

Cross-Lagged Structural Equation Modeling of Loneliness, Problematic Social Media Use, Self-Esteem, and Depressive Symptoms Among Adolescents

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ABSTRACT

Objective: This study aimed to examine the reciprocal longitudinal relationships among loneliness, problematic social media use, self-esteem, and depressive symptoms across three measurement waves among adolescents in Slovenia.

Methods and Materials: A three-wave longitudinal correlational design was conducted with 612 Slovenian adolescents aged 13–18 years ($M = 15.47$, $SD = 1.36$). Participants completed assessments at baseline, six months, and twelve months. Loneliness was measured using the UCLA Loneliness Scale, problematic social media use using the Social Media Disorder Scale, self-esteem using the Rosenberg Self-Esteem Scale, and depressive symptoms using the Patient Health Questionnaire-9. Data were analyzed using descriptive statistics, Pearson correlations, confirmatory factor analysis, longitudinal measurement invariance testing, and cross-lagged structural equation modeling. Missing data were handled using full information maximum likelihood estimation, and age and gender were included as covariates.

Findings: The final structural model showed good fit, $\chi^2(432) = 861.37$, $CFI = .956$, $TLI = .948$, $RMSEA = .040$, and $SRMR = .046$. All four constructs demonstrated significant temporal stability across both intervals. Loneliness predicted greater subsequent problematic social media use ($\beta = .18$ and $.20$), lower self-esteem ($\beta = -.17$ and $-.18$), and higher depressive symptoms ($\beta = .21$ and $.22$; all $p < .001$). Reverse effects were also significant, with problematic social media use, lower self-esteem, and depressive symptoms predicting later loneliness. Problematic social media use predicted lower subsequent self-esteem and higher depressive symptoms, while self-esteem and depressive symptoms showed significant reciprocal effects across both intervals. Equality-constrained analyses indicated that the principal cross-lagged effects were stable across time.

Conclusion: The findings indicate that loneliness, problematic social media use, self-esteem, and depressive symptoms form a reciprocal and relatively stable longitudinal network during adolescence, with loneliness emerging as a particularly important prospective predictor of later psychosocial difficulties.

Keywords: Adolescents; Loneliness; Problematic Social Media Use; Self-Esteem; Depressive Symptoms.

1. Introduction

Adolescence is a developmental period characterized by rapid biological maturation, expanding social networks, heightened sensitivity to interpersonal evaluation, and increasing reliance on digital communication environments. During these years, adolescents are required to negotiate changing relationships with parents, peers, schools, and broader social systems while simultaneously developing a more coherent sense of self. These developmental demands can create both opportunities for psychological growth and vulnerabilities to emotional and behavioral difficulties. Depression, loneliness, impaired self-evaluation, and maladaptive forms of digital engagement have therefore become increasingly important concerns in adolescent mental health research. Recent epidemiological and clinical work indicates that depressive disorders and depressive symptom burden among adolescents remain substantial and may evolve over time under the influence of multiple biological, interpersonal, and social determinants (Zeng et al., 2026). Research on diagnostic transitions among adolescent psychiatric inpatients further demonstrates that adolescent mental health presentations can be dynamic rather than fixed, highlighting the importance of longitudinal approaches that capture changes in symptom patterns across developmental time (Kong & Mao, 2026). Within this context, understanding how psychosocial factors interact across time is especially important because apparently distinct experiences such as loneliness, excessive social media involvement, diminished self-esteem, and depressive symptoms may function as components of a mutually reinforcing developmental system rather than as isolated phenomena.

Loneliness represents a subjective perception that an individual's existing social relationships are insufficient in quality, intimacy, or availability relative to desired relationships. It is conceptually distinct from objective social isolation because adolescents can experience loneliness even when surrounded by peers, classmates, and family members. This distinction is especially relevant in adolescence, when social belonging and peer acceptance assume increased psychological importance. Developmental research on solitude has further emphasized that time spent alone can have both beneficial and detrimental functions depending on whether solitude is voluntarily chosen, emotionally regulated, and developmentally appropriate or instead reflects exclusion, disconnection, and unmet social needs (Haidabieke et al., 2024). Accordingly, loneliness is not

simply equivalent to being alone; rather, it reflects a negative appraisal of one's social connectedness. Social exclusion and inclusion also influence emotional adaptation, suggesting that interpersonal belonging is closely tied to the regulation of affective responses and social adjustment (Meng, Chen, et al., 2024). For adolescents whose peer relationships are unstable or whose perceived social resources are limited, persistent loneliness may contribute to maladaptive cognitive and behavioral patterns, including increased dependence on online environments for reassurance, social monitoring, and perceived connection.

One increasingly salient behavioral correlate of adolescent loneliness is problematic social media use. Social media platforms offer adolescents opportunities for interaction, identity expression, entertainment, information acquisition, and maintenance of peer relationships; however, these advantages coexist with risks associated with excessive or poorly regulated use. Problematic social media use generally refers to a pattern of persistent, difficult-to-control engagement with social platforms that interferes with daily functioning, emotional well-being, academic responsibilities, sleep, or offline relationships. Chmiel et al. specifically demonstrated an association between loneliness and problematic social media use among adolescents and identified fear of missing out as an important explanatory mechanism, indicating that socially disconnected adolescents may be especially vulnerable to compulsive monitoring of online social activity (Chmiel et al., 2026). Related evidence from the broader literature on digital behavior has shown that adverse childhood experiences and relational difficulties are associated with elevated risk of internet addiction, suggesting that problematic digital engagement may partly emerge as a maladaptive coping response to psychosocial adversity (Xianxin et al., 2024). These findings support the possibility that loneliness may precede problematic social media use because adolescents who feel insufficiently connected offline may increasingly seek compensatory connection online.

At the same time, the relationship between loneliness and problematic social media use is unlikely to be unidirectional. Excessive social media use may itself intensify loneliness by displacing face-to-face interaction, increasing exposure to social comparison, amplifying perceived exclusion, fragmenting attention, or producing repeated experiences of online social monitoring without genuine interpersonal intimacy. Research on information and communication technologies in childhood has underscored the increasingly important role of digital environments in shaping children's

and adolescents' interaction with social and spatial contexts (Chen et al., 2024). The effects of digital engagement may therefore depend not only on the amount of use but also on the meaning, context, and psychological function of that use. Intensive longitudinal research examining smartphone-related stress has likewise demonstrated that adolescents' digital experiences are meaningfully related to mental health and that these relationships can vary across analytical specifications and temporal contexts (Huang et al., 2024). Network literacy may also influence the association between online engagement and depressive outcomes, with evidence suggesting that the way young people understand and navigate online environments can be related to depression levels (Zhang & Lin, 2026). Together, these findings indicate that problematic social media use may both emerge from psychosocial vulnerability and contribute to its maintenance.

Self-esteem constitutes another central component of adolescent psychosocial development. Global self-esteem reflects an individual's overall evaluation of personal worth and adequacy and is shaped through repeated interactions with family members, peers, teachers, and increasingly digital audiences. Adolescence is a period during which self-evaluations may become particularly sensitive to social acceptance, achievement, appearance, and comparison with others. Secure interpersonal relationships are generally associated with better mental health, whereas difficulties in attachment and interpersonal security can contribute to poorer psychological functioning (Yongmei & Hongyu, 2023). Family functioning is similarly important. A three-level meta-analysis has shown that family dysfunction is associated with poorer mental health among children and adolescents, demonstrating that the quality and predictability of the family environment can have broad psychological consequences (Wen et al., 2024). More recent evidence has also indicated that family environmental unpredictability is associated with adolescent physiological and psychological health, while a positive school climate may buffer some of these adverse effects (Gao et al., 2026). These findings suggest that self-esteem is embedded within a broader ecology of social relationships and may deteriorate when adolescents repeatedly experience instability, rejection, exclusion, or perceived inadequacy.

Loneliness may undermine self-esteem because persistent perceived disconnection can be interpreted by adolescents as evidence of low social desirability, personal inadequacy, or failure to establish meaningful relationships. In turn, low self-esteem may increase vulnerability to

loneliness by promoting negative expectations about social interaction, fear of rejection, withdrawal, or heightened sensitivity to perceived exclusion. This reciprocal formulation is consistent with evidence that social inclusion changes the emotional consequences of exclusion and contributes to adaptive emotional processing (Meng, Chen, et al., 2024). It is also compatible with research showing that school connectedness is systematically associated with depression, reinforcing the broader proposition that perceived belonging across important social contexts is closely linked to emotional well-being (Meng, Luo, et al., 2024). Thus, self-esteem may function simultaneously as an outcome of social experiences and as a psychological factor that influences how adolescents interpret and respond to those experiences.

The association between self-esteem and problematic social media use may also be reciprocal. Adolescents with lower self-esteem may rely more heavily on online reassurance, feedback, social comparison, or idealized self-presentation to regulate feelings of inadequacy. In contrast, repeated exposure to curated portrayals of peers, popularity metrics, appearance-focused content, and socially evaluative feedback may contribute to increasingly negative self-appraisals. Such processes can become particularly influential when adolescents already possess heightened sensitivity to social judgment or difficulties regulating emotional responses. Research on the neuropsychological mechanisms of social and emotional information processing in children, although conducted in specific clinical populations, highlights the broader relevance of accurate interpretation of facial expressions and interpersonal cues to emotional functioning (Chen & Feng, 2024). Digital communication environments may alter these processes by reducing access to nuanced interpersonal information while emphasizing quantified indicators of approval such as likes, views, and follower counts. Consequently, adolescents with lower self-esteem may become increasingly dependent on social media feedback while simultaneously becoming more vulnerable to its negative evaluative consequences.

Depressive symptoms represent another major component of the proposed longitudinal system. Depression during adolescence is characterized not only by low mood but also by loss of interest, fatigue, sleep or appetite disturbance, concentration problems, negative self-evaluation, and in some cases self-harm or suicidal thinking. Contemporary research increasingly recognizes adolescent depression as a heterogeneous and developmentally complex condition involving interactions among emotional

dysregulation, interpersonal stress, environmental adversity, and biological vulnerability. Qualitative and theoretical work on emotional dysregulation in depressed adolescents has emphasized that dysregulation may develop as a continuous process across multiple stages rather than appearing abruptly (Wang et al., 2024). Research on neurofeedback similarly reflects growing interest in interventions that target affective processes and positive emotion enhancement in depression (Che et al., 2024). At the biological level, work examining phosphodiesterase-4 inhibitors in central nervous system disorders illustrates the expanding investigation of neurobiological pathways relevant to psychiatric and neurological conditions (Adili et al., 2024). Although such biological mechanisms are distinct from the psychosocial processes examined in the present study, they reinforce the broader understanding that depressive symptoms arise from multiple interacting levels of influence.

The relationship between loneliness and depressive symptoms is particularly important because the two constructs can reinforce one another over time. Persistent loneliness may increase rumination, negative self-appraisal, perceived helplessness, and reduced access to social support, thereby contributing to depressive symptom development. Conversely, depressive symptoms may promote social withdrawal, reduced motivation, negative interpretation of social encounters, and diminished responsiveness to available relationships, thereby increasing later loneliness. The importance of social and environmental support in depression is consistent with meta-analytic evidence demonstrating an association between school connectedness and depression (Meng, Luo, et al., 2024). It is also consistent with findings showing that family dysfunction is related to poorer child and adolescent mental health (Wen et al., 2024). From an ecological perspective, even physical and environmental characteristics of everyday settings may contribute to perceived restoration and psychological well-being, as reflected in research concerning healing-oriented residential environments (Song & Xu, 2024). Similarly, research on protective environments in medical populations illustrates the broader principle that environmental conditions can influence health outcomes, although the mechanisms and populations differ substantially from adolescent psychosocial development (Zhou et al., 2024).

Problematic social media use may provide another pathway through which depressive symptoms develop or persist. Adolescents experiencing emotional distress may turn to social media for distraction, reassurance, or escape,

potentially increasing the risk of compulsive use. In the opposite direction, problematic use may contribute to depressive symptoms through sleep disruption, cybervictimization, negative comparison, reduced physical activity, academic interference, and exposure to stressful or emotionally provocative content. The relationship between digital stress and adolescent mental health documented in intensive longitudinal research supports the importance of temporal analysis rather than reliance solely on cross-sectional associations (Huang et al., 2024). Moreover, the protective or harmful effects of online engagement may depend partly on adolescents' competencies in navigating digital environments, as suggested by research linking network literacy with depression (Zhang & Lin, 2026). The likely bidirectionality of these relationships makes conventional cross-sectional designs insufficient for determining whether problematic social media use primarily reflects pre-existing emotional difficulties, contributes to later psychological problems, or operates through both pathways.

Self-esteem and depressive symptoms are likewise closely interconnected. Low self-esteem can contribute to depression by increasing negative self-beliefs, hopeless interpretations, and sensitivity to interpersonal failure, whereas depressive symptoms can further erode self-esteem through negative cognitive biases and diminished perceptions of competence. The etiological role of emotional dysregulation in adolescent depression further suggests that persistent difficulty managing negative emotional experiences may contribute to reinforcing cycles between self-evaluation and depressive affect (Wang et al., 2024). Broader intervention research also demonstrates that depressive symptoms are modifiable through multiple pathways, including behavioral and physiological mechanisms. For example, evidence from exercise interventions has shown reductions in anxiety and depressive symptoms in clinical populations, while neuroscience research has increasingly examined how physical activity influences brain and psychological functioning (Liu et al., 2026; Wei et al., 2024). Although these findings derive from populations and intervention contexts different from the present adolescent sample, they emphasize that depressive symptoms are dynamic and responsive to interacting behavioral and neuropsychological processes rather than being static traits.

The broader depression literature also demonstrates the importance of differentiating developmental populations and etiological contexts. Research on multimorbidity and

depressive symptoms among middle-aged and older adults, for example, shows how combinations of health conditions may be associated with depressive symptom profiles later in life (Sun et al., 2026). Such evidence cannot be directly generalized to adolescents, but it illustrates the wider methodological importance of modeling multiple interacting risk factors rather than examining single predictors in isolation. Adolescence similarly involves interconnected systems of biological development, family relations, peer relationships, school experiences, digital behaviors, and self-perceptions. A model that simultaneously considers loneliness, problematic social media use, self-esteem, and depressive symptoms may therefore provide a more realistic account of adolescent psychosocial adjustment than separate bivariate analyses.

Cross-lagged structural equation modeling is particularly appropriate for examining these reciprocal processes because it allows the temporal stability of each construct to be controlled while estimating prospective paths between constructs across repeated measurement occasions. In this approach, an association between an earlier predictor and a later outcome can be examined while accounting for the prior level of that outcome, thereby providing stronger evidence regarding temporal precedence than cross-sectional correlation. Three-wave models are especially informative because they permit examination of whether cross-lagged relationships are replicated across more than one interval and whether the magnitudes of effects remain relatively stable over time. This is particularly important for adolescent mental health, where psychosocial processes may change rapidly and where reciprocal influence is theoretically plausible. Recent research increasingly uses longitudinal, multilevel, and network-oriented perspectives to understand psychological functioning, reflecting recognition that emotional and behavioral outcomes often arise from dynamic systems rather than single causal pathways (Gao et al., 2026; Huang et al., 2024).

Despite accumulating evidence linking loneliness with problematic social media use, self-esteem with depression, and digital behavior with mental health, important gaps remain. Many studies have examined only two or three of these constructs simultaneously, have relied on cross-sectional designs, or have tested mediation models that presuppose a particular direction of influence. Such approaches may obscure reciprocal processes. For example, loneliness may promote problematic social media use, but problematic social media use may also increase later loneliness; low self-esteem may precede depressive

symptoms, but depression may subsequently further reduce self-esteem. Similarly, the same adolescent may experience several of these processes concurrently. Theoretical progress therefore requires longitudinal models in which these constructs are examined together, while controlling their prior levels and contemporaneous associations. This is particularly relevant in European adolescent populations, where patterns of digital engagement and psychosocial development may differ from those reported in other cultural contexts. A three-wave investigation conducted among adolescents in Slovenia can therefore contribute evidence regarding the temporal organization of these interrelated psychosocial variables and clarify whether the observed associations are predominantly unidirectional or reciprocal.

The aim of this study was to examine the reciprocal longitudinal relationships among loneliness, problematic social media use, self-esteem, and depressive symptoms across three measurement waves among adolescents in Slovenia using cross-lagged structural equation modeling.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a three-wave longitudinal correlational design to examine the temporal and reciprocal relationships among loneliness, problematic social media use, self-esteem, and depressive symptoms in adolescents using cross-lagged structural equation modeling. The study population consisted of adolescents enrolled in lower- and upper-secondary schools in Slovenia during the 2025–2026 academic year. Participants were recruited from public secondary schools located in Ljubljana, Maribor, Celje, Kranj, and Koper to provide representation of adolescents from different geographic and educational settings. A multistage cluster sampling procedure was used in which schools were first selected from the participating regions and intact classrooms were subsequently recruited within each school. A total of 612 adolescents participated at baseline (Time 1), with ages ranging from 13 to 18 years. The participants had a mean age of 15.47 years ($SD = 1.36$). Data were collected at three measurement occasions separated by approximately six months, resulting in an overall observation period of approximately one year. Time 1 assessments were conducted at the beginning of the academic year, Time 2 assessments approximately six months later, and Time 3 assessments approximately twelve months after the baseline assessment. The longitudinal intervals were selected to provide sufficient time for

meaningful changes in psychosocial functioning to emerge while remaining short enough to examine developmental processes during adolescence. Eligible participants were students aged 13–18 years who were enrolled in one of the participating schools, regularly used at least one social media platform, had sufficient proficiency in Slovenian to understand the questionnaires, and provided informed assent together with parental or legal guardian consent when required. Adolescents with severe cognitive or developmental difficulties that prevented independent completion of the questionnaires were excluded. Data collection was conducted during regular school hours in classroom settings under standardized conditions by trained research assistants. Participants were informed that participation was voluntary, responses would remain confidential, and they could discontinue participation at any time without consequences. To link participants' responses across measurement waves while maintaining confidentiality, each participant generated a unique anonymous identification code. The study procedures were conducted in accordance with established ethical principles for research involving adolescents, and institutional and school-level permissions were obtained before data collection.

2.2. Measures

UCLA Loneliness Scale. Loneliness was assessed using the UCLA Loneliness Scale, originally developed by Russell, Peplau, and Ferguson and subsequently revised by Russell. The scale is one of the most extensively used standardized self-report instruments for evaluating perceived social isolation and subjective feelings of loneliness. The commonly used revised version contains 20 items addressing the extent to which individuals perceive deficiencies in the quantity and quality of their interpersonal relationships, including feelings of social disconnection, lack of companionship, exclusion, and interpersonal closeness. Participants indicate how frequently they experience each statement on a four-point Likert-type scale ranging from 1 (never) to 4 (often). Positively worded items are reverse scored before the responses are summed, with higher total scores indicating greater perceived loneliness. The scale has been used extensively with adolescent and young adult populations and has demonstrated satisfactory internal consistency, test–retest reliability, convergent validity, and construct validity across different cultural contexts. In the present study, the same version and scoring

procedure were used at all three measurement occasions to ensure longitudinal comparability of loneliness scores.

Social Media Disorder Scale. Problematic social media use was measured using the Social Media Disorder Scale developed by van den Eijnden, Lemmens, and Valkenburg in 2016. The instrument was specifically designed to assess problematic and potentially addictive patterns of social media use among adolescents and is theoretically based on behavioral addiction criteria. The nine-item short form evaluates nine domains associated with problematic social media behavior, including preoccupation, tolerance, withdrawal, persistence, displacement of other activities, interpersonal or intrapersonal problems, deception, escape, and conflict. Participants respond to each item with a dichotomous yes/no response referring to their social media behavior during the specified period. Affirmative responses are coded as 1 and negative responses as 0, producing a total score ranging from 0 to 9, with higher scores indicating a greater number of problematic social media use symptoms. In addition to its use for identifying adolescents with elevated patterns of problematic use, the total score can be treated as a continuous indicator of symptom severity in correlational and structural equation analyses. Previous research involving adolescent samples has supported the scale's factorial validity, internal consistency, criterion validity, and cross-cultural applicability. The instrument was administered identically at Time 1, Time 2, and Time 3.

Rosenberg Self-Esteem Scale. Global self-esteem was assessed using the Rosenberg Self-Esteem Scale developed by Morris Rosenberg in 1965. This 10-item self-report measure assesses an individual's overall positive or negative evaluation of the self and is among the most widely applied measures of global self-worth in adolescent and adult research. The instrument contains both positively and negatively worded statements reflecting feelings of personal worth, self-respect, competence, and satisfaction with oneself. Participants rate each statement using a four-point Likert-type response format ranging from 1 (strongly disagree) to 4 (strongly agree). Negatively phrased items are reverse scored, after which item scores are summed to generate an overall self-esteem score, with higher scores representing greater global self-esteem. The Rosenberg Self-Esteem Scale has demonstrated strong internal consistency, temporal stability, convergent validity, discriminant validity, and construct validity in adolescent populations and has been translated and validated across numerous cultural and linguistic settings. The same scoring procedures were applied at each measurement wave to permit evaluation of

both stability and longitudinal associations involving self-esteem.

Patient Health Questionnaire-9. Depressive symptoms were measured using the Patient Health Questionnaire-9, developed by Kroenke, Spitzer, and Williams in 2001. The PHQ-9 is a nine-item standardized self-report instrument designed to assess the frequency and severity of depressive symptoms corresponding to the principal symptom domains of depressive disorders. Respondents indicate how frequently they have experienced each symptom during the preceding two weeks using a four-point scale ranging from 0 (not at all) to 3 (nearly every day). Item scores are summed to generate a total score ranging from 0 to 27, with higher scores reflecting greater severity of depressive symptomatology. The instrument assesses symptoms including depressed mood, reduced interest or pleasure, sleep disturbance, fatigue, changes in appetite, negative self-evaluation, concentration difficulties, psychomotor changes, and thoughts related to death or self-harm. The PHQ-9 has been extensively examined in adolescent populations and has demonstrated satisfactory internal consistency, criterion validity, convergent validity, and sensitivity for detecting different levels of depressive symptom severity. In the present longitudinal study, the PHQ-9 was administered using the same instructions and scoring procedure at all three measurement occasions.

2.3. Data Analysis

Data were analyzed using IBM SPSS Statistics and structural equation modeling software. Preliminary analyses included examination of data completeness, missing-value patterns, univariate distributions, outliers, and descriptive statistics for all study variables at each of the three measurement occasions. Means, standard deviations, minimum and maximum values, skewness, and kurtosis were calculated, and bivariate Pearson correlation coefficients were estimated to describe contemporaneous and longitudinal associations among loneliness, problematic social media use, self-esteem, and depressive symptoms. Internal consistency of each measure was evaluated separately at Time 1, Time 2, and Time 3. Patterns of attrition across waves were also examined to determine whether participants who completed all assessments differed systematically from those who did not participate in subsequent waves. Missing observations were handled using full information maximum likelihood estimation within the structural equation modeling framework, thereby allowing

available information from participants with incomplete longitudinal data to contribute to model estimation under the assumption that data were missing at random. Prior to testing the structural relationships, longitudinal measurement properties were evaluated to ensure that the constructs were measured sufficiently consistently across the three assessment occasions. Confirmatory factor analyses were conducted, followed by examination of longitudinal measurement invariance where applicable through progressively constrained configural, metric, and scalar models.

A three-wave cross-lagged panel structural equation model was subsequently estimated to investigate the direction and magnitude of temporal associations among loneliness, problematic social media use, self-esteem, and depressive symptoms. The model simultaneously included autoregressive stability paths for each construct from Time 1 to Time 2 and from Time 2 to Time 3, thereby accounting for temporal stability in each psychological characteristic. Within-wave correlations among the four constructs were freely estimated at each measurement occasion. Cross-lagged paths were specified from every Time 1 construct to the other constructs at Time 2 and from every Time 2 construct to the other constructs at Time 3. This modeling strategy made it possible to determine whether an earlier level of one variable predicted subsequent changes in another variable after controlling for the prior level of the outcome and concurrent associations among all study variables. Thus, for example, the model estimated whether loneliness predicted subsequent problematic social media use, lower self-esteem, or greater depressive symptoms while simultaneously examining the reverse temporal pathways from those variables to later loneliness. Equivalent reciprocal pathways were evaluated among problematic social media use, self-esteem, and depressive symptoms. Age and gender were included as covariates where appropriate to reduce potential confounding of the longitudinal associations.

Model parameters were estimated using a robust maximum likelihood estimator to reduce the influence of departures from multivariate normality. Statistical significance was evaluated at an alpha level of .05, and standardized regression coefficients, standard errors, confidence intervals, and p values were reported for the structural paths. Overall model adequacy was evaluated using multiple goodness-of-fit indices, including the chi-square statistic relative to degrees of freedom, the Comparative Fit Index, Tucker-Lewis Index, Root Mean

Square Error of Approximation with its 90% confidence interval, and Standardized Root Mean Square Residual. Values of CFI and TLI of approximately .90 or higher and RMSEA and SRMR values below approximately .08 were considered indicative of acceptable model fit, while more stringent values were interpreted as evidence of good fit. Nested models were compared when theoretically appropriate to determine whether corresponding cross-lagged paths could be constrained to equality across the Time 1–Time 2 and Time 2–Time 3 intervals without a meaningful deterioration in model fit. The interpretation of the final model focused on both the statistical significance and standardized magnitude of the autoregressive and cross-lagged coefficients, allowing examination of the reciprocal developmental relationships among loneliness, problematic social media use, self-esteem, and depressive symptoms across adolescence.

3. Findings and Results

At baseline, 612 adolescents participated in the study. Of these, 311 participants (50.82%) were girls and 301 (49.18%) were boys. Participants ranged in age from 13 to 18 years, with a mean age of 15.47 years ($SD = 1.36$). Regarding age distribution, 68 participants (11.11%) were 13 years old, 103 (16.83%) were 14 years old, 139 (22.71%)

were 15 years old, 132 (21.57%) were 16 years old, 101 (16.50%) were 17 years old, and 69 (11.27%) were 18 years old. At Time 2, 574 adolescents completed the assessment, corresponding to a retention rate of 93.79%, while 548 participants completed the Time 3 assessment, corresponding to an overall retention rate of 89.54% from baseline to the final wave. Comparisons between participants who completed all three assessments and those who did not complete the final assessment revealed no statistically significant baseline differences in age, gender distribution, loneliness, problematic social media use, self-esteem, or depressive symptoms, suggesting that attrition was unlikely to have introduced substantial systematic bias into the longitudinal analyses. Examination of the distributions of the study variables indicated acceptable univariate normality. Across all three assessment occasions, absolute skewness values ranged from 0.08 to 0.79 and absolute kurtosis values ranged from 0.04 to 0.96, remaining within commonly accepted limits for structural equation modeling. No severe univariate outliers were detected, and inspection of Mahalanobis distances did not indicate a pattern of multivariate observations sufficiently extreme to warrant exclusion. The proportion of missing observations was low across all variables and waves and was handled using full information maximum likelihood estimation in subsequent structural equation models.

Table 1

Descriptive Statistics, Internal Consistency, and Bivariate Correlations Among the Study Variables Across the Three Measurement Waves

Variable	M	SD	α	1	2	3	4	5	6	7	8	9	10	11	12
1. Loneliness T1	42.73	9.18	.91	—											
2. PSMU T1	3.27	2.11	.84	.46***	—										
3. Self-esteem T1	27.84	5.36	.88	-.58***	-.34***	—									
4. Depression T1	8.91	5.47	.89	.61***	.42***	-.56***	—								
5. Loneliness T2	43.19	9.41	.92	.68***	.39***	-.48***	.52***	—							
6. PSMU T2	3.48	2.19	.85	.38***	.64***	-.29***	.37***	.47***	—						
7. Self-esteem T2	27.29	5.48	.89	-.47***	-.28***	.70***	-.49***	-.57***	-.35***	—					
8. Depression T2	9.36	5.63	.90	.52***	.36***	-.47***	.69***	.62***	.44***	-.58***	—				
9. Loneliness T3	43.71	9.55	.92	.57***	.34***	-.42***	.45***	.71***	.41***	-.51***	.55***	—			
10. PSMU T3	3.66	2.24	.86	.31***	.55***	-.24***	.32***	.40***	.67***	-.31***	.39***	.48***	—		
11. Self-esteem T3	26.81	5.62	.90	-.41***	-.24***	.59***	-.43***	-.49***	-.30***	.72***	-.52***	-.58***	-.36***	—	
12. Depression T3	9.84	5.78	.91	.46***	.32***	-.41***	.57***	.54***	.39***	-.49***	.72***	.64***	.46***	-.61***	—

As shown in Table 1, the descriptive pattern indicated modest increases over time in loneliness, problematic social media use, and depressive symptoms, accompanied by a gradual decline in self-esteem. Mean loneliness scores increased from 42.73 ($SD = 9.18$) at Time 1 to 43.19 ($SD = 9.41$) at Time 2 and 43.71 ($SD = 9.55$) at Time 3.

Problematic social media use similarly increased from $M = 3.27$ ($SD = 2.11$) at baseline to $M = 3.48$ ($SD = 2.19$) at Time 2 and $M = 3.66$ ($SD = 2.24$) at Time 3. Mean depressive symptom scores increased from 8.91 ($SD = 5.47$) at Time 1 to 9.36 ($SD = 5.63$) at Time 2 and 9.84 ($SD = 5.78$) at Time 3. In contrast, self-esteem declined from $M = 27.84$ ($SD =$

5.36) to $M = 27.29$ ($SD = 5.48$) and $M = 26.81$ ($SD = 5.62$) across the three respective waves. All scales demonstrated satisfactory to strong internal consistency, with Cronbach's alpha coefficients ranging from .84 to .92. The correlation matrix revealed statistically significant associations in theoretically expected directions across both concurrent and longitudinal measurements. Loneliness was positively correlated with problematic social media use and depressive symptoms and negatively correlated with self-esteem at all waves. At Time 1, for example, loneliness was positively

associated with problematic social media use ($r = .46$, $p < .001$) and depressive symptoms ($r = .61$, $p < .001$), whereas it was negatively associated with self-esteem ($r = -.58$, $p < .001$). Self-esteem was consistently negatively associated with depressive symptoms, with within-wave correlations ranging from $r = -.56$ at Time 1 to $r = -.61$ at Time 3. Moderate-to-strong correlations between the same constructs across successive waves also suggested considerable temporal stability, particularly for self-esteem, depressive symptoms, and loneliness.

Table 2

Longitudinal Measurement Invariance and Overall Fit of the Measurement Models

Model	χ^2	df	χ^2/df	CFI	TLI	RMSEA	90% CI RMSEA	SRMR	ΔCFI
Configural invariance	1184.26	594	1.99	.951	.944	.040	[.037, .044]	.044	—
Metric invariance	1221.63	626	1.95	.950	.946	.040	[.036, .043]	.047	-.001
Scalar invariance	1264.91	658	1.92	.948	.946	.039	[.036, .043]	.050	-.002
Residual invariance	1327.45	694	1.91	.945	.943	.039	[.036, .042]	.054	-.003
Final structural model	861.37	432	1.99	.956	.948	.040	[.036, .044]	.046	—

The results of the longitudinal measurement analyses are presented in Table 2. The configural model demonstrated a satisfactory fit to the data, $\chi^2(594) = 1184.26$, $\chi^2/df = 1.99$, $CFI = .951$, $TLI = .944$, $RMSEA = .040$, $90\% CI [.037, .044]$, and $SRMR = .044$, indicating that the underlying factorial structure of the constructs was comparable across the three measurement occasions. Constraining corresponding factor loadings to equality across time produced the metric invariance model, which also fitted the data well, $\chi^2(626) = 1221.63$, $CFI = .950$, $TLI = .946$, $RMSEA = .040$, and $SRMR = .047$. The decrease in CFI relative to the configural model was only .001, substantially below conventional thresholds for meaningful deterioration in model fit. The subsequent scalar invariance model, in which item intercepts were additionally constrained to equality across time,

retained satisfactory fit, $\chi^2(658) = 1264.91$, $CFI = .948$, $TLI = .946$, $RMSEA = .039$, and $SRMR = .050$, with $\Delta CFI = -.002$. Even the more restrictive residual invariance model remained acceptable, $\chi^2(694) = 1327.45$, $CFI = .945$, $TLI = .943$, $RMSEA = .039$, and $SRMR = .054$. These findings supported the longitudinal comparability of the measurements and justified examination of changes and cross-lagged associations across the three waves. The final structural model also demonstrated a good overall fit, $\chi^2(432) = 861.37$, $\chi^2/df = 1.99$, $CFI = .956$, $TLI = .948$, $RMSEA = .040$, $90\% CI [.036, .044]$, and $SRMR = .046$, indicating that the hypothesized network of autoregressive, concurrent, and cross-lagged paths adequately represented the observed data.

Table 3

Autoregressive and Cross-Lagged Effects From Time 1 to Time 2

Predictor T1	Outcome T2	B	SE	β	z	p
Loneliness	Loneliness	0.59	0.04	.58	14.75	<.001
PSMU	PSMU	0.61	0.04	.59	15.25	<.001
Self-esteem	Self-esteem	0.65	0.04	.63	16.25	<.001
Depression	Depression	0.58	0.04	.57	14.50	<.001
Loneliness	PSMU	0.05	0.01	.18	4.71	<.001
PSMU	Loneliness	0.42	0.15	.10	2.80	.005
Loneliness	Self-esteem	-0.10	0.02	-.17	-4.56	<.001
Self-esteem	Loneliness	-0.19	0.07	-.11	-2.71	.007
Loneliness	Depression	0.13	0.02	.21	5.65	<.001
Depression	Loneliness	0.16	0.06	.10	2.67	.008

PSMU	Self-esteem	-0.19	0.07	-.08	-2.71	.007
Self-esteem	PSMU	-0.04	0.02	-.09	-2.42	.016
PSMU	Depression	0.21	0.07	.09	3.00	.003
Depression	PSMU	0.03	0.01	.08	2.39	.017
Self-esteem	Depression	-0.16	0.03	-.16	-5.33	<.001
Depression	Self-esteem	-0.09	0.03	-.09	-3.00	.003

Table 3 presents the autoregressive and cross-lagged effects from Time 1 to Time 2 after accounting simultaneously for the baseline levels of all four constructs and their concurrent covariances. All autoregressive paths were statistically significant and comparatively strong, demonstrating substantial stability across the first six-month interval. Baseline self-esteem showed the strongest autoregressive association with Time 2 self-esteem ($\beta = .63$, $p < .001$), followed by problematic social media use ($\beta = .59$, $p < .001$), loneliness ($\beta = .58$, $p < .001$), and depressive symptoms ($\beta = .57$, $p < .001$). Beyond these stability effects, several significant reciprocal cross-lagged relationships emerged. Higher loneliness at Time 1 predicted greater problematic social media use at Time 2 ($\beta = .18$, $p < .001$), whereas problematic social media use at Time 1 also predicted greater subsequent loneliness, although this reverse effect was smaller ($\beta = .10$, $p = .005$). Loneliness additionally predicted lower subsequent self-esteem ($\beta = -.17$, $p < .001$) and higher depressive symptoms ($\beta = .21$, $p < .001$). Reverse paths from self-esteem to later loneliness (β

$= -.11$, $p = .007$) and from depressive symptoms to later loneliness ($\beta = .10$, $p = .008$) were also statistically significant, suggesting bidirectional relationships rather than exclusively unidirectional effects. Problematic social media use predicted lower subsequent self-esteem ($\beta = -.08$, $p = .007$) and higher depressive symptoms ($\beta = .09$, $p = .003$), while self-esteem and depressive symptoms also predicted subsequent problematic social media use at smaller magnitudes. A particularly consistent protective pattern was observed for self-esteem, which negatively predicted depressive symptoms at Time 2 after accounting for baseline depression ($\beta = -.16$, $p < .001$). Conversely, higher baseline depressive symptoms predicted lower subsequent self-esteem ($\beta = -.09$, $p = .003$). Taken together, the Time 1-to-Time 2 model indicated that loneliness occupied a central position in the longitudinal system, displaying prospective associations with all three other psychological constructs even after substantial autoregressive stability had been controlled.

Table 4

Autoregressive and Cross-Lagged Effects From Time 2 to Time 3

Predictor T2	Outcome T3	B	SE	β	z	p
Loneliness	Loneliness	0.62	0.04	.61	15.50	<.001
PSMU	PSMU	0.64	0.04	.62	16.00	<.001
Self-esteem	Self-esteem	0.67	0.04	.65	16.75	<.001
Depression	Depression	0.61	0.04	.60	15.25	<.001
Loneliness	PSMU	0.06	0.01	.20	5.17	<.001
PSMU	Loneliness	0.48	0.15	.11	3.20	.001
Loneliness	Self-esteem	-0.11	0.02	-.18	-4.88	<.001
Self-esteem	Loneliness	-0.21	0.07	-.12	-3.00	.003
Loneliness	Depression	0.14	0.02	.22	6.09	<.001
Depression	Loneliness	0.18	0.06	.11	3.00	.003
PSMU	Self-esteem	-0.22	0.07	-.09	-3.14	.002
Self-esteem	PSMU	-0.05	0.02	-.10	-2.67	.008
PSMU	Depression	0.24	0.07	.10	3.43	.001
Depression	PSMU	0.04	0.01	.09	2.77	.006
Self-esteem	Depression	-0.18	0.03	-.18	-6.00	<.001
Depression	Self-esteem	-0.10	0.03	-.10	-3.33	.001

The pattern of effects from Time 2 to Time 3, presented in Table 4, closely replicated and slightly strengthened the temporal relationships identified during the first interval. All

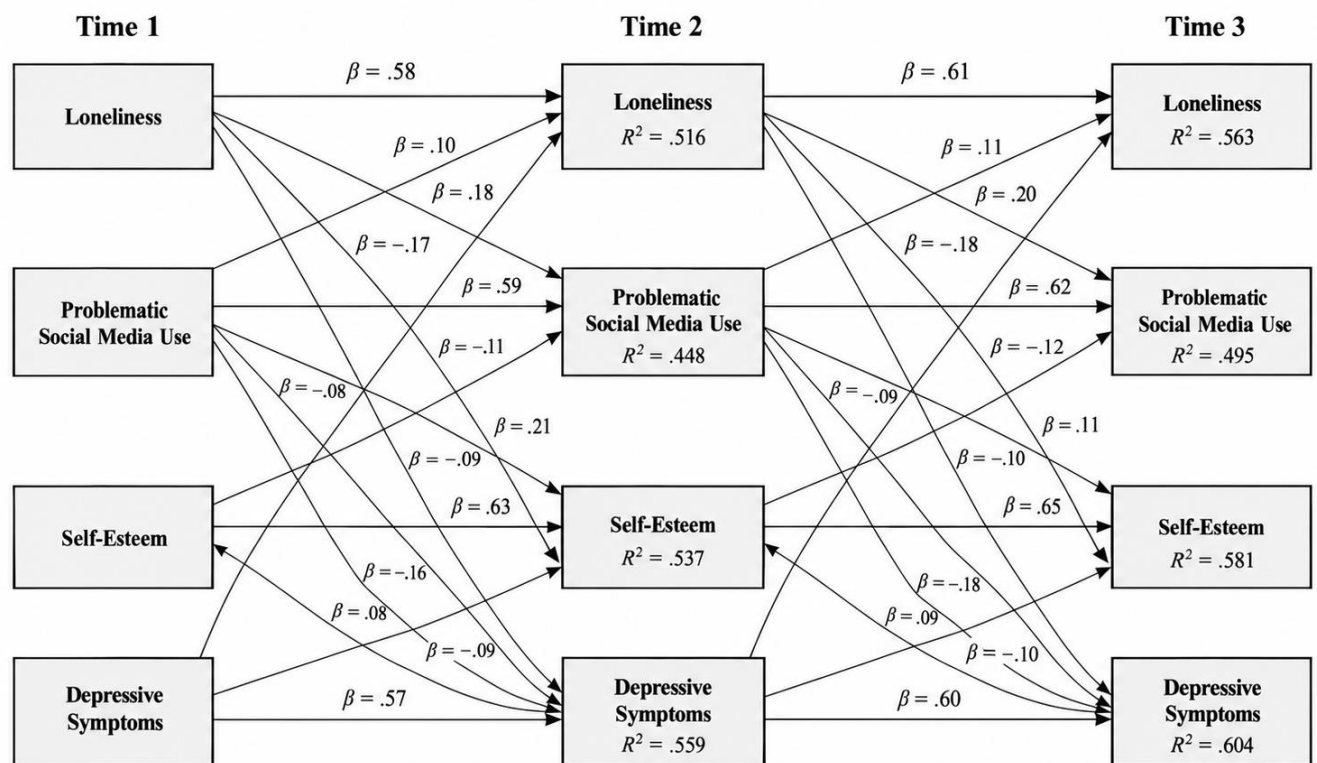
four constructs again showed substantial temporal stability, with standardized autoregressive coefficients ranging from .60 to .65. Self-esteem demonstrated the highest stability (β

= .65, $p < .001$), followed by problematic social media use ($\beta = .62$, $p < .001$), loneliness ($\beta = .61$, $p < .001$), and depressive symptoms ($\beta = .60$, $p < .001$). Importantly, loneliness at Time 2 continued to prospectively predict higher problematic social media use at Time 3 ($\beta = .20$, $p < .001$), lower self-esteem ($\beta = -.18$, $p < .001$), and higher depressive symptoms ($\beta = .22$, $p < .001$). Problematic social media use also predicted later loneliness ($\beta = .11$, $p = .001$), although the effect remained smaller than the loneliness-to-problematic-social-media-use pathway. Similarly, lower self-esteem predicted higher subsequent loneliness ($\beta = -.12$, $p = .003$), and depressive symptoms predicted higher later loneliness ($\beta = .11$, $p = .003$). Problematic social media use prospectively predicted both reduced self-esteem ($\beta = -.09$,

$p = .002$) and greater depressive symptoms ($\beta = .10$, $p = .001$), while low self-esteem also predicted increased problematic social media use ($\beta = -.10$, $p = .008$). The reciprocal association between self-esteem and depressive symptoms was particularly clear: higher self-esteem at Time 2 predicted lower depressive symptoms at Time 3 ($\beta = -.18$, $p < .001$), whereas greater depressive symptoms predicted lower subsequent self-esteem ($\beta = -.10$, $p = .001$). The close correspondence between the coefficients observed across the two time intervals indicated that the longitudinal associations were not limited to a single developmental period but were relatively stable over the approximately one-year observation period.

Figure 1

Three-Wave Cross-Lagged Structural Equation Model of Loneliness, Problematic Social Media Use, Self-Esteem, and Depressive Symptoms Among Adolescents



Note. Standardized coefficients are shown. All displayed paths are statistically significant ($p < .05$). Within-wave covariances were estimated but are omitted for visual clarity.

Model fit: $\chi^2(432) = 861.37$, CFI = .956, TLI = .948, RMSEA = .040, SRMR = .046.

The structural pattern represented in Figure 1 summarizes the reciprocal longitudinal relationships among the four psychological constructs after adjustment for autoregressive stability and within-wave covariance. The strongest prospective cross-domain effects consistently originated from loneliness. Across both longitudinal intervals, greater

loneliness predicted greater subsequent depressive symptoms, with standardized effects of $\beta = .21$ from Time 1 to Time 2 and $\beta = .22$ from Time 2 to Time 3. Loneliness also predicted increased problematic social media use ($\beta = .18$ and $\beta = .20$, respectively) and reduced self-esteem ($\beta = -.17$ and $\beta = -.18$, respectively). Although significant reverse

effects were observed in each case, their magnitudes were generally smaller, indicating asymmetry in the reciprocal associations. Specifically, problematic social media use predicted later loneliness with standardized coefficients of .10 and .11, self-esteem predicted later loneliness with coefficients of -.11 and -.12, and depressive symptoms predicted later loneliness with coefficients of .10 and .11. A second notable pattern involved the reciprocal longitudinal association between self-esteem and depressive symptoms. Higher self-esteem prospectively predicted fewer depressive symptoms across both intervals, whereas elevated depressive symptoms predicted modest subsequent decreases in self-esteem. Problematic social media use additionally showed prospective relationships with both poorer self-esteem and greater depressive symptomatology, indicating that problematic engagement with social media may function as part of a broader mutually reinforcing psychosocial process rather than as an isolated behavioral outcome.

Additional equality-constrained analyses were conducted to determine whether the principal cross-lagged effects differed significantly between the Time 1-to-Time 2 and Time 2-to-Time 3 intervals. Constraining corresponding longitudinal paths to equality resulted in only a negligible change in global model fit, $\Delta CFI = -.003$ and $\Delta RMSEA = .001$, indicating that the magnitude of the cross-lagged effects was largely stable across the two six-month intervals. None of the equality constraints for the principal pathways from loneliness to problematic social media use, self-esteem, or depressive symptoms produced a significant deterioration in model fit. Similarly, the reciprocal pathways involving self-esteem and depressive symptoms were statistically comparable across intervals. These findings supported temporal consistency in the structural relations among the constructs.

The model accounted for meaningful proportions of variance in the endogenous variables. At Time 2, the combined autoregressive and cross-lagged predictors explained 51.6% of the variance in loneliness, 44.8% of the variance in problematic social media use, 53.7% of the variance in self-esteem, and 55.9% of the variance in depressive symptoms. At Time 3, explained variance increased slightly to 56.3% for loneliness, 49.5% for problematic social media use, 58.1% for self-esteem, and 60.4% for depressive symptoms. The relatively high proportion of explained variance in depressive symptoms reflected both the strong temporal continuity of depressive symptomatology and its prospective associations with

loneliness, problematic social media use, and self-esteem. Likewise, the substantial explained variance in self-esteem indicated that self-evaluative functioning during adolescence was influenced not only by prior self-esteem but also by earlier loneliness, problematic social media use, and depressive symptoms.

Age and gender were included as covariates in the structural model. Age showed small positive associations with problematic social media use and depressive symptoms at baseline, but its prospective effects were substantially attenuated after the psychological variables were entered simultaneously into the model. Gender was significantly associated with depressive symptoms, with girls reporting higher symptom levels than boys, but inclusion of gender did not materially alter the magnitude or statistical significance of the principal autoregressive and cross-lagged coefficients. Thus, the longitudinal relationships among loneliness, problematic social media use, self-esteem, and depressive symptoms remained robust after accounting for these demographic characteristics.

Overall, the findings demonstrated a stable and reciprocal longitudinal network among the four study variables. Loneliness emerged as the most consistent prospective predictor across domains, preceding increases in problematic social media use and depressive symptoms as well as decreases in self-esteem. At the same time, problematic social media use, reduced self-esteem, and depressive symptoms each contributed to subsequent loneliness, supporting a reciprocal rather than strictly unidirectional developmental process. The persistence of these pathways across both six-month intervals, together with the substantial autoregressive stability of all constructs, indicates that loneliness, problematic social media use, self-evaluation, and depressive symptomatology may become mutually reinforcing across adolescence.

4. Discussion

The present study examined the reciprocal longitudinal relationships among loneliness, problematic social media use, self-esteem, and depressive symptoms across three measurement waves in a sample of Slovenian adolescents. The findings demonstrated substantial temporal stability in all four constructs and revealed a consistent pattern of reciprocal cross-lagged associations across both six-month intervals. Loneliness emerged as the most prominent prospective predictor in the model, predicting subsequent increases in problematic social media use and depressive

symptoms and subsequent decreases in self-esteem. Reverse pathways were also significant, although generally smaller in magnitude, indicating that problematic social media use, lower self-esteem, and depressive symptoms each contributed to later loneliness. In addition, problematic social media use predicted subsequent reductions in self-esteem and increases in depressive symptoms, while lower self-esteem predicted later increases in problematic social media use. A robust reciprocal relationship was also found between self-esteem and depressive symptoms. Importantly, these associations remained evident after accounting for the autoregressive stability of each construct and their within-wave relationships, and the pattern of effects was largely replicated from Time 1 to Time 2 and from Time 2 to Time 3. Collectively, these results support a dynamic developmental model in which loneliness, problematic social media use, self-evaluation, and depressive symptoms reinforce one another over time rather than operating as independent or strictly unidirectional processes.

The finding that loneliness prospectively predicted problematic social media use is consistent with growing evidence that adolescents who perceive their social relationships as inadequate may increasingly turn toward digital environments to compensate for unmet interpersonal needs. The cross-lagged coefficient from loneliness to problematic social media use was statistically significant across both temporal intervals and was stronger than the reverse pathway, suggesting that loneliness may be an especially important antecedent of maladaptive social media engagement. This result closely aligns with research demonstrating a meaningful relationship between loneliness and problematic social media use among adolescents, with fear of missing out identified as an important psychological mechanism connecting social disconnection with excessive engagement in online social environments (Chmiel et al., 2026). Adolescents who experience loneliness may become more vigilant to signs of peer activity, online inclusion, and social opportunities, increasing the likelihood of frequent checking, reassurance seeking, and difficulty disengaging from social platforms. The finding is also compatible with evidence that adverse relational experiences and childhood maltreatment are associated with greater risk of internet addiction, indicating that problematic digital engagement may partly represent an attempt to manage or compensate for deficiencies in offline social experiences (Xianxin et al., 2024). Thus, problematic social media use may not simply reflect a preference for technology but may sometimes

function as a behavioral response to perceived interpersonal deprivation.

At the same time, problematic social media use also predicted subsequent loneliness, supporting a reciprocal interpretation. Although this reverse effect was smaller, its replication across both measurement intervals suggests that problematic online engagement may itself contribute to the maintenance or intensification of loneliness. Excessive social media use can increase opportunities for upward social comparison, exposure to exclusionary social information, and repeated monitoring of others' activities without corresponding increases in meaningful interpersonal intimacy. It may also displace direct social interaction or reduce the quality of offline engagement. Research on children's and adolescents' interactions with information and communication technology has emphasized that digital environments have become integral components of social experience rather than merely external tools (Chen et al., 2024). Similarly, intensive longitudinal work has demonstrated that smartphone-related stress is associated with adolescent mental health, suggesting that the psychological consequences of digital behavior depend partly on the temporal and situational characteristics of technology use (Huang et al., 2024). The reciprocal pattern observed in the present study therefore suggests a potential self-reinforcing cycle in which loneliness increases reliance on social media, while maladaptive patterns of social media use subsequently deepen perceptions of social disconnection.

The prospective association between loneliness and depressive symptoms was among the strongest cross-lagged effects identified in the model. Adolescents reporting greater loneliness at one wave experienced higher depressive symptoms at the next wave even after prior depressive symptoms were controlled. This finding is consistent with theoretical perspectives proposing that persistent social disconnection may increase negative self-focused attention, perceived helplessness, reduced access to emotional support, and vulnerability to depressive affect. The importance of belonging for adolescent mental health is supported by meta-analytic evidence demonstrating that stronger school connectedness is associated with lower depression (Meng, Luo, et al., 2024). Likewise, family dysfunction has been linked to poorer mental health among children and adolescents, emphasizing that emotional well-being is strongly embedded within the quality of interpersonal environments (Wen et al., 2024). Research on family environmental unpredictability further suggests that unstable

relational environments can adversely affect adolescent psychological health, whereas supportive school climates may buffer some of these effects (Gao et al., 2026). These findings support the interpretation that loneliness may operate as an interpersonal risk process through which inadequate or insecure social connectedness contributes to depressive symptom development.

The reverse pathway from depressive symptoms to later loneliness was also statistically significant, although weaker than the loneliness-to-depression pathway. This reciprocal association is theoretically plausible because depressive symptoms can alter patterns of social behavior and social cognition. Adolescents experiencing depressed mood, fatigue, anhedonia, low motivation, or negative expectations may withdraw from peers, participate less in social activities, interpret ambiguous interactions more negatively, or perceive themselves as less socially valued. Such processes may increase subjective loneliness even in the continued presence of objectively available relationships. Recent conceptual work on depressed adolescents has characterized emotional dysregulation as an evolving process that can intensify across stages, suggesting that difficulties in managing negative affect may progressively influence interpersonal functioning (Wang et al., 2024). Clinical research also shows that adolescent mental health presentations can shift over time rather than remaining diagnostically stable, reinforcing the value of examining reciprocal developmental processes longitudinally (Kong & Mao, 2026). The present findings therefore suggest that loneliness and depressive symptoms may become mutually reinforcing, with each increasing vulnerability to the other across adolescence.

The relationship between loneliness and self-esteem showed a similar reciprocal structure. Higher loneliness predicted subsequent reductions in self-esteem, while lower self-esteem predicted greater later loneliness. The loneliness-to-self-esteem path was consistently stronger, suggesting that repeated perceptions of interpersonal disconnection may contribute substantially to negative self-evaluation. Adolescents often derive important aspects of self-worth from peer acceptance, social belonging, and perceived relational competence. When these needs are not met, loneliness may be internalized as evidence of personal inadequacy or social undesirability. Conversely, adolescents with lower self-esteem may anticipate rejection, avoid social risks, interpret interpersonal ambiguity negatively, or become excessively dependent on external validation, thereby increasing subsequent loneliness. Research showing

that social inclusion alters the emotional impact of social exclusion supports the broader proposition that interpersonal belonging and self-related affect are tightly interconnected (Meng, Chen, et al., 2024). Findings concerning attachment and mental health similarly indicate that interpersonal security is relevant to psychological well-being and self-evaluative functioning (Yongmei & Hongyu, 2023). The reciprocal association observed in this study therefore suggests that self-esteem should be understood not only as an individual trait but also as a construct continually shaped by adolescents' interpretations of their social relationships.

Problematic social media use also predicted lower subsequent self-esteem, while lower self-esteem predicted increases in later problematic social media use. This reciprocal relationship indicates that adolescents with diminished self-worth may be especially vulnerable to problematic online behavior, perhaps because they rely more heavily on digital feedback, social comparison, approval metrics, or idealized self-presentation as sources of reassurance. However, repeated exposure to curated peer content, visible popularity indicators, and opportunities for social comparison may further undermine self-esteem. This interpretation is consistent with broader evidence suggesting that digital competencies and patterns of online engagement are relevant to psychological well-being. Research on network literacy has shown that differences in how young people understand and navigate online environments are associated with depression levels, suggesting that the psychological consequences of internet use are shaped not only by exposure but also by how online information is interpreted and managed (Zhang & Lin, 2026). Furthermore, the increasing integration of ICT into children's social and developmental environments means that self-evaluation increasingly occurs in contexts where social feedback is immediate, visible, and quantitatively represented (Chen et al., 2024). The present results suggest that problematic social media use and self-esteem may therefore operate in a feedback loop, with low self-worth increasing vulnerability to maladaptive online engagement and maladaptive engagement subsequently contributing to poorer self-evaluation.

The finding that problematic social media use prospectively predicted depressive symptoms also supports concerns about the mental-health consequences of maladaptive digital engagement. Adolescents with higher problematic use at one assessment reported greater depressive symptoms at the next assessment after controlling for prior depression. Although the standardized effect was

modest, its consistency across both intervals strengthens confidence in its temporal relevance. Potential mechanisms may include sleep disruption, cybervictimization, social comparison, reduced physical activity, academic interference, emotional overstimulation, or dependence on online reassurance. Intensive longitudinal evidence linking smartphone-related stress with adolescent mental health supports the proposition that digital experiences can contribute to emotional difficulties over relatively short periods (Huang et al., 2024). At the same time, depressive symptoms also predicted subsequent problematic social media use, suggesting that digital behavior may function as a coping response to psychological distress. Adolescents experiencing low mood or reduced motivation may use social media for distraction, mood regulation, passive consumption, or social reassurance. This reciprocal pattern is consistent with the broader conceptualization of depressive symptoms as dynamic phenomena that interact with behavioral and environmental factors rather than developing through a single pathway (Zeng et al., 2026).

The reciprocal association between self-esteem and depressive symptoms was another important finding. Higher self-esteem prospectively predicted fewer depressive symptoms, whereas greater depressive symptoms predicted lower subsequent self-esteem. This result is consistent with cognitive models in which negative self-evaluation contributes to depressive affect, while depression itself further strengthens unfavorable self-beliefs. Adolescents with low self-esteem may interpret setbacks as evidence of global inadequacy, experience greater sensitivity to rejection, and show reduced confidence in their ability to cope with stress. Once depressive symptoms emerge, reduced motivation, diminished pleasure, impaired concentration, and persistent negative cognition may further erode perceptions of competence and self-worth. The present results also correspond with work emphasizing the role of emotional dysregulation in adolescent depression (Wang et al., 2024). In addition, research on neurofeedback approaches for enhancing positive emotion in depression illustrates increasing recognition that depressive states involve not only excessive negative affect but also disturbances in the generation and maintenance of positive emotional experience (Che et al., 2024). The bidirectional self-esteem–depression pathway identified here suggests that interventions focused solely on depressive symptoms without addressing adolescents' broader self-evaluative processes may overlook an important mechanism of symptom maintenance.

The strong autoregressive coefficients observed for all four variables are also noteworthy. Loneliness, problematic social media use, self-esteem, and depressive symptoms each showed substantial continuity from one wave to the next, with self-esteem exhibiting particularly high stability. These findings indicate that, although adolescence is characterized by developmental change, individual differences in these psychosocial constructs remain relatively stable over periods of six months. This stability makes the statistically significant cross-lagged paths especially informative because each prospective effect represented prediction beyond the prior level of the outcome. The replicated cross-lagged pattern across both intervals further indicates that the identified relationships were not limited to a single transition period. Such temporal consistency is compatible with broader evidence that adolescent mental-health difficulties can persist and evolve across development (Kong & Mao, 2026; Zeng et al., 2026). At the same time, the fact that a substantial proportion of variance remained unexplained indicates that other factors, including family functioning, school climate, peer victimization, physical health, sleep, academic stress, and individual emotion-regulation capacity, may also contribute to trajectories of these outcomes.

The broader psychosocial context may help explain why the four constructs became interconnected over time. Adolescents do not experience loneliness, digital behavior, self-esteem, and depressive symptoms in isolation from family, school, and environmental contexts. Meta-analytic evidence indicates that family dysfunction is related to poorer child and adolescent mental health (Wen et al., 2024), while positive school climate may buffer the adverse psychological consequences of environmental unpredictability (Gao et al., 2026). School connectedness is also associated with depression, further demonstrating the importance of belonging within institutional contexts (Meng, Luo, et al., 2024). These contextual influences may shape whether adolescents use social media adaptively or problematically, whether loneliness becomes persistent, and whether reductions in self-esteem develop into depressive symptoms. The present model therefore should not be interpreted as suggesting that the four variables constitute a closed causal system. Rather, the findings identify a meaningful set of reciprocal relationships embedded within a larger ecological network of developmental influences.

Although several references in the broader literature concern different populations or clinical mechanisms, they nevertheless reinforce the importance of conceptualizing

depression and psychological health as multidimensional outcomes. Research on exercise interventions demonstrates that depressive symptoms can respond to behavioral and physiological pathways (Liu et al., 2026), while developments in sports and exercise neuroscience have highlighted the interaction between physical activity, brain function, and psychological processes (Wei et al., 2024). Biological research on phosphodiesterase-4 inhibitors also illustrates continuing efforts to understand central nervous system mechanisms associated with psychiatric conditions (Adili et al., 2024). Likewise, studies examining multimorbidity and depression in older populations demonstrate the methodological importance of considering interacting risk patterns rather than single predictors (Sun et al., 2026). Although these studies are not directly comparable to the present adolescent sample, they converge on a broader understanding of depressive symptoms as products of interacting biological, behavioral, social, and environmental processes.

5. Conclusion

The findings also underscore the distinction between beneficial solitude and maladaptive loneliness. Developmental work has shown that solitude can serve adaptive functions when it is voluntary, restorative, and appropriately regulated, but can become costly when it reflects exclusion or unmet social needs (Haidabieke et al., 2024). This distinction is important when interpreting the present results because the observed relationships concern loneliness as a negative subjective experience rather than simply time spent alone. Similarly, environmental research emphasizing restorative or healing-oriented settings suggests that psychological functioning can be influenced by characteristics of everyday environments (Song & Xu, 2024). Research on protective environments in clinical medicine, although focused on different outcomes and populations, also illustrates the broader principle that contextual conditions can alter health-related trajectories (Zhou et al., 2024). These perspectives reinforce the idea that adolescent well-being depends not only on individual psychological characteristics but also on the quality of environments in which social interaction and emotional regulation occur.

6. Limitations & Suggestions

Several limitations should be considered when interpreting the present findings. First, all primary variables

were measured using adolescent self-report instruments, which may have introduced shared-method variance, recall bias, social desirability, and response-style effects. Second, although the three-wave design provides stronger temporal information than cross-sectional research, cross-lagged associations do not by themselves establish causality because unmeasured third variables may influence both predictors and outcomes. Third, the six-month intervals were theoretically appropriate for detecting developmental change, but shorter or longer intervals could produce different estimates of temporal influence. Fourth, the study involved adolescents from Slovenia and therefore the magnitude of the identified associations may not generalize directly to adolescents in countries with different educational systems, cultural norms, patterns of social media use, or family structures. Fifth, problematic social media use was assessed as an overall construct rather than separately examining specific platforms, activities, motives, or forms of engagement. Finally, although participant retention was high, some attrition occurred across waves, and statistical methods for handling missing data cannot fully eliminate the possibility that unmeasured attrition-related differences influenced the longitudinal estimates.

Future studies should extend the present model by incorporating additional waves and longer follow-up periods to examine whether the reciprocal pathways remain stable across later adolescence and the transition into emerging adulthood. Research would also benefit from combining self-report measures with behavioral indicators of social media use, passive smartphone sensing, peer or parent reports, and clinical assessments of depressive symptoms. Future models should distinguish between active and passive social media use, specific platform characteristics, cybervictimization, fear of missing out, online social comparison, and digital reassurance seeking to identify the mechanisms underlying problematic use. It would also be valuable to examine potential moderators such as gender, socioeconomic status, personality, emotion regulation, family functioning, school connectedness, and offline peer support. Random-intercept cross-lagged panel models and intensive longitudinal designs could help separate stable between-person differences from within-person temporal changes. Cross-cultural replication is also needed to determine whether the observed reciprocal relationships are consistent across different digital, educational, and social environments.

The findings suggest that prevention and intervention programs for adolescents should address loneliness,

problematic social media use, self-esteem, and depressive symptoms as interconnected rather than isolated concerns. School-based mental-health programs may benefit from combining social connectedness interventions with digital well-being education, emotional regulation training, and strategies for strengthening realistic and stable self-worth. Screening procedures could consider persistent loneliness and problematic social media use as possible indicators of broader psychosocial vulnerability, particularly when they occur together with declining self-esteem or depressive symptoms. Parents and educators should be encouraged to focus not only on the amount of time adolescents spend on social media but also on the emotional function of that use, including whether it is driven by reassurance seeking, fear of exclusion, or avoidance of offline difficulties. Interventions designed to strengthen peer belonging, supportive classroom climates, face-to-face social competence, and adaptive coping may reduce the likelihood that loneliness develops into a reinforcing cycle involving excessive social media use and depressive symptoms. Clinical practitioners working with depressed or socially isolated adolescents should also assess online behavior and self-esteem because improvement in one domain may be more sustainable when the interconnected processes identified in this study are addressed simultaneously.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contributed to this article.

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