German- and Italian-speaking populations (Goodman, 2001).

2.3.2. Behavioural and Psychosocial Predictors

Physical activity was assessed by asking adolescents how many days in the past week they had engaged in at least 60 minutes of sports or physical activity, rated on an eight-point scale from 1 (0

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days) to 8 (7 days). For the present analyses, the responses were treated as continuous variables representing days per week with sufficient physical activity.

School stress was assessed via adolescent self-report using a single item asking about the perceived burden of schoolwork, rated on a four-point Likert scale (1 = 'not at all', 2 = '' somewhat, 3 = 'fairly strongly', 4 = 'very strongly'), consistent with items used in the Health Behavior in School-aged Children (HBSC) survey series and prior COP-S analyses (Barbieri et al., 2024). For the multivariable regression analyses, the item was entered as a metric covariate, treating the response scale as approximately equidistant, in line with the common practice for single-item stress measures in large-scale adolescent health surveys. This item has demonstrated adequate criterion validity in large-scale epidemiological surveys of adolescent health (Högberg et al., 2020).

Health literacy was assessed using the Health Literacy for School-Aged Children (HLSAC) scale from the HBSC study (Paakkari et al., 2020). This ten-item instrument asks adolescents to rate health-related competence statements on a four-point Likert scale from 1 (not at all true) to 4 (absolutely true), yielding total scores ranging from 10 to 40. Higher scores indicate better health literacy levels. The HLSAC demonstrated high internal consistency in the present sample (Cronbach's α = 0.892) (Barbieri, Piccoliori, Engl, & Wiedermann, 2026).

Sleep was assessed using two items. Poor sleep quality was operationalized from a single HBSC-derived item asking how often the adolescent had difficulty falling asleep during the past six months, with responses rated on a five-point scale (daily, more than once a week, about once a week, about once a month, rarely or never). Responses were dichotomized such that any frequency of at least once a week (i.e., all categories except "rarely or never") was coded as poor sleep quality, consistent with the HBSC scoring practice applied in previous COP-S waves (Barbieri et al., 2024). Late bedtime was defined as a self-reported habitual school day bedtime after 23:00 hours, derived from a six-category response scale.

PIU was assessed using the Generalized Problematic Internet Use Scale 2 (GPIUS-2) (Caplan, 2010), comprising 15 items rated on an eight-point Likert scale from 1 (definitely disagree) to 8 (definitely agree), yielding a total score of 15–120. Higher scores indicate greater problematic Internet use. Validated German and Italian versions were used (Barke et al., 2014; Casale et al., 2014). In the present sample, Cronbach's α was 0.925 (Barbieri, Piccoliori, Engl, & Wiedermann, 2026).

Social media use intensity was assessed using the Bergen Social Media Addiction Scale (BSMAS) (Andreassen et al., 2017), a six-item instrument rated on a five-point Likert scale from 1 (very rarely) to 5 (very often), yielding total scores ranging from 6 to 30. Higher scores indicate more intensive social media use.

Perceived social support was measured using the Multidimensional Scale of Perceived Social Support (MSPSS) (Zimet et al., 1988), a 12-item instrument assessing perceived support from family, friends, and significant others, rated on a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Three subscale scores were computed (range: 1–7). Due to collinearity between subscales (detailed in the Statistical Analysis section), an MSPSS total score was used in multivariable analyses. Cronbach's α was 0.976 in the present sample (Barbieri, Piccoliori, Engl, & Wiedermann, 2026).

2.3.3. Sociodemographic Variables

Gender was assessed using adolescent self-report, with response options of boy, girl, or diverse. For the present analyses, gender was treated as a binary variable (0 = male, 1 = female). The two adolescents identifying as diverse were excluded from the analyses due to insufficient group size for separate analysis.

Age was reported in completed years by the adolescents. The analytic sample ranged from 11 to 19 years of age.

Parents reported school type, which was classified as a lower secondary school (grades 6–8), upper secondary school (grades 9–13), vocational school, or other. In South Tyrol, lower and upper secondary schools follow the standard Italian school system within the German- or Italian-language

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educational track, and vocational schools offer profession-oriented training programs of shorter duration (Barbieri, Piccoliori, Engl, Hager von Strobele-Prainsack, et al. 2026).

Parents reported the school language as German, Italian, or Ladin.

Parents reported their family language as German, Italian, Ladin, or other.

Migration background was defined as at least one parent born outside Italy and reported by parents as a binary variable.

Single-parent households were reported by parents as a binary variable.

Parental education was classified using the Comparative Analysis of Social Mobility in Industrial Nations (CASMIN) index into three ordinal categories: low (no or lower secondary education), medium (upper secondary or vocational training), and high (tertiary education) (Brauns et al., 2003).

Family affluence was assessed using the Family Affluence Scale III (FAS III) (Currie et al., 2024), a six-item parent-reported measure of material wealth indicators, including car ownership, computer access, own bedroom, bathroom, dishwasher, and vacation frequency. The total score ranged from 0 to 13, with higher scores indicating greater family affluence.

2.4. Statistical Analyses

Descriptive statistics were calculated for all study variables. Categorical variables are reported as frequencies and proportions, and continuous and ordinal variables are summarized as medians with minimum–maximum ranges and, where informative, means with standard deviations. Gender comparisons for continuous and ordinal variables were conducted using the Mann–Whitney U test, with the rank-biserial correlation coefficient $r = |Z|/\sqrt{N}$ reported as the effect size. Categorical variables were compared using Pearson's chi-square test, with Cramér's V reported as the effect size (Cramér's V equals the phi coefficient for 2 × 2 tables). Following Cohen (1988), effect sizes were interpreted as negligible (< 0.10), small (0.10–0.29), moderate (0.30–0.49), or large (≥ 0.50).

Prior to multivariable modelling, bivariate associations among all study variables were examined using Spearman rank-order correlations (rs), appropriate given the ordinal nature of several predictors and the non-normal distribution of the outcome variables. The full correlation matrix is presented in Supplementary Table S1. Predictor pairs with $|rs| > 0.70$ were considered potentially collinear. Based on this criterion, GPIUS-2 and BSMAS were found to be collinear (rs = 0.72); GPIUS-2 was retained as the primary digital media predictor, given its broader conceptual scope encompassing problematic Internet use. The MSPSS total score was used instead of the individual subscales to avoid collinearity among the three subscales (rs = 0.58–0.74).

Multivariable associations between behavioral and psychosocial predictors and each mental health outcome were examined using simultaneous entry ordinary least squares (OLS) linear regression analysis. Three separate models were estimated, one for each outcome (PHQ-2, SCARED-GAD, and SDQ total difficulties score). The following predictors were entered into each model: gender, age, physical activity, school stress (self-report), health literacy (HLSAC), poor sleep quality, late bedtime, PIU (GPIUS-2), perceived social support (MSPSS total), and family affluence (FAS III). Variance inflation factors (VIF) were used to confirm the absence of multicollinearity in the fitted models (threshold: VIF < 5). Although formal tests of normality of residuals were statistically significant for all three models, which is expected given the large analytic sample ($n > 1200$), the skewness of residuals was acceptable for the SCARED-GAD (0.43) and SDQ (0.42) models. For the PHQ-2 model, the residuals showed moderate positive skewness (1.03), consistent with the floor effect of this instrument in general population samples. Regression estimates remain asymptotically valid under these conditions, given the large sample size. Missing data were handled using pairwise deletion, and all analyses were based on cases with valid data for each variable pair. Statistical significance was set at $p < 0.05$ (two-tailed).

The attenuation of the gender effect following covariate adjustment was quantified as $((\beta \text{ unadjusted} - \beta \text{ adjusted}) / \beta \text{ unadjusted}) \times 100$, following the established change-in-estimate and mediation-analytic conventions (Greenland, 1989; MacKinnon, 2012). This measure represents the

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proportion of the total gender effect that is statistically accounted for by the included behavioral and psychosocial covariates. This should be interpreted as statistical mediation under the assumption that covariates are measured without error and that no unmeasured confounders distort the gender–covariate–outcome relationships.

All analyses were conducted using the IBM SPSS Statistics software (version 25.0; IBM Corp., Armonk, NY, USA).

2.5. Use of Generative Artificial Intelligence

GenAI (ChatGPT, OpenAI) was used to assist in structuring and refining the manuscript text, including the formulation of the Introduction and Methods sections, based on the study protocol and validated instruments. Artificial intelligence (AI) was also used to synthesize and cross-reference the existing literature for clarity and contextualization. No generative AI was used for data collection, statistical analysis, or interpretation of the results. All content was reviewed and approved by the authors.

3. Results

3.1. Sample Characteristics

The analytic sample comprised 2,428 adolescents aged 11–19 years, evenly distributed by gender (51.4% males). Age, family language, migration background, single-parent household, parental education, and urban residence were comparable between male and female adolescents (all V ≤ 0.04; see Table 1). School type and family affluence reached statistical significance in gender comparisons ($p < 0.001$ and $p = 0.004$, respectively); however, both effects were negligible in magnitude (V ≤ 0.09), reflecting the power of the large sample rather than substantive group differences.

Table 1. Sociodemographic, behavioral, and mental health characteristics of the study sample (n = 2,428), stratified by gender, with effect sizes.

Variable	Males (n = 1,247)	Females (n = 1,181)	Total (n = 2,428)	p-value	Effect size
Sociodemographic characteristics					
Age, years — Median (min–max)	15 (11–19)	15 (11–19)	15 (11–19)	0.742 †	r = 0.007
Mean ± SD	14.71 ± 2.33	14.74 ± 2.35	14.73 ± 2.34		
School type, n (%)				< 0.001 *	V = 0.085
Middle school	519 (41.6)	468 (39.6)	987 (40.7)		
High school	591 (47.4)	629 (53.3)	1,220 (50.2)		
Vocational school	122 (9.8)	68 (5.8)	190 (7.8)		
Other	15 (1.2)	16 (1.4)	31 (1.3)		
School language, n (%)				0.402 *	V = 0.027
German	1,073 (86.7)	1,005 (85.3)	2,078 (86.0)		
Italian	137 (11.1)	138 (11.7)	275 (11.4)		

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Ladin	27 (2.2)	35 (3.0)	62 (2.6)		
Family language, *n* (%)				0.312 *	V = 0.038
German	1,016 (81.8)	942 (80.2)	1,958 (81.0)		
Italian	186 (15.0)	178 (15.1)	364 (15.1)		
Ladin	25 (2.0)	36 (3.1)	61 (2.5)		
Other	15 (1.2)	19 (1.6)	34 (1.4)		
Migration background, *n* (%)	73 (6.0)	69 (5.9)	142 (5.9)	0.974 *	V = 0.001
Single-parent household, *n* (%)	144 (11.6)	159 (13.5)	303 (12.5)	0.150 *	V = 0.029
Parental education (CASMIN), *n* (%)				0.157 *	V = 0.039
Low	225 (18.2)	215 (18.4)	440 (18.3)		
Medium	493 (40.0)	507 (43.4)	1,000 (41.6)		
High	516 (41.8)	446 (38.2)	962 (40.0)		
Urban residence, *n* (%)	371 (29.8)	336 (28.5)	707 (29.1)	0.481 *	V = 0.014
Family affluence (FAS-III), n (%)				0.004 *	V = 0.068
Low	178 (14.3)	218 (18.7)	396 (16.5)		
Medium	738 (59.4)	623 (53.5)	1,361 (56.6)		
High	326 (26.2)	323 (27.7)	649 (27.0)		
Median (min–max)	9 (3–13)	9 (3–13)	9 (3–13)	0.172 †	r = 0.028
Mean ± SD	9.36 ± 1.79	9.27 ± 1.93	9.31 ± 1.86		
Behavioral and lifestyle indicators					
Sleep difficulties ≥ 1 × / week, *n* (%)	289 (38.2)	351 (45.9)	640 (42.1)	0.002 *	V = 0.079
Late bedtime on schooldays (> 23:00), *n* (%)	103 (13.6)	89 (11.6)	192 (12.6)	0.247 *	V = 0.030
Physical activity ≥ 3 × / week, *n* (%)	608 (75.6)	478 (59.8)	1,086 (67.7)	< 0.001 *	V = 0.169
Perceived global-crises burden, *n* (%)	300 (39.3)	344 (44.8)	644 (42.0)	0.028 *	V = 0.056
Problematic internet use (GPIUS-2 elevated), *n* (%)	190 (25.8)	218 (29.7)	408 (27.8)	0.093 *	V = 0.044

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Total score, Median (min–max)	36 (15–120)	38 (15–110)	37 (15–120)	0.258 †	r = 0.030
Mean ± SD	39.46 ± 19.22	40.74 ± 19.83	40.10 ± 19.53		
Perceived social support (MSPSS) category, *n* (%)				0.943 *	V = 0.009
Low	54 (6.8)	55 (7.0)	109 (6.9)		
Moderate	92 (11.5)	87 (11.0)	179 (11.3)		
High	651 (81.7)	646 (82.0)	1,297 (81.8)		
Total score, Median (min–max)	6.17 (1–7)	6.25 (1–7)	6.17 (1–7)	0.043 †	r = 0.051
Mean ± SD	5.76 ± 1.45	5.83 ± 1.44	5.79 ± 1.44		
Health literacy (HLSAC) category, *n* (%)				0.600 *	V = 0.026
Low	73 (10.0)	84 (11.5)	157 (10.8)		
Medium	494 (68.0)	480 (65.9)	974 (66.9)		
High	160 (22.0)	164 (22.5)	324 (22.3)		
Total score, Median (min–max)	32 (10–40)	32 (10–40)	32 (10–40)	0.883 †	r = 0.004
Mean ± SD	31.59 ± 5.03	31.56 ± 5.09	31.58 ± 5.06		
Mental health screening results					
PHQ-2 elevated (≥ 3), *n* (%)	67 (9.0)	104 (13.8)	171 (11.4)	0.003 *	V = 0.076
PHQ-2 total score, Median (min–max)	1 (0–6)	1 (0–6)	1 (0–6)	< 0.001 †	r = 0.134
Mean ± SD	0.90 ± 1.15	1.28 ± 1.44	1.09 ± 1.32		
SCARED GAD-9 elevated (≥ 9), *n* (%)	144 (19.5)	278 (37.6)	422 (28.5)	< 0.001 *	V = 0.200
SCARED total score, Median (min–max)	4 (0–18)	6 (0–18)	5 (0–18)	< 0.001 †	r = 0.236
Mean ± SD	4.94 ± 4.19	7.21 ± 4.95	6.08 ± 4.72		
SDQ elevated (borderline / abnormal), *n* (%)	82 (11.4)	123 (16.9)	205 (14.2)	0.003 *	V = 0.079
SDQ total score, Median (min–max)	8 (0–30)	8 (0–30)	8 (0–30)	0.002 †	r = 0.081
Mean ± SD	8.51 ± 5.32	9.58 ± 5.99	9.05 ± 5.69		

Values are presented as *n* (%) for categorical variables and as median (minimum–maximum) or mean ± standard deviation (SD) for continuous variables. The denominators varied because of item-specific missingness; *n* reflects the number of cases with valid data for each variable. Valid data were available for 2,402–2,428 adolescents (98.9–

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100%) for sociodemographic characteristics, 1,455–1,604 (59.9–66.1%) for behavioral and lifestyle indicators, and 1,448–1,500 (59.6–61.8%) for mental health screening. Gender comparisons: * Pearson χ^2 test for categorical variables, with Cramér's V (V) as effect size; † Mann–Whitney U test for continuous and ordinal variables, with rank-biserial correlation coefficient $r = |Z|/\sqrt{N}$ as effect size: V or $r \approx 0.10$ indicates a small, ≈ 0.30 a medium, and ≈ 0.50 a large effect (Cohen, 1988). Abbreviations: CASMIN, Comparative Analysis of Social Mobility in Industrial Nations; FAS-III, Family Affluence Scale III; GPIUS-2, Generalized Problematic Internet Use Scale 2; HLSAC, Health Literacy for School-Aged Children; MSPSS, Multidimensional Scale of Perceived Social Support; PHQ-2, Patient Health Questionnaire-2; SCARED, Screen for Child Anxiety-Related Emotional Disorders; SDQ, Strengths and Difficulties Questionnaire.

3.2. Gender Differences in Mental Health Outcomes

Female adolescents scored higher than male adolescents on all three screening instruments, with the anxiety domain showing the most pronounced gap. Elevated SCARED GAD-9 scores were nearly twice as prevalent in female as in male adolescents, corresponding to a small-to-moderate effect ($V = 0.20$; $r = 0.24$), the largest gender difference observed in the study. Depressive (PHQ-2) and general (SDQ) mental health scores also showed a significant female excess both at the cut-off and on the continuous scale, although with markedly smaller effects ($V \leq 0.08$; $r \leq 0.13$). Across all three domains, effect sizes remained below the conventional threshold for moderate effects, indicating that the observed gender disparities, while statistically robust, were of limited magnitude at the population level.

3.3. Gender Differences in Behavioral and Psychosocial Correlates

Behavioral and psychosocial data were available for 1,448–1,603 adolescents in each wave. Physical activity differed markedly by gender ($V = 0.17$), with male adolescents substantially more likely than female adolescents to report at least three active days per week; this was the second-largest effect observed after SCARED anxiety. Sleep problems and perceived burden from global crises were more frequent in female adolescents, although both effects were small ($V \leq 0.08$). Late bedtimes on school days, problematic Internet use, perceived social support, and health literacy did not differ meaningfully between genders (all $V \leq 0.05$, $r \leq 0.05$), where nominal significance emerged on continuous scales, and the corresponding rank-biserial correlations were vanishingly small, again reflecting sample size rather than substantive group differences.

3.4. Multivariable Associations Between Correlates and Mental Health

The results of the three multivariable linear regression models are presented in Table 2. All models explained a substantial and comparable proportion of variance in mental health outcomes, with adjusted R^2 values of 0.36 for depression scores, 0.35 for anxiety scores, and 0.42 for emotional and behavioral scores. The VIF ranged from 1.02 to 1.18 across all predictors and models, confirming the absence of multicollinearity in the dataset.

School stress was the most consistent and strongest predictor across all three outcomes. Higher self-reported school burden, entered as a metric predictor on the original four-point response scale, was associated with higher PHQ-2 (standardized $\beta = 0.23$), SCARED-GAD ($\beta = 0.28$), and SDQ total difficulties scores ($\beta = 0.24$; all $p < 0.001$). PIU (GPIUS-2) was also a significant predictor of all three outcomes, with particularly strong associations with SDQ total difficulty scores ($\beta = 0.38$, $p < 0.001$) and comparable associations with depressive ($\beta = 0.26$) and anxiety scores ($\beta = 0.24$). Poor sleep quality was independently associated with all three outcomes ($\beta = 0.17$–0.21; $p < 0.001$). Higher perceived social support (MSPSS total) was inversely associated with all outcomes ($\beta = -0.07$ to -0.16, all $p \leq 0.002$), indicating a consistent protective role across mental health domains.

Gender showed a heterogeneous pattern across the three mental health domains after adjusting for behavioral and psychosocial factors. Female gender was a significant independent predictor of depressive scores ($\beta = 0.09$, $p < 0.001$) and anxiety scores ($\beta = 0.18$, $p < 0.001$), with the largest effect

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observed for anxiety, where gender was the second strongest predictor after school stress. In contrast, the gender effect on SDQ total difficulties scores no longer reached statistical significance after covariate adjustment (β = 0.04, p = 0.078), indicating that the gender difference in emotional and behavioral scores was fully accounted for by the measured behavioral and psychosocial factors.

Several predictors showed outcome-specific associations. Late bedtime was independently associated with depression scores (β = 0.08, p = 0.002) but not with anxiety or SDQ scores. Physical activity was inversely associated with depression scores (β = −0.08, p < 0.001) and, more modestly, with anxiety scores (β = −0.05, p = 0.036), but was not a significant predictor of SDQ scores. Health literacy was a significant inverse predictor of SDQ scores (β = −0.10, p < 0.001) but not of depression or anxiety scores. Age was positively associated with depressive scores (β = 0.09, p < 0.001) and inversely associated with SDQ scores (β = −0.06, p = 0.011) but not significantly associated with anxiety scores. Family affluence (FAS-III) was not significantly associated with any outcome in the multivariate models, consistent with the near-zero bivariate correlations observed in Supplementary Table S1.

Table 2. Multivariable linear regression models for depression (PHQ-2), anxiety (SCARED-GAD), and emotional/behavioral (SDQ) scores.

Predictor	PHQ-2 depressive score (n = 1,329)			SCARED-GAD anxiety score (n = 1,311)			SDQ total difficulties score (n = 1,275)		
	B (SE)	β	p	B (SE)	β	p	B (SE)	β	p
Gender (female)	0.23 (0.06)	0.09	< 0.001	1.70 (0.22)	0.18	< 0.001	0.44 (0.25)	0.04	0.078
Age	0.06 (0.01)	0.09	< 0.001	0.07 (0.05)	0.03	0.174	-0.15 (0.06)	-0.06	0.011
Physical activity	-0.06 (0.02)	-0.08	< 0.001	-0.13 (0.06)	-0.05	0.036	-0.10 (0.07)	-0.03	0.150
School stress[1]	0.35 (0.04)	0.23	< 0.001	1.53 (0.13)	0.28	< 0.001	1.56 (0.15)	0.24	< 0.001
HLSAC	0.00 (0.01)	0.01	0.763	-0.02 (0.02)	-0.02	0.429	-0.12 (0.03)	-0.10	< 0.001
Poor sleep quality	0.48 (0.06)	0.18	< 0.001	1.96 (0.22)	0.20	< 0.001	1.95 (0.26)	0.17	< 0.001
Late bedtime	0.29 (0.09)	0.07	0.002	0.30 (0.33)	0.02	0.365	0.48 (0.38)	0.03	0.213
PIU (GPIUS-2)	0.02 (0.00)	0.26	< 0.001	0.06 (0.01)	0.24	< 0.001	0.11 (0.01)	0.38	< 0.001
MSPSS	-0.14 (0.02)	-0.15	< 0.001	-0.25 (0.08)	-0.07	0.002	-0.67 (0.09)	-0.16	< 0.001
FAS-III	0.02 (0.02)	0.02	0.271	0.06 (0.06)	0.03	0.265	-0.04 (0.07)	-0.01	0.542
Model fit statistics									
R^2 (adjusted R^2)	0.36 (0.36)			0.35 (0.35)			0.43 (0.42)		
F (df1, df2)	74.66 (10, 1318)			71.31 (10, 1300)			94.53 (10, 1264)		
Model p-value	< 0.001			< 0.001			< 0.001		

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Predictor	PHQ-2 depressive score (n = 1,329)			SCARED-GAD anxiety score (n = 1,311)			SDQ total difficulties score (n = 1,275)		
	B (SE)	β	p	B (SE)	β	p	B (SE)	β	p
VIF range	1.02 – 1.18			1.02 – 1.18			1.02 – 1.18		

B, unstandardized regression coefficient; SE, standard error; β, standardized regression coefficient. All models used simultaneous entry (Enter method) with the listwise deletion of missing values. PHQ-2 range: 0–6; SCARED-GAD range: 0–18; SDQ total difficulties range: 0–40. [1] School stress was entered as a metric covariate on the original four-point response scale (1 = 'not at all', 4 = 'very strongly'). Abbreviations: GPIUS-2, Generalized Problematic Internet Use Scale 2; HLSAC, Health Literacy for School-Aged Children; MSPSS, Multidimensional Scale of Perceived Social Support (total score); PIU, problematic internet use; PHQ-2, Patient Health Questionnaire-2; SCARED-GAD, Screen for Child Anxiety-Related Emotional Disorders, GAD-9 subscale; SDQ, Strengths and Difficulties Questionnaire; FAS-III, Family Affluence Scale III. Gender was coded as 0 = male and 1 = female.

3.5. Gender Differences in Mental Health After Multivariable Adjustment

Table 3 presents the unadjusted and fully adjusted regression coefficients for gender across all three mental health outcomes. In unadjusted models, female gender was associated with significantly higher scores on all three outcomes (all $p < 0.001$), with the largest unadjusted effect observed for anxiety symptoms (β = 0.24), followed by depressive symptoms (β = 0.14) and emotional and behavioral difficulties (β = 0.09).

After full adjustment for age, physical activity, school stress, health literacy, sleep behavior, problematic Internet use, perceived social support, and family affluence, the gender coefficient was substantially attenuated in all three models. The residual gender effect remained highly significant for anxiety (adjusted β = 0.18, $p < 0.001$) and depression scores (β = 0.09, $p < 0.001$) but no longer reached statistical significance for emotional/behavioral scores (β = 0.04, $p = 0.078$).

The magnitude of attenuation differed markedly among the outcomes. Adjustment for the full set of behavioral and psychosocial covariates reduced the gender effect on emotional/behavioral scores by 58.5%, on depressive scores by 37.1%, and on anxiety scores by 25.3%. The comparatively modest attenuation for anxiety indicates that the female excess in anxiety is less explained by the measured behavioral and psychosocial factors than by the female excess in depressive and emotional/behavioral scores. Conversely, the near-complete attenuation of the gender effect on SDQ scores, such that it no longer reached statistical significance after adjustment, suggests that the gender gap in emotional and behavioral difficulties was largely mediated by the measured covariates. The variables most likely contributing to this attenuation, given that they both differed significantly by gender in Table 1 and were significant predictors in Table 2, included physical activity, poor sleep quality, and problematic Internet use.

Taken together, these findings indicate that gender differences in adolescent mental health persist independently of the behavioral and psychosocial factors examined, although a meaningful proportion of the gender effect, particularly for depression and behavioral difficulties, is accounted for by modifiable factors.

Table 3. Attenuation of the gender effect on mental health outcomes after adjustment for behavioral and psychosocial factors.

Mental health outcome	Unadjusted β (p-value)	Adjusted β (p-value)	Attenuation of β	95% CI for adjusted B	Model n (adj. R^2)
Depressive score (PHQ-2)	0.14 (< 0.001)	0.09 (< 0.001)	37.1%	[0.12, 0.35]	1,329 (0.36)

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Anxiety score (SCARED-GAD)	0.24 (< 0.001)	0.18 (< 0.001)	25.3%	[1.27, 2.12]	1,311 (0.35)
Total difficulties score (SDQ)	0.09 (< 0.001)	0.04 (0.078)	58.5%	[-0.05, 0.92]	1,275 (0.42)

Unadjusted models regressed each outcome on gender alone; adjusted models additionally included age, physical activity, school stress, health literacy (HLSAC), poor sleep quality, late bedtime, problematic Internet use (GPIUS-2), perceived social support (MSPSS total), and family affluence (FAS-III). Attenuation of β was computed as ((β unadjusted − β adjusted) / β unadjusted) × 100 following established change-in-estimate and mediation-analytic conventions (Greenland, 1989; MacKinnon, 2012), indicating the proportion of the unadjusted gender effect accounted for by the measured behavioral and psychosocial covariates. Bold values indicate statistical significance at $p < 0.05$. The 95% confidence interval is reported for the unstandardized coefficient B in the adjusted model. A higher attenuation value indicates that a larger share of the observed gender difference is mediated or explained by covariates.

4. Discussion

This population-based cross-sectional study examined gender differences in adolescent mental health and behavioral and psychosocial determinants among 2,428 adolescents aged 11–19 years in South Tyrol, Italy. Three principal findings were obtained. First, female adolescents consistently showed higher symptom levels across all three mental health domains, with the largest and most clinically relevant disparity observed for anxiety symptoms. Second, school stress and PIU were the strongest and most consistent predictors of mental health outcomes across all three domains, followed by poor sleep quality and perceived social support, with several additional predictors showing specific associations. Third, gender differences in mental health outcomes persisted after comprehensive multivariable adjustment, although a meaningful proportion of the gender effect was attenuated by the measured behavioral and psychosocial factors, most substantially for behavioral difficulties and depression, and least for anxiety.

4.1. Gender Differences in Mental Health Outcomes

The prevalence of elevated anxiety scores in female adolescents (37.6%) was nearly double that of males (19.5%), with an effect size (r = 0.236) nearing moderate and much higher than that of depression scores (r = 0.134) and emotional/behavioural scores (r = 0.081). These results align with meta-analytic evidence showing a persistent female excess in internalizing psychopathology during adolescence (Madigan et al., 2023; Rutter et al., 2003)and replicate patterns from previous COP-S waves in 2021, 2022, and 2023, where females consistently had higher anxiety rates than males (phi = 0.176–0.189, all $p < 0.001$) (Barbieri et al., 2023, 2024). Developmental models highlighting hormonal, cognitive, and social mechanisms that specifically increase anxiety in females support this pattern (Hale et al., 2010; McLaughlin & Nolen-Hoeksema, 2011).

The prevalence of elevated depression scores (PHQ-2 ≥ 3:13.8% female, 9.0% male) aligns with post-pandemic estimates from similar European settings (Madigan et al., 2023). Within the COP-S series, this 11.4% prevalence shows a decline from 15.4% in 2021 and 13.7% in 2022, with female rates dropping from 20.1% in 2021 to 13.5% in 2023 and stabilizing by 2025 (Barbieri et al., 2023, 2024). The present sample included all adolescents with valid responses, unlike Barbieri et al., who restricted their study to complete cases (Barbieri, Piccoliori, Engl, & Wiedermann, 2026), causing minor numerical differences; however, the pattern remained the same. Despite the stabilization of depressive symptom rates, the gender gap persists, showing proportional improvement for both genders without closing the disparity.

The significant gender difference in the SDQ total difficulties scores (female 16.9% vs. male 11.4% in the elevated range) requires careful interpretation. SDQ behavioral difficulties are often higher in males owing to conduct and hyperactivity subscales (Goodman, 2001). The excess in females likely

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reflects the emotional symptoms subscale, which is more prevalent in females (Marzocchi et al., 2004). This aligns with the gender effect on SDQ being most reduced after multivariable adjustment (44.7%), indicating shared variance with behavioral and psychosocial factors, such as school stress and social support, more than anxiety or depressive symptoms.

4.2. Gender Differences in Behavioral and Psychosocial Correlates

Physical activity showed the second largest gender difference among all behavioral variables. Male adolescents were substantially more likely than female adolescents to report at least three active days per week (75.6% vs. 59.8%; Cramér's V = 0.169).This gap is consistent with the European HBSC survey findings, which consistently document lower physical activity levels in female adolescents, with widening disparities during mid-adolescence (Inchley et al., 2020; Ruiz-Ranz & Asín-Izquierdo, 2025). The association between gender and physical activity is relevant because physical inactivity may constitute a mechanistic pathway through which gender indirectly influences mental health, a possibility supported by the significant association between physical activity and depressive symptoms in the multivariable models.

Female adolescents reported poor sleep quality more often (45.9% vs. 38.2%), aligning with evidence linking sleep disturbance to mental health issues in females (Goldstone et al., 2020; Lemke et al., 2025). Notably, late bedtime was similar across genders, indicating that differences in sleep quality stem from factors such as sleep onset difficulties or rumination. School stress was slightly higher among females ($p = 0.004$), supporting previous findings (Högberg et al., 2020), which found that school stress contributes to gender gaps in mental health in Sweden. Health literacy was similar between the genders ($p = 0.934$), matching the European HBSC data showing no gender advantage (Paakkari et al., 2020).

PIU (GPIUS-2) was similar across genders, but social media use (BSMAS) was slightly higher among females. This aligns with findings that gender differences in digital media are domain-specific: girls engage more in social networking, and boys in gaming (Cai et al., 2023). Females reported higher perceived social support from friends and significant others, reflecting gender differences in social orientation during adolescence (Rose & Rudolph, 2006). No gender difference in family support suggests that parental relationships do not affect mental health differently in males and females.

4.3. Multivariable Associations Between Correlates and Mental Health Outcomes

School stress was the strongest predictor of all three mental health outcomes ($\beta = 0.23–0.28$), confirming evidence from the COP-S series (Barbieri et al., 2024; Barbieri, Piccoliori, Engl, & Wiedermann, 2026) and European research that academic burden is a key risk factor for adolescent psychopathology (Hill et al., 2025; Högberg et al., 2020). School stress affects depression, anxiety, and behavioral difficulties, making it a transdiagnostic risk factor. These findings suggest that reducing the academic burden may benefit mental health across multiple domains.

PIU was the second strongest predictor and showed the largest association with the SDQ total difficulties ($\beta = 0.38$), surpassing its association with depression and anxiety scores. This aligns with meta-analytic evidence linking PIU to conduct problems, hyperactivity, and peer difficulties (Wartberg et al., 2017). The strong SDQ association may reflect shared mechanisms related to impulse regulation, attentional difficulties, and peer conflict in both externalizing psychopathology and PIU (Cai et al., 2023). Notably, GPIUS-2 and BSMAS were collinear ($r_s = 0.720$) and could not be included in the same model; GPIUS-2 was retained as the primary predictor, given its broader conceptual scope. GPIUS-2 predicted all outcomes after controlling for social media use, sleep, school stress, and social support, indicating that the effects of PIU on mental health are not fully mediated by co-occurring factors.

Poor sleep quality was linked to all outcomes ($\beta = 0.17–0.21$) after adjustment, consistent with evidence that sleep issues predict adolescent psychopathology (Scott et al., 2021), and COP-S findings showing sleep as a consistent correlate (Barbieri et al., 2026). Perceived social support had a protective

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effect (β = −0.07 to −0.16) and was strongest for SDQ behavioral difficulties. This supports the evidence that social connectedness buffers stress and aids coping (Scardera et al., 2020), and COP-S analyses identify low MSPSS as a predictor of mental health problems (Barbieri et al., 2026).

The predictors showed outcome-specific associations. Late bedtimes were linked to depressive symptoms, not anxiety or SDQ scores, aligning with evidence that circadian phase delay affects depressive mood more than anxiety (Alvaro et al., 2013). Physical activity is inversely related to depressive symptoms, matching meta-analytic evidence of exercise's stronger impact on depression than anxiety in adolescents (Biddle & Asare, 2011). Health literacy inversely predicted SDQ difficulties (β = −0.104), suggesting the relevance of behavioral self-regulation over affective symptoms. Family affluence was not significantly linked to any outcome, echoing Barbieri et al.'s (2025) findings of no association between parental education, material affluence, and self-reported mental health in this group of adolescents.

4.4. Attenuation of Gender Effects After Multivariable Adjustment

The attenuation analysis revealed heterogeneous sex differences in adolescent mental health after adjusting for behavioral and psychosocial factors. Attenuation ranged from 25.3% for anxiety to 37.1% for depression and 58.5% for emotional/behavioral difficulties, showing that female anxiety is least explained by the measured factors, while the gender gap in emotional/behavioral difficulties is fully accounted for by the modifiable exposures.

The modest 25.3% attenuation for anxiety suggests two interpretations: anxiety-specific vulnerability factors in females may operate independently of the factors examined in this study, or the SCARED-GAD subscale may measure a stable trait-like vulnerability that is less affected by situational factors. The substantial residual gender effect on anxiety implies that interventions targeting mechanisms beyond sleep, digital media, school stress, and social support may be necessary to reduce the gender gap in anxiety. The near-complete attenuation for emotional and behavioral difficulties, such that the gender difference no longer reaches statistical significance after adjustment, shows that the female excess in SDQ scores is substantially mediated by the measured factors. Physical activity, problematic Internet use, and poor sleep quality differed markedly by gender and were significant predictors in the models, likely being the main contributors to this attenuation. Universal interventions targeting these factors could, therefore, substantially reduce the gender gap in emotional and behavioral difficulties. For depression, the observed 37.1% attenuation suggests that modifiable factors explain approximately two-fifths of the female excess, with the remainder potentially due to unmeasured sex- or gender-specific mechanisms, similar to the findings of cross-national studies (Michl et al., 2013; Rood et al., 2009).

Overall, the findings align with a model in which gender differences in adolescent mental health result from modifiable factors differing across genders, are amenable to intervention, and residual gender-specific vulnerabilities requiring targeted approaches. Identifying modifiable factors such as school stress, sleep, social media use, social support, and physical activity offers a target profile for preventive intervention design.

4.5. Strengths and Limitations

This study had several strengths. The large population-based sample (n = 2,428) was representative of the gender and age distribution in South Tyrol, as confirmed by provincial statistics (ASTAT). The use of three validated, internationally standardized screening instruments provides comprehensive coverage of adolescent mental health issues. The simultaneous entry of multiple behavioral and psychosocial predictors in a single analytical framework enabled the assessment of relative predictor contributions and direct quantification of gender effect attenuation. The inclusion of both continuous and dichotomized outcome analyses provides complementary perspectives on the clinical burden and severity distribution. The present findings extend the prior COP-S 2025 dataset analyses. Barbieri et al. (2026) identified within-gender predictors of mental health issues using gender-stratified logistic regression, finding school stress, PIU, sleep, and physical activity

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significant in both genders, with single parenthood and health literacy significant for females, and low social support for males. This study shifts the focus to the determinants of the gender gap, using continuous outcomes and simultaneous entry regression for precise predictor effect estimation and gender effect attenuation quantification, which have not been previously examined. The novel finding that the gender effect on anxiety is least attenuated was not addressed in Barbieri et al.'s (2026) framework.

This study has several limitations. First, the cross-sectional design precludes causal inference. Second, although the base sample was large and population-based, the regression analyses were restricted to adolescents with complete data on all predictors and outcomes (n = 1,275–1,329 of 2,428). A comparison of respondents with complete versus sparsely completed self-report data in the same COP-S 2025 wave is reported in Supplementary Material 1 of Barbieri et al. (2026), showing that adolescents with incomplete data reported slightly higher average levels of problematic Internet use and school burden and lower perceived social support. This selective attrition suggests that the associations reported here may be conservative, as adolescents at higher behavioral and psychosocial risk were underrepresented in the analytical sample. Third, the response rate of 23 % may have introduced selection bias. Nonetheless, the demographic distribution of the base sample matched the regional statistics for the corresponding age group (Barbieri et al., 2026), supporting demographic representativeness at the descriptive level. Fourth, conducted in a high-income, trilingual European region, generalizability is limited to different educational, cultural, and economic contexts. Fifth, several predictors were unavailable, including clinical history and pubertal status, which contributed to unexplained gender effects. Sixth, the positive skewness of the PHQ-2 residuals (skewness 1.03) may reduce the depression model estimate precision, but the large sample size ensured asymptotic validity of the results. Seventh, the BSMAS and GPIUS-2 could not be entered simultaneously because of collinearity (rs 0.72); digital media effects reflect PIU, and separate social media addiction examination was not possible.

5. Conclusions

Gender differences in adolescent mental health are consistent, with female adolescents scoring higher than male adolescents in the depressive, anxiety, and emotional/behavioral domains. After comprehensive adjustment for behavioral and psychosocial factors, the gender difference remained statistically significant for anxiety and depression scores but was fully accounted for by the measured covariates in the case of emotional and behavioral scores. The proportion of the gender effect explained by modifiable exposures ranged from 25.3% for anxiety to 37.1% for depression and 58.5% for emotional/behavioral difficulties, indicating that the female excess in anxiety is least explained by the measured factors and warrants anxiety-specific preventive strategies targeting mechanisms beyond the behavioral correlates examined here. School stress and problematic Internet use were the strongest and most consistent predictors across the three mental health domains. Together with poor sleep quality, physical activity, and perceived social support, these represent priority targets for school-based prevention that may simultaneously benefit multiple outcomes and partially narrow gender disparities. Continued population-based monitoring through the COP-S survey series provides an essential foundation for evidence-based adolescent mental health policies in bilingual high-income regions and comparable settings.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org. Table S1: Spearman rank-order correlations among study variables (n = 2,428, pairwise deletion).

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Autonomous Province of Bolzano, Italy (protocol code 11-2025 on 19 February 2025).

Informed Consent Statement: Informed consent was obtained from all the participants involved in the study.

Data Availability Statement: The data presented in this study are available from the corresponding author upon reasonable request.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial intelligence
BSMAS	Bergen Social Media Addiction Scale
CASMIN	Comparative Analysis of Social Mobility in Industrial Nations
COP-S	Corona and Psyche South Tyrol
FAS III	Family Affluence Scale III
GAD-9	Generalized Anxiety Disorder subscale
GPIUS-2	Generalized Problematic Internet Use Scale 2
HBSC	Health Behavior in School-aged Children
HLSAC	Health Literacy for School-Aged Children
IQR	Interquartile range
MSPSS	Multidimensional Scale of Perceived Social Support
OLS	Ordinary least squares
PHQ-2	Patient Health Questionnaire-2
PIU	Problematic internet use
SCARED	Screen for Child Anxiety Related Emotional Disorders
SDQ	Strengths and Difficulties Questionnaire
VIF	Variance inflation factor

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