

RESEARCH ARTICLE

Daily screen exposure and health-related quality of life in children and adolescents: Gender-differentiated effects across developmental stages

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Abstract

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Background: Prolonged recreational screen exposure adversely affects health-related quality of life (HRQoL), yet developmental shifts in gender-differentiated susceptibility across youth remain understudied.

Objective: This study aimed to investigate both physical and psychosocial HRQoL in relation to daily recreational screen exposure among children and adolescents, asking in particular whether gender differences depend on developmental stage.

Methods: In this cross-sectional study, data were obtained for 1,505 students using the Pediatric Quality of Life Inventory 4.0: 678 children aged 7–12 years were assessed by parent-proxy report, and 827 adolescents aged 13–18 years completed the self-report version. Within each cohort, two-way multivariate analyses of covariance and follow-up univariate analyses of covariance, adjusting for age and parental education, compared HRQoL across screen-exposure levels and gender.

Results: Among children, physical ($p = 0.013$) and psychosocial ($p = 0.004$) HRQoL scores were lower at higher screen-exposure levels, and boys and girls did not differ in either domain ($p > 0.05$). Among adolescents, both physical and psychosocial HRQoL scores were also lower at higher exposure levels for both genders, but a small gender $\times$ screen time difference emerged for physical health, $F_{(3,816)} = 3.65$, $p = 0.012$, $\eta^2_p = 0.013$, with girls scoring lower than boys at the higher exposure levels. Psychosocial health showed no such difference, $F_{(3,816)} = 0.71$, $p = 0.544$, $\eta^2_p = 0.003$.

Conclusion: In childhood, HRQoL did not differ by gender across screen-exposure levels. In adolescence, a small gender difference emerged, limited to physical health. Given the modest effect size and cross-sectional design, these group differences should not be interpreted causally, and reverse causation cannot be ruled out. Age- and gender-sensitive guidance on screen use may still be worth considering for adolescents, pending confirmation in longitudinal research.

Keywords: Adolescents; Children; Gender differences; Health-related quality of life; Recreational screen exposure; Pediatric Quality of Life Inventory

1. Introduction

Childhood and adolescence represent critical developmental periods characterized by identity formation, emotional regulation, and increased sensitivity to social influences.¹ In parallel with rapid technological advancement, digital screen engagement has become deeply integrated into the daily lives of children and adolescents, raising growing concerns regarding its potential effects on mental health and health-related quality of life (HRQoL).² HRQoL encompasses both physical and psychosocial well-being and is widely recognized as an important indicator of youth health status.³

The COVID-19 pandemic further intensified concerns regarding excessive screen exposure, as school closures and social restrictions substantially increased children's and adolescents' reliance on digital devices for education, communication, and entertainment. International evidence indicates that daily media use during the pandemic nearly doubled or tripled among young people.^{4,5} These behavioral shifts have highlighted the importance of understanding the long-term psychological and physical consequences of prolonged recreational screen exposure across childhood and adolescence.⁶

Previous research has consistently demonstrated that excessive screen use is associated with poorer psychological well-being, lower HRQoL, sleep disturbances, and elevated symptoms of anxiety and depression.⁷⁻⁹ Several theoretical mechanisms may explain these associations. The Time Displacement Hypothesis proposes that heavy digital media use reduces opportunities for physical activity, face-to-face social interaction, and sufficient sleep, all of which are essential for healthy development in childhood and adolescence.^{8,10} Prolonged exposure to blue light emitted from screens may disrupt circadian rhythms by suppressing melatonin secretion, thereby impairing sleep onset and cognitive recovery.¹¹ Finally, emotionally stimulating online content—particularly social media—may heighten cognitive-affective arousal and social comparison, contributing to greater psychological distress among youth.⁷

The psychological effects of digital media exposure appear to depend more on the nature of screen engagement than on duration alone.¹² Social media use, for instance, has been more consistently linked to depressive symptoms and lower life satisfaction than activities such as gaming or television viewing.¹³ This complexity suggests that screen exposure likely affects youth well-being through several distinct, and possibly overlapping, pathways.¹⁴

Gender differences appear to be another important factor influencing the relationship between screen exposure

and health outcomes, although the evidence base for this claim comes predominantly from adolescent and young-adult samples rather than younger children. Several studies suggest that adolescent girls may be more susceptible than boys to the negative psychosocial effects of social media use.^{1,12} Girls are more likely to use digital platforms for emotional expression, interpersonal communication, and social comparison, whereas boys more commonly engage in gaming and entertainment-oriented activities.¹² Moreover, systematic reviews have shown that girls demonstrate greater vulnerability to social comparison processes and fear of missing out, both of which are associated with anxiety and reduced self-esteem.¹¹ In contrast, certain forms of group gaming among boys may enhance social connectedness and peer belonging.¹⁵

A developmental perspective offers one explanation for why gender-differentiated vulnerability to screen exposure might be specific to, or intensify during, adolescence rather than being uniform across childhood. Objectification theory proposes that girls and women are progressively socialized to internalize an external evaluative perspective on themselves, a process that becomes more pronounced during adolescence and has been linked to negative psychological outcomes such as anxiety.¹⁶ Neurodevelopmental accounts of adolescent "social re-orientation" describe a similar pattern: a shift in brain systems governing social-evaluative sensitivity that increases responsiveness to peer feedback relative to childhood.¹⁷ Both frameworks were developed primarily within Western cultural contexts, and their specific expression may vary across cultural settings.^{14,18} Together, they point to a broader developmental principle: peer-evaluation and social comparison concerns become more salient with the transition into adolescence, and gender-related differences in psychosocial functioning may accordingly be more likely to emerge during this period than in childhood.

These theoretical and empirical strands converge on the idea that screen exposure could affect physical and psychosocial HRQoL through behavioral, biological, and socio-emotional pathways that plausibly differ across developmental stages.^{19,20} Yet most prior research has examined either children or adolescents in isolation, typically using age-appropriate but non-comparable assessment formats (parent-proxy versus self-report), which prevents any single study from directly testing whether gender-related vulnerability to screen exposure is stable across development or instead emerges specifically during adolescence. Findings on gender differences across HRQoL dimensions also remain inconsistent, particularly in non-Western populations where cultural norms shape

digital behavior,^{14,18} and few studies have examined physical and psychosocial HRQoL together in relation to varying levels of recreational screen exposure.²⁰

Given the rapid expansion of digital technology use among youth and the resulting public health concerns, a study directly comparing children and adolescents is warranted. The present study therefore examined differences in physical and psychosocial HRQoL across levels of daily recreational screen exposure among children (7–12 years) and adolescents (13–18 years), asking specifically whether, and how, gender differences vary across these two developmental stages. The findings may inform age-appropriate, school-based interventions and evidence-based recommendations for healthy digital media use across childhood and adolescence.

2. Methods

A cross-sectional comparative design was used to examine differences in HRQoL across levels of recreational screen exposure and gender among students.

2.1. Participants

Data were collected from primary and secondary school students in Tehran, Iran (Tehran city and Tehran Province), using a three-stage cluster sampling method. First, eight educational districts were selected to ensure socioeconomic and geographic variability: three within Tehran city (North, South, and Central) and five from the 21 districts of Tehran Province's counties. Second, within each district, one girls' school and one boys' school were selected at each of four educational levels (elementary cycles 1–2, middle school, high school), yielding 64 participating schools (32 girls', 32 boys'). Third, following school administration approval, the questionnaire link was distributed to all enrolled students in each selected school via the school's physical education teacher. Because all students within selected schools were invited rather than a random subset, inclusion probability varied with school size; no weighting was applied to adjust for this, which we note as a limitation.

The sample included children aged 7–12 years (grades 1–6) and adolescents aged 13–18 years (grades 7–12). Inclusion criteria were parental consent, regular school attendance, and the ability to complete the study instruments. After excluding cases with missing data on the covariates required for the multivariate models, the analytic sample used in all multivariate analysis of covariance (MANCOVA)/univariate analysis of covariance (ANCOVA) analyses comprised 1,505 participants (678 children; 827 adolescents). A sensitivity power analysis (noncentral *F*-distribution framework) indicated that, with

the achieved adolescent sample size ($n = 827$, $df_1 = 3$, $df_2 = 816$, $\alpha = 0.05$), the study had 80% power to detect effects as small as $\eta^2_p \approx 0.013$ —closely matching the magnitude of the gender $\times$ screen time interaction subsequently observed for physical health.

2.2. Instruments

2.2.1. Demographic and screen exposure questionnaire

A structured questionnaire was administered to collect demographic characteristics and recreational screen exposure information. Demographic variables included age, gender, grade level, and parental educational attainment. Parental education was assessed separately for mothers and fathers and was coded according to the International Standard Classification of Education 2011. Given its potential effects on developmental and socioeconomic factors, parental education was included as a covariate in subsequent multivariate analyses.

Additional background characteristics, including residential area, general health status, height, weight, and body mass index (BMI; calculated as weight divided by height squared, kg/m^2), were collected during the initial assessment for sample characterization but were not included as analytical variables in the present study.

Recreational screen exposure was assessed using a single-item questionnaire. For children, responses were obtained through parent-proxy report, whereas adolescents provided self-reported responses. Participants were asked to estimate their average daily recreational screen exposure during the previous month by answering: "Over the past month, how many hours per day on average did you spend using electronic screens (e.g., television, smartphone, tablet, computer, and video games) for recreational purposes?" This measure captured total leisure-related use across electronic devices and excluded screen use required for academic or school-related activities. Responses were categorized into four levels: <2 h/day, 2–4 h/day, 4–6 h/day, and >6 h/day.

This four-category structure was anchored to commonly used pediatric screen-time guidelines (e.g., the 2 h/day benchmark referenced in American Academy of Pediatrics recommendations) and was intended to capture potential non-linear, threshold-like effects across exposure levels rather than assuming a strictly linear dose-response relationship.

2.2.2. Health-related quality of life

The HRQoL was measured using the Pediatric Quality of Life Inventory (PedsQL 4.0),²¹ which includes 23 items

across four domains: physical, emotional, social, and school functioning. Items are rated on a 5-point Likert scale and transformed to a 0–100 scale, with higher scores indicating better quality of life; physical and psychosocial summary scores were calculated, along with a total HRQoL score. Children aged 7–12 years were assessed via parent-proxy report and adolescents aged 13–18 years via self-report; although a self-report version exists for younger children, proxy reporting is commonly used in early childhood to improve response accuracy. The PedsQL 4.0 has demonstrated strong internal consistency (Cronbach's $\alpha > 0.85$) and acceptable construct validity across diverse populations.²¹

This study used the Persian translation of the PedsQL 4.0 Generic Core Scales, which has demonstrated acceptable reliability and validity with moderate-to-high agreement between child self-report and parent-proxy versions,²² obtained and used under a formal non-commercial academic user agreement from Mapi Research Trust (Lyon, France).

2.3. Procedure

After obtaining approval from school authorities, data collection was conducted online; the study questionnaire link was distributed to students via the school's physical education teacher rather than administered in person in classrooms. Parents completed proxy reports for younger children, while adolescents completed self-report forms. All responses referred to the preceding month. All ethical considerations adhered to the Declaration of Helsinki. As this was a cross-sectional, anonymous, minimal-risk survey study, formal ethics committee approval could not be obtained, since our institution's Research Ethics Committee does not review already-completed research retrospectively. Instead, the study protocol, sampling methodology, and operational procedures were formally reviewed and authorized by the Office of the Vice Chancellor for Research and Technology, Shahid Rajaei Teacher Training University (Ref No. 1200; Date: 2025-12-25), which classified the study as minimal-risk and confirmed adherence to core ethical principles, including parental/guardian consent and child/adolescent assent. Written informed consent was obtained from the parent or legal guardian of each participant, and assent was additionally obtained from each child/adolescent participant prior to data collection.

2.4. Data analysis

This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology statement for cross-sectional studies. Because the PedsQL was administered via parent-proxy

report for children and self-report for adolescents, all statistical analyses were performed separately by age cohort—children (7–12 years) and adolescents (13–18 years)—so that reporting format was structurally controlled as a cohort-specific factor. Data were analyzed using the Statistical Package for Social Sciences (SPSS 26, IBM, United States). Descriptive statistics were computed for all variables. Screen exposure was categorized into four categories (<2 h, 2–4 h, 4–6 h, and >6 h per day) to examine non-linear thresholds and dose-response gradients. A MANCOVA was conducted to evaluate differences in HRQoL dimensions—specifically the physical health summary score and the psychosocial health summary score across screen exposure levels and gender, while controlling for potential covariates. Follow-up univariate ANCOVAs and appropriate post hoc analyses were performed to identify specific group differences. Statistical significance was set at $p < 0.05$. Assumptions of normality, homogeneity of variance, and multivariate normality were assessed prior to analysis.

3. Results

3.1. Participant characteristics

The socio-demographic characteristics of participants, stratified by age group and gender, are presented in [Table 1](#). Preliminary analyses indicated significant baseline differences in age between boys and girls among both children ($t(707) = -4.92, p < 0.001$) and adolescents ($t(891) = 8.99, p < 0.001$). Furthermore, significant baseline differences were observed in parental educational attainment among children for both paternal education ($\chi^2(2) = 16.06, p < 0.001$) and maternal education ($\chi^2(2) = 8.69, p < 0.013$). Given these baseline imbalances, age, paternal education, and maternal education (coded according to the International Standard Classification of Education 2011) were entered as covariates in all subsequent multivariate analyses.

3.2. Descriptive findings on health outcomes across screen exposure levels

Descriptive statistics indicated an inverse trajectory between daily recreational screen exposure and health outcomes across both cohorts and genders. Psychosocial health scores declined progressively with increasing screen time, particularly among adolescent girls (mean = 87.04, standard deviation [SD] = 11.70 at <2 h/day vs. mean = 73.64, SD = 16.39 at >6 h/day). Reductions in physical health scores were more pronounced among girls, whereas scores among adolescent boys remained relatively stable across exposure categories. Full descriptive statistics (n , mean, SD) are reported in [Table 2](#), and [Figures 1](#) and [2](#) depict physical and psychosocial health trajectories across

Table 1. Socio-demographic characteristics of participants categorized by age group and gender (*n* = 1,602)

Variable	Children (<i>n</i> = 709)		Adolescents (<i>n</i> = 893)	
	Girls (<i>n</i> = 388)	Boys (<i>n</i> = 321)	Girls (<i>n</i> = 474)	Boys (<i>n</i> = 419)
Age (years), mean $\pm$ SD	9.83 $\pm$ 1.84	10.49 $\pm$ 1.70	15.88 $\pm$ 1.75	14.89 $\pm$ 1.51
Father's education level, <i>n</i> (%)				
Low (ISCED 0–2)	136 (36.1%)	68 (22.1%)	141 (31.8%)	132 (33.8%)
Medium (ISCED 3–5)	160 (42.4%)	155 (50.3%)	250 (56.4%)	202 (51.7%)
High (ISCED 6–8)	81 (21.5%)	85 (27.6%)	52 (11.7%)	57 (14.6%)
Mother's education level, <i>n</i> (%)				
Low (ISCED 0–2)	46 (12.2%)	20 (6.4%)	123 (27.5%)	93 (23.9%)
Medium (ISCED 3–5)	218 (58.0%)	176 (56.6%)	282 (62.9%)	247 (63.5%)
High (ISCED 6–8)	112 (29.8%)	115 (37.0%)	43 (9.6%)	49 (12.6%)

Notes: Low: ISCED 0–2 (below high school diploma); Medium: ISCED 3–5 (high school diploma or associate degree); High: ISCED 6–8 (bachelor's degree or higher); percentages for parental education levels are calculated based on valid cases (*n* valid for children: fathers = 685, mothers = 687; *n* valid for adolescents: fathers = 834, mothers = 837) after excluding missing values (*n* missing for children: fathers = 24 [3.4%], mothers = 22 [3.1%]; *n* missing for adolescents: fathers = 59 [6.6%], mothers = 56 [6.3%]).

Abbreviations: ISCED: International Standard Classification of Education (United Nations Educational, Scientific and Cultural Organization Institute for Statistics, 2011); SD: Standard deviation.

Table 2. Descriptive statistics for physical and psychosocial health across daily recreational screen exposure levels

Age cohort	Gender	Daily recreational screen exposure (h/day)	<i>n</i>	Physical health (M $\pm$ SD)	Psychosocial health (M $\pm$ SD)
Children (parent-proxy)	Girls	<2	224	86.08 $\pm$ 14.20	85.55 $\pm$ 11.35
		2–4	95	85.95 $\pm$ 14.11	83.60 $\pm$ 13.92
		4–6	43	83.07 $\pm$ 15.13	81.74 $\pm$ 12.55
		>6	26	79.81 $\pm$ 20.90	82.05 $\pm$ 11.70
		Total	388	85.29 $\pm$ 14.85	84.42 $\pm$ 12.22
	Boys	<2	160	88.42 $\pm$ 14.93	85.93 $\pm$ 13.39
		2–4	92	89.44 $\pm$ 13.27	87.54 $\pm$ 10.60
		4–6	41	83.31 $\pm$ 16.82	82.68 $\pm$ 12.87
		>6	28	82.14 $\pm$ 13.44	78.27 $\pm$ 11.40
		Total	321	87.51 $\pm$ 14.76	85.31 $\pm$ 12.63
Adolescents (self-report)	Girls	<2	124	87.60 $\pm$ 12.41	87.04 $\pm$ 11.70
		2–4	154	85.31 $\pm$ 12.81	82.94 $\pm$ 12.69
		4–6	94	79.55 $\pm$ 16.44	75.37 $\pm$ 16.80
		>6	102	77.08 $\pm$ 15.18	73.64 $\pm$ 16.39
		Total	474	83.00 $\pm$ 14.59	80.51 $\pm$ 15.14
	Boys	<2	188	89.96 $\pm$ 15.01	87.23 $\pm$ 12.10
		2–4	118	89.33 $\pm$ 12.35	86.82 $\pm$ 11.16
		4–6	56	87.61 $\pm$ 14.28	79.20 $\pm$ 15.24
		>6	57	88.43 $\pm$ 12.98	77.43 $\pm$ 15.11
		Total	419	89.26 $\pm$ 13.91	84.71 $\pm$ 13.30

Note: Children's scores (aged 7–12) are based on the parent-proxy format of the PedsQL, whereas adolescent scores (aged 13–18) are based on the self-report format.

Abbreviations: M: Mean; SD: Standard deviation.

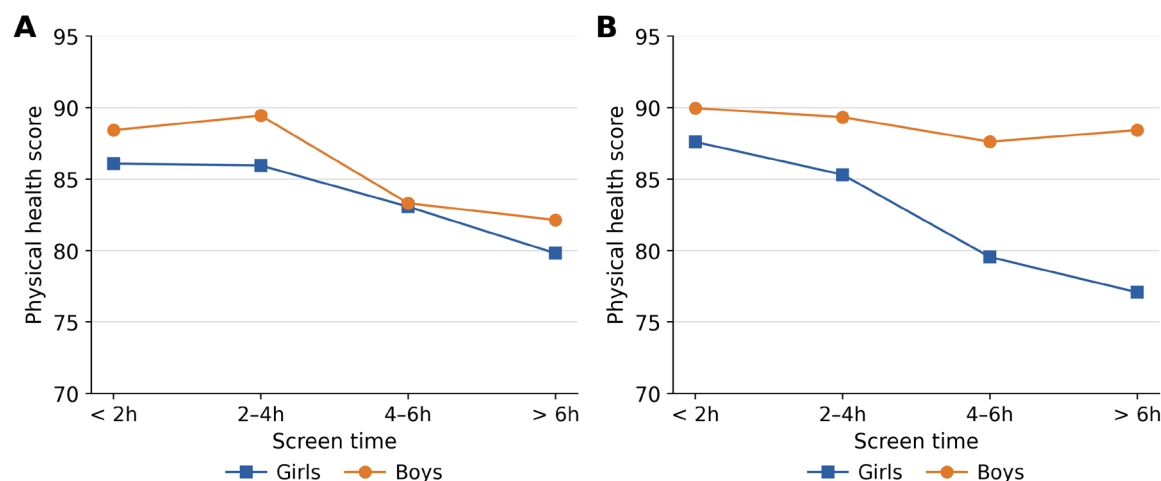


Figure 1. Physical health trajectories across daily screen exposure categories stratified by age cohort and gender. (A) Scores for children (aged 7–12 years; parent-proxy report). (B) Scores for adolescents (aged 13–18 years; self-report). Higher scores indicate better physical health.

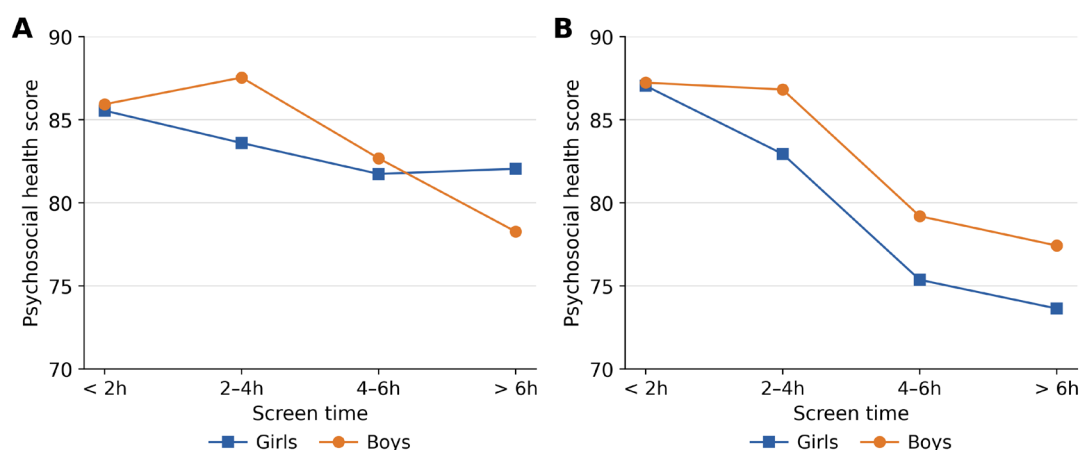


Figure 2. Psychosocial health trajectories across daily screen exposure categories stratified by age cohort and gender. (A) Scores for children (aged 7–12 years; parent-proxy report). (B) Scores for adolescents (aged 13–18 years; self-report). Higher scores indicate better psychosocial health.

screen exposure categories.

3.3. Multivariate and univariate analyses of covariance

To examine the primary study objectives, two separate two-way MANCOVAs (gender $\times$ screen time) were conducted for children and adolescents, controlling for age, paternal education, and maternal education. Preliminary assumption testing was conducted. Homogeneity of variance-covariance matrices was assessed using Box's M test, and homogeneity of variances was confirmed via Levene's test ($p > 0.05$ for all variables). No severe

multicollinearity was observed among the dependent variables.

3.3.1. Children (parent-proxy report)

For children, the covariates (age, father's education, mother's education) showed no significant multivariate effects (all $p > 0.05$). The multivariate main effect of recreational screen exposure was statistically significant, Wilks' Lambda = 0.977, $F_{(6, 1,332)} = 2.56$, $p = 0.018$, $\eta_p^2 = 0.011$. Neither the main effect of gender (Wilks' Lambda = 0.995, $F_{(2, 666)} = 1.60$, $p = 0.203$) nor the interaction between gender and screen exposure (Wilks' Lambda = 0.988, $F_{(6,$

$_{1,332}) = 1.35, p = 0.231$) reached statistical significance.

Univariate follow-up tests revealed a significant main effect of screen exposure on physical health, $F_{(3,667)} = 3.64, p = 0.013, \eta^2_p = 0.016$, and psychosocial health, $F_{(3,667)} = 4.46, p = 0.004, \eta^2_p = 0.020$. Post hoc Bonferroni comparisons indicated that children with >6 h/day of screen exposure reported significantly lower physical health compared to those with 2–4 h/day ($p = 0.037$). For psychosocial health, scores for children in the >6 h/day category were significantly lower than those with <2 h/day ($p = 0.012$) and 2–4 h/day ($p = 0.028$).

3.3.2. Adolescents (self-report)

Among adolescents, the multivariate main effects were significant for both gender, Wilks' Lambda = 0.953, $F_{(2,815)} = 19.94, p < 0.001, \eta^2_p = 0.047$, and daily screen exposure, Wilks' Lambda = 0.898, $F_{(6,1,630)} = 15.00, p < 0.001, \eta^2_p = 0.052$. A significant gender $\times$ screen exposure interaction effect was observed, Wilks' Lambda = 0.981, $F_{(6,1,630)} = 2.57, p = 0.018, \eta^2_p = 0.009$.

Follow-up univariate ANCOVAs were subsequently examined for each dependent variable. For psychosocial health, the main effect of screen exposure was statistically significant, $F_{(3,816)} = 30.57, p < 0.001, \eta^2_p = 0.101$, with post hoc Bonferroni tests indicating a significant decline in psychosocial health when daily screen exposure exceeded 4 h ($p < 0.001$). However, the gender $\times$ screen exposure interaction for psychosocial health was not significant, $F_{(3,816)} = 0.71, p = 0.544$.

For physical function, significant main effects were observed for both gender, $F_{(1,816)} = 38.00, p < 0.001, \eta^2_p = 0.045$, and screen exposure, $F_{(3,816)} = 10.14, p < 0.001, \eta^2_p = 0.036$. A statistically significant gender $\times$ screen exposure interaction effect emerged, $F_{(3,816)} = 3.65, p = 0.012, \eta^2_p = 0.013$. To deconstruct the significant gender $\times$ screen time interaction, simple main effects analyses were conducted in two directions:

(i) Simple main effects of screen time within each gender

Adolescent girls ($n = 440$): Daily screen exposure had a statistically significant simple effect on physical functioning, $F_{(3,816)} = 14.39, p < 0.001, \eta^2_p = 0.050$. Bonferroni-adjusted pairwise comparisons demonstrated that girls using screens < 2 h/day (adjusted mean [M_{adj}] = 88.07, standard error [SE] = 1.25) and 2–4 h/day (M_{adj} = 85.55, SE = 1.14) scored significantly higher in physical functioning compared to those spending 4–6 h/day (M_{adj} = 79.36, SE = 1.46, $p < 0.001$) and > 6 h/day (M_{adj} = 77.37, SE = 1.41, $p < 0.001$). There was no significant difference between < 2 h and 2–4 h ($p = 0.838$), nor between 4–6 h and > 6 h ($p = 1.000$).

Adolescent Boys ($n = 387$): In contrast, daily screen exposure had no statistically significant effect on physical functioning among adolescent boys, $F_{(3,816)} = 1.33, p = 0.265, \eta^2_p = 0.005$. Boys maintained high adjusted physical functioning scores across all screen time categories (< 2 h: M_{adj} = 90.93, SE = 1.07; 2–4 h: M_{adj} = 89.43, SE = 1.28; 4–6 h: M_{adj} = 86.86, SE = 1.86; > 6 h: M_{adj} = 88.78, SE = 1.83).

(ii) Simple main effects of gender within each screen time category

Comparing boys and girls across each category revealed an expanding gender gap as screen exposure increased:

- <2 h/day: The difference between adolescent girls (M_{adj} = 88.07) and boys (M_{adj} = 90.93) was not statistically significant, $F_{(1,816)} = 3.07, p = 0.080, \eta^2_p = 0.004$ (mean difference = 2.86).
- 2–4 h/day: Adolescent boys (M_{adj} = 89.43) scored significantly higher than girls (M_{adj} = 85.55), $F_{(1,816)} = 5.10, p = 0.024, \eta^2_p = 0.006$ (mean difference = 3.88).
- 4–6 h/day: Adolescent boys (M_{adj} = 86.86) maintained a significantly higher score than girls (M_{adj} = 79.36), $F_{(1,816)} = 10.03, p = 0.002, \eta^2_p = 0.012$ (mean difference = 7.51).
- >6 h/day: The gender discrepancy reached its peak, with boys (M_{adj} = 88.78) scoring markedly higher than girls (M_{adj} = 77.37), $F_{(1,816)} = 24.45, p < 0.001, \eta^2_p = 0.029$ (mean difference = 11.42).

4. Discussion

This study examined differences in physical and psychosocial HRQoL across levels of recreational screen exposure among children and adolescents, with particular attention to gender. Among children, both physical ($F_{(3,667)} = 3.64, p = 0.013, \eta^2_p = 0.016$) and psychosocial health scores ($F_{(3,667)} = 4.46, p = 0.004, \eta^2_p = 0.020$) were lower at higher levels of screen exposure, with no gender differences in either domain. Among adolescents, both physical ($F_{(3,816)} = 10.14, p < 0.001, \eta^2_p = 0.036$) and psychosocial health scores ($F_{(3,816)} = 30.57, p < 0.001, \eta^2_p = 0.101$) were lower at higher exposure levels; a small but statistically significant gender $\times$ screen time difference also emerged specifically for physical health ($F_{(3,816)} = 3.65, p = 0.012, \eta^2_p = 0.013$): girls showed a pronounced decline at higher exposure levels ($F_{(3,816)} = 14.39, p < 0.001, \eta^2_p = 0.050$), while boys' physical health scores remained comparatively stable ($F_{(3,816)} = 1.33, p = 0.265$). No corresponding gender difference was found for psychosocial health ($F_{(3,816)} = 0.71, p = 0.544, \eta^2_p = 0.003$).

The overall pattern of lower HRQoL at higher levels of recreational screen exposure, observed in both cohorts, is consistent with a substantial body of prior work reporting

poorer psychological well-being, greater sleep disturbance, and elevated anxiety and depressive symptoms among youth with higher levels of screen use.⁷⁻⁹ The non-linear, threshold-like decline observed among adolescent girls—stable scores below 4 h/day followed by a marked drop beyond that point—is broadly consistent with dose-response patterns reported in cross-sectional screen-time research more generally,^{10,20} and with evidence that girls report greater susceptibility to the psychosocial correlates of digital engagement, including social comparison and fear of missing out.^{1,11,12} The absence of a comparable gender difference in childhood is, to our knowledge, not directly contradicted by prior literature, since few studies have examined this age range separately from adolescents using a comparable design; this itself is a gap the present study addresses rather than a point of disagreement with existing findings.

Some findings diverge from prior reports in ways that merit explicit discussion rather than being absorbed into a general narrative of agreement. First, Twenge and Campbell¹³ reported broad differences in psychological well-being by screen time that were not clearly domain-specific or gender-differentiated in the way observed here. A plausible explanation is measurement: that study, like much of the broader literature, relied on general well-being indices rather than a multidimensional instrument such as the PedsQL that separates physical from psychosocial functioning; aggregated outcome measures may obscure a pattern—such as ours, confined to the physical domain—that only becomes visible when domains are analyzed separately. Second, Chang²³ found that differences in well-being by screen use depended substantially on the type of screen activity (e.g., social versus passive use) and on parental education, rather than on duration alone. The present study measured only aggregate recreational screen time via a single item, without distinguishing activity type; this reduced granularity may have attenuated the gender-differentiated pattern we detected, and could explain why our observed interaction effect size ($\eta^2_p = 0.013$) is smaller than gender-related effects reported in studies that isolate more psychosocially loaded activities such as social media use specifically. Third, several prior studies analyzed children and adolescents jointly or examined only one age group (e.g., adolescents or university students),^{8,10} which would tend to either dilute or mask an age-dependent gender pattern of the kind identified here; by stratifying analyses by developmental cohort, the present study was able to detect that the gender difference is not a stable feature of childhood but appears to emerge specifically in adolescence—a distinction that studies combining age groups are structurally unable to make.

The pattern observed—an absence of gender differentiation in childhood alongside a small, physical-health-specific gender difference in adolescence—is consistent with the developmental framework. Objectification theory¹⁶ proposes that girls become progressively socialized to internalize an external evaluative perspective on themselves, a process that grows more pronounced during adolescence rather than operating uniformly across development. Similarly, neurodevelopmental accounts of adolescent social re-orientation¹⁷ describe heightened sensitivity to peer feedback and social comparison during this developmental period, which could plausibly interact with screen-based social content to produce the adolescence-specific pattern observed here. These frameworks are consistent with, but not directly tested by, the present cross-sectional design; they should be read as a plausible explanatory account rather than a confirmed mechanism. The overall decline in HRQoL with increasing screen exposure, present in both cohorts and both genders, remains more parsimoniously explained by the Time Displacement Hypothesis^{8,10,24} and by circadian disruption from screen-light exposure,^{11,25,26} both of which are developmentally general mechanisms not specific to gender or age.

Several limitations should be considered when interpreting these findings. First, the cross-sectional design precludes causal inference; it is equally plausible that poorer physical or psychosocial functioning leads some children and adolescents to increase screen use—for example, as a coping or avoidance behavior—rather than the reverse, and reverse causation cannot be ruled out. Second, recreational screen exposure was measured with a single self-reported item that did not distinguish among specific activities (e.g., social media, gaming, television), which, as discussed above, may have limited our ability to detect activity-specific patterns reported elsewhere in the literature. Third, because the study questionnaire was distributed to all enrolled students within each selected school rather than to a randomly sampled subset of students, individual students' probability of inclusion varied with school enrollment size, and no post-stratification weighting was applied; this may limit the representativeness of the achieved sample relative to the sampling frame. Fourth, students were sampled within schools and classrooms via a multistage design, and the assumption of independent observations may have been partially violated; multilevel modeling or cluster-robust standard errors were not employed to formally account for school-level clustering, which we treat as a substantive limitation rather than a purely technical caveat. Fifth, smaller subgroup sizes at the highest exposure levels may have reduced the stability of some estimates. Sixth, comparability between the parent-

proxy (children) and self-report (adolescent) versions of the PedsQL, while supported by prior validation work, was not formally tested for measurement invariance in the present sample. Seventh, achieved statistical power varied by effect: a sensitivity power analysis indicated approximately 80% power to detect the observed physical-health interaction ($\eta^2_p = 0.013$) but only approximately 23% power to detect an effect as small as the non-significant psychosocial-health interaction ($\eta^2_p = 0.003$); the latter null result should therefore not be interpreted as evidence of no gender difference in the psychosocial domain. Finally, given that data were collected exclusively in Tehran city and Province, the generalizability of these findings to other regions of Iran with different socioeconomic or cultural characteristics should be considered with caution. Additionally, although categorization allowed for detection of non-linear thresholds, screen exposure was not examined as a continuous variable; future work should consider continuous or ordinal treatment of exposure to complement the categorical approach used here.

Longitudinal designs are needed to establish the direction of change between screen exposure and HRQoL over time and to test whether the gender-differentiated pattern observed in adolescence genuinely emerges during the pubertal transition, as the developmental framework proposed here would predict, or instead reflects a stable individual-level difference present earlier but undetected in the present childhood sample. Future studies should also assess screen use by activity type rather than aggregate duration, employ multilevel or cluster-robust analytic approaches appropriate to school-based sampling designs, and formally test measurement invariance between parent-proxy and self-report HRQoL instruments across developmental stages.

Notwithstanding these limitations, the pattern of findings suggests that screen-time guidance for youth may benefit from being age-sensitive rather than uniform: general recommendations to limit recreational screen exposure appear relevant across both childhood and adolescence, while gender-sensitive attention to physical health—though based on a small effect that should be replicated—may be particularly relevant for adolescent girls specifically, rather than being generalized across all developmental stages or extended to psychosocial health.

5. Conclusion

In childhood, physical and psychosocial HRQoL did not differ by gender across levels of recreational screen exposure. In adolescence, a small but statistically significant gender difference emerged, limited to physical health, with girls showing a threshold-like decline beyond 4 h of

daily exposure that was not observed among boys. Given the modest effect size, the cross-sectional design, and the possibility of reverse causation, these findings should be interpreted as group differences rather than causal effects. Age- and gender-sensitive guidance on recreational screen use may be worth considering for adolescents specifically, pending confirmation through longitudinal and multilevel research.

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Conflict of interest

The authors declare no conflict of interest.

Author contributions

Conceptualization: All authors

Formal analysis: All authors

Investigation: All authors

Methodology: All authors

Writing—original draft: All authors

Writing—review & editing: All authors

Ethics approval and consent to participate

This research was conducted in accordance with the Declaration of Helsinki and adhered to all relevant ethical principles. As this was a cross-sectional, anonymous, minimal-risk survey study, formal ethics committee approval could not be obtained, since our institution's Research Ethics Committee does not review already-completed research retrospectively. Instead, the study protocol, sampling methodology, and operational procedures were formally reviewed and authorized by the Office of the Vice Chancellor for Research and Technology, Shahid Rajaei Teacher Training University (Ref No. 1200; date: December 25, 2025). Written informed consent was obtained from the parent or legal guardian of each participant, and assent was additionally obtained from each child/adolescent participant.

Consent for publication

Consent for publication was not applicable because this

study used anonymized data, and no identifiable individual information is included in this manuscript.

Availability of data

The data underlying this study are available from the corresponding author upon reasonable request.

Further disclosure

Artificial intelligence (AI) assistance (Claude Sonnet 5, Anthropic, USA) was used for translation and language/structural editing of the Introduction, Discussion, and Abstract sections. All AI-assisted content was reviewed and verified by the authors. AI was not involved in study design, data collection, data analysis, or in deriving the study's substantive conclusions.

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