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ORIGINAL RESEARCH

Mapping Severe Child Nomophobia with Hierarchical Clustering and ROC

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Background and Aims: Nomophobia, the anxiety associated with smartphone separation, is well-studied in adolescents and adults, but less so in younger children. This study aimed to evaluate nomophobia severity among Spanish children aged 9–13 in urban settings and establish a data-driven cutoff for identifying severe risk.

Methods: A sample of 1153 children with weekly smartphone use from seven urban schools (populations >50,000) completed the 32-item Nomophobia Questionnaire for Children (NQC) and the STAIC State Anxiety measure. Data were collected from February to April 2024. Hierarchical clustering grouped NQC scores into severity categories, followed by Receiver Operating Characteristic (ROC) analysis to determine a severe-risk threshold.

Results: Hierarchical clustering identified two groups: a "Low-to-Moderate Nomophobia" cluster (96.88%; n=1117) and a "Severe Nomophobia" cluster (3.12%; n=36). ROC analysis established a cutoff of 101.5 (AUC=0.993, sensitivity=0.889, specificity=0.979), with 4.86% (n=56) exceeding this threshold. Children above the cutoff showed higher state anxiety (p=0.019), with no significant sex differences.

Discussion: Most children exhibited mild to moderate nomophobia, but ~5% displayed severe levels associated with increased state anxiety and phone use duration. The NQC ≥ 101.5 cutoff effectively identifies this at-risk minority without overestimating prevalence, offering a practical screening tool.

Conclusion: Combining hierarchical clustering and ROC analysis yielded a robust threshold (NQC ≥ 101.5) for detecting severe nomophobia in urban Spanish children, highlighting a small subgroup at elevated psychological risk. Future studies should validate this cutoff cross-culturally and longitudinally to guide early interventions.

Keywords: nomophobia, children, smartphone anxiety, ROC analysis, hierarchical clustering, mental health

Introduction

Smartphones are ubiquitous in modern urban life, providing instant access to information, social networks, and diverse applications.[1,2] This shift has fostered global connectivity, linking geographically distant individuals.[3] However, alongside these benefits, excessive smartphone use is increasingly tied to adverse physical and mental health outcomes.[4–6] One emerging concern is nomophobia— defined as the fear, anxiety, nervousness, or anguish experienced when being without a mobile phone or unable to use it.[4,7–9] This construct encompasses four dimensions in adults: fear of not being able to communicate, fear of losing connectedness, fear of not being able to access information, and fear of giving up convenience.[2,10] Nomophobia is now considered a potential public health challenge in our hyper-connected age.[4,8,11] Prevalence estimates for nomophobia vary widely, from 6% to nearly 99%, reflecting diverse cultural contexts and methodological inconsistencies.[8–15] Research has largely centered on older adolescents and university students, with some studies reporting mild, moderate, and severe nomophobia rates of 24%, 56%, and 17%, respectively.[4,15–184,16–20] In contrast, research on younger children aged 9–13 is scarce.[21] While two studies have included pre-adolescents within broader age ranges (10–19 years),[22,23] their focus was not specifically on this developmentally distinct population. To date, only the study by López et al[21] has specifically examined this age

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group using the validated Nomophobia Questionare for Children (NQC). This research gap is concerning given the evidence linking nomophobia to anxiety, stress, poor sleep and impaired school performance.[4,10] Furthermore,[24] nomophobia may induce a profound shift in developmental attachment,[19] where the smartphone could supplant the role of parental figures, producing a qualitatively deeper impact in children. This dependency also disrupts school functioning by affecting attention and behaviour.

This research gap is particularly relevant in Spain, where 69.6% of 10–15-year-olds regularly use smartphones.[25] Urban children often gain access early, frequently with limited supervision, raising concerns about maladaptive habits.[21,26–28] Given their developmental vulnerability, owing to immature executive functions and heightened sensitivity to social rewards, pre-adolescents may be especially susceptible to technology's negative effects.[26,27] Identifying severe nomophobia—beyond mild or moderate levels—could thus be key to prioritizing prevention and intervention efforts to mitigate disruptions in social functioning and academic achievement.This study builds on the pioneering work of López et al in 2023,[21] which developed the NQC to assess nomopobia in children aged 9–13, by applying advanced classification techniques to establish severity thresholds. Unlike traditional percentile-based or arbitrary cutoffs, we employ hierarchical clustering and ROC analysis to empirically derive classifications. To address this, we examine nomophobia among Spanish children aged 9–13 in urban settings, where smartphone access is near-universal.[8,21] Using hierarchical clustering and Receiver Operating Characteristic (ROC) analysis, we pursue two aims: (1) to estimate nomophobia severity in this cohort, and (2) to establish a conservative, data-driven cutoff for severe risk, validated against state anxiety and phone exposure duration. This binary threshold seeks to pinpoint a vulnerable minority—found to be ~5% in our sample, a prevalence that, while lower than in older groups, is clinically significant given the developmental risks and potential for early intervention—offering educators, parents, and clinicians a practical tool to detect when smartphone-related anxiety signals a need for support. This aligns with calls to curb problematic digital dependencies early.[8]

Methods

Study Design

This cross-sectional, observational study employed an ex post facto design to identify and validate severity thresholds for nomophobia among Spanish children aged 9–13. The study utilized a quantitative approach combining hierarchical clustering and Receiver Operating Characteristic (ROC) analysis to empirically derive clinically meaningful cutoff scores.

Setting and Participants

The study was conducted in seven urban primary schools (Madrid, Valladolid, Ávila, cities with populations >50,000), López et al, 2023) between February and April 2024. The target population comprised all Spanish children aged 9–13 attending primary education in urban settings where smartphone exposure is widespread.

Sampling Method

We employed a two-stage convenience sampling approach. First, schools were selected based on geographic accessibility and administrative willingness to participate. Second, all students aged 9–13 within participating schools were invited to participate, yielding 1233 initial respondents.

Inclusion Criteria

(1) Age 9–13 years, (2) weekly smartphone use, (3) ability to complete questionnaires in Spanish, and (4) parental consent.

Final Sample

After excluding one participant with an invalid response pattern (all items scored '4'), the analytical sample comprised 1153 children. Table 1 presents detailed demographic characteristics.

Sample Size Justification

Post-hoc power analysis indicated favorable statistical power (>0.99) to detect the observed effect size (Cohen's d = 2.87) between nomophobia severity clusters, confirming adequate sample size for the primary analyses.

Table 1 Participant Demographics (N=1153)

Characteristic	n (%) or M±SD
Age	11.35 ± 1.29 years
− 9 years	98 (8.5%)
− 10 years	124 (10.8%)
− 11 years	267 (23.1%)
− 12 years	389 (33.7%)
− 13 years	275 (23.8%)
Sex	
- Girls	611 (53.0%)
- Boys	542 (47.0%)
Smartphone ownership	1153 (100%)
Years with phone	1.50 ± 1.34

Measures

Nomophobia Questionnaire for Children (NQC)

- The Spanish child-specific adaptation Nomophobia Questionnaire for Children (NQC) by[21] was employed. This 32-item inventory captures psychological (emotional regulation and dependency), social (social connectivity), and biological (physiological and behavioral symptoms) elements of nomophobia (eg, "I get anxious if I can't use my phone when I want"). Each item is scored on a 5-point Likert scale (1 = "Strongly disagree", 5 = "Strongly agree"), yielding possible total scores between 32 and 160. Higher values indicate greater nomophobia severity. In the current sample, the NQC demonstrated excellent internal consistency (Cronbach's alpha = 0.91), supporting its reliability for assessing nomophobia in Spanish children.

Anxiety Assessment

- The State-Trait Anxiety Inventory for Children (STAIC) measured situational anxiety via its 20-item State Anxiety subscale, delivered online. Scores sum reverse-coded positive items (eg, "I feel calm") and negative items (eg, "I feel nervous"), ranging from 20–60, with higher scores indicating greater anxiety. The STAIC showed good internal consistency in this study (Cronbach's alpha = 0.847), confirming its adequacy for evaluating anxiety in this population.

Demographic and Smartphone Usage Variables

- Age and sex were documented, along with children's approximate daily smartphone usage (daily/weekend/weekdays) and years since first phone ownership to contextualize phone-exposure levels.

Procedures

This quantitative, cross-sectional study employed an ex post facto design. School directors were contacted to secure collaboration, highlighting nomophobia prevention through understanding children's smartphone use. Data collection occurred from February to April 2024, with the research team visiting participating schools. Children completed questionnaires online via Google Forms in the classroom under supervision, ensuring standardized administration. Participants and parents were informed of the study's aims, provided digital consent through the platform, and could withdraw without consequence. Data confidentiality and anonymity adhered to the Helsinki protocol. The study was approved by the Research Ethics Committee of Universidad San Pablo CEU (code 431/20/25).

Data Collection

Following ethics approval, school directors were contacted and provided with study information emphasizing nomophobia prevention benefits. Upon agreement, information sheets and consent forms were distributed to parents two weeks before data collection.

Data collection occurred during regular school hours in computer laboratories. The research team administered questionnaires via Google Forms under standardized conditions. Team members remained present throughout the 20–30 minute session to clarify item wording without influencing responses. Children could withdraw at any time without consequence. All responses were anonymous, identified only by numerical codes.

Statistical Analysis

Analyses were conducted in R (version 4.4.2). Online responses were cleaned, excluding one outlier (NQC=128, all '4's). Descriptive statistics (means, SDs, frequencies) summarized NQC and STAIC State Anxiety scores.

1. Cluster-Based Identification of Severe-Risk Nomophobia.

   - Hierarchical clustering used the agnes algorithm (R package cluster) with complete linkage and Euclidean distances on NQC scores. The optimal number of clusters was determined through:

1. Visual inspection of the dendrogram for clear separation points.
2. Silhouette analysis to assess cluster cohesion and separation (k=2: silhouette width=0.317).
3. Elbow method examining within-cluster sum of squares across solutions.

   - These methods converged on a two-cluster solution, labeled "Low-to-Moderate Nomophobia" (96.88%, n=1117) and "Severe Nomophobia" (3.12%, n=36) based on mean scores.

2. ROC-Derived Cutoff Criterion

   - A ROC analysis (using the pROC package) was performed to refine the classification boundaries. Cluster membership (Severe vs Low-to-Moderate Nomophobia) served as the reference, while the continuous NQC total score was the predictor.
   - Multiple thresholds were examined, with the final cutoff chosen based on maximizing specificity and Youden's index. This approach aimed to correctly flag only those likely to experience impactful nomophobia-related impairments. The cutoff (101.5) achieved AUC=0.993, sensitivity=0.889, and specificity=0.979, weighted by severe-cluster prevalence (3.12%), using the "closest.topleft" method.

3. Inferential Statistics and Validity Checks

- Between-Group Comparisons: Independent-samples t-tests compared STAIC State Anxiety between severe- vs low-to-moderate-nomophobia groups (NQC $\geq$ 101.5 vs < 101.5). Cohen's d provided effect sizes for group differences.
- Sex Differences: Additional t-tests assessed whether boys and girls differed in NQC total scores.
- Correlational Analyses: Pearson's correlations determined how NQC total scores related to STAIC State Anxiety, aligning with reports that nomophobia correlates with various anxiety indicators.
- Statistical significance was set at $p < .05$ throughout.

Ethical Considerations and Funding

This study was a multi-center collaboration involving researchers from several institutions. To streamline the ethical review process, all procedures were submitted to the Research Ethics Committee of Universidad San Pablo CEU, which agreed to serve as the central approving body. The study adhered to the ethical standards of San Pablo CEU University Research Ethics Committee (CEINDO, approval code: 431/20/25) and complied with Spanish regulations for research involving minors. Each child's anonymity and the right to withdraw were firmly upheld. No external grants supported this research, and the authors declare no conflicts of interest. The authors acknowledge the collaboration of participating schools, educators, families, and

other administrative staff in enabling data collection. This study with file number 11172/2024, has received funding from the Call For Research Grants On Avila Topics (Gran Duque de Alba), 2024 (general modality and young researchers).

Results

Hierarchical Clustering

Using complete-linkage hierarchical clustering on total Nomophobia Questionnaire for Children (NQC) scores, a two-cluster solution was visually identified from the dendrogram (Figure 1). One large cluster ("Low-to-Moderate Nomophobia") and a much smaller, distinct cluster ("Severe Nomophobia") emerged, suggesting a clear separation in nomophobia severity (Figure 1). Additionally, silhouette analysis (k=2: silhouette width=0.317) and the elbow method confirmed that two clusters were the best option for this cohort.

Descriptive Statistics by Cluster

Table 2 summarizes each cluster's characteristics. The Low-to-Moderate Nomophobia cluster accounted for 96.88% of the sample (n = 1117), displaying a mean NQC score of 65.29 (SD = 17.28). By contrast, the Severe Nomophobia cluster comprised 3.12% (n = 36) with an elevated mean NQC score of 114.61 (SD = 12.71). A Welch's *t*-test ($t = -19.92$, $df \approx 37$, $p < .001$) indicated the difference between these two groups was highly significant and represented a large effect size (Cohen's $d = 2.95$). The distribution of the NQC scores in both populations can be visualized in Figure 2.

At the selected cutoff (101.5), false negatives (children with severe nomophobia incorrectly classified as low-risk) represent 11.1% of true severe cases, while false positives (children without severe nomophobia incorrectly flagged) represent 2.1% of true low-risk cases. This balance favors accurate identification of the most severe cases while avoiding over-pathologizing normal behavior.

Receiver Operating Characteristic (ROC) Analysis

To refine the severe-risk classification, membership in the "Severe Nomophobia" cluster served as the reference standard ("true" severe group) in an ROC analysis. The NQC total scores demonstrated strong discriminative capability (AUC = 0.993, 95% CI: [0.984, 0.999]; $p < .001$). An optimal cutoff point was identified at 101.5 using a closest.topleft approach that partially weighted cluster prevalence. This threshold achieved a sensitivity of 0.889 and specificity of 0.979 (Youden's index ≈ 0.868), see Table 3. Overall, 56 participants (4.86% of the total sample) met or surpassed the 101.5 cutoff. High specificity was

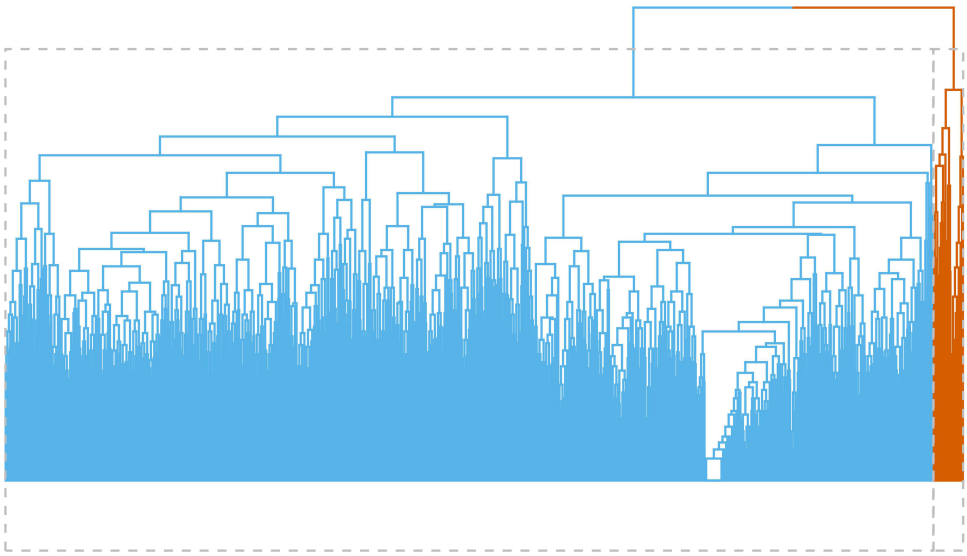

Figure 1 Hierarchical clustering dendrogram of total Nomophobia Questionnaire for Children (NQC) scores. Two distinct clusters are evident, with most participants in the low-to-moderate group (blue) and a smaller subset in the severe group (Orange).

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Table 2 Main Two Clusters Identified via Hierarchical Clustering on Total Nomophobia Questionnaire for Children (NQC) Scores

Cluster	N	Mean NQC (SD)	Range	% of Sample
Low-to-Moderate Nomophobia	1117	65.29 (17.28)	32–115	96.88%
Severe Nomophobia	36	114.61 (12.71)	79–149	3.12%

Notes: The Low-to-Moderate Nomophobia cluster comprises most participants, whereas the Severe Nomophobia cluster represents a smaller subgroup with notably higher mean NQC scores. The numeric range for each cluster and its percentage of the overall sample are also provided.

prioritized to ensure that only the most severe cases of nomophobia were flagged. Furthermore, total NQC scores differed significantly between the two groups (64.79 ± 16.92 vs 114.29 ± 11.03, p <0.001, Cohen's d = 3.06), as illustrated in Figure 2.

Validity Checks of the 101.5 Cutoff

Subdimension Scores

We examined whether children at or above the 101.5 cutoff (Severe Nomophobia) reported higher scores on each nomophobia subdimension (Psychological, Social, Physiological) compared to those below the cutoff (Low-to-Moderate Nomophobia). As shown in our continuous data (see Table 4), the Severe group exhibited significantly higher means in all three subdimensions (all ps <.001), with large effect sizes (Cohen's d ranging from 1.96 to 2.84). These findings indicate that children meeting or exceeding the cutoff show heightened symptoms across psychological, social, and physiological domains.

Gender Differences

We also compared the proportion of boys and girls in each group. Of 56 children above the cutoff, 4.21% were boys (n=23) and 5.45% were girls (n=33), with no significant difference (p=0.393, Cramer's V = 0.03). Hence, gender did not appear to significantly influence nomophobia severity in our sample.

Anxiety Associations

Children in the Severe group showed higher STAIC State Anxiety scores (M=38.68, SD=5.64) than those below (M=36.83, SD=4.84; t=−2.36, p=0.019, Cohen's d=0.38), indicating moderate elevation in situational anxiety. This

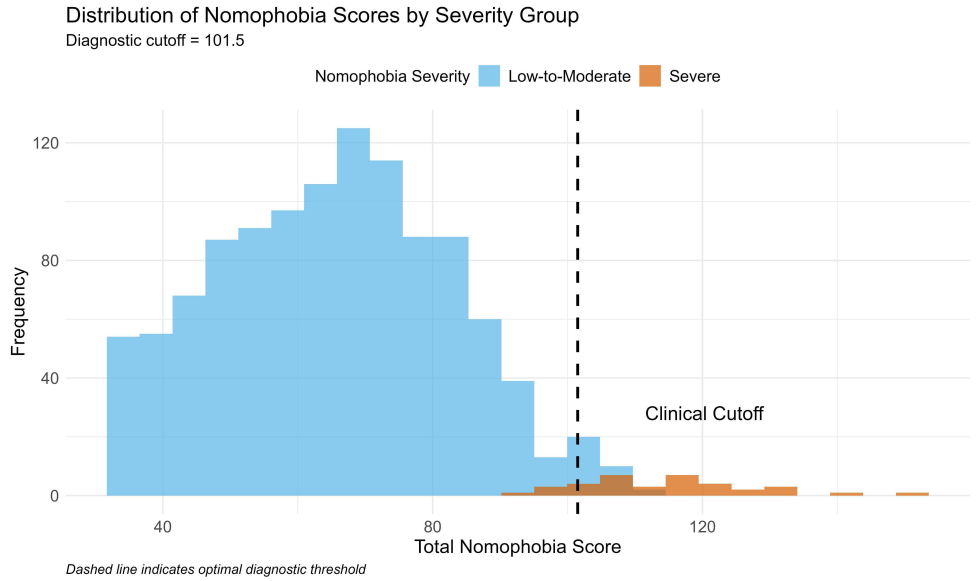

Figure 2 Histogram illustrating the distribution of total NQC scores for the same sample. Blue bars represent the low-to-moderate scores, whereas Orange bars indicate severe scores (≥ 101.5). The dashed vertical line marks the empirically derived cutoff of 101.5.

Table 3 Optimal Cutoff Value Identified for Classifying Participants into Severe vs Low-to-Moderate Nomophobia

Cutoff	TP	FP	FN	TN	Sensitivity	Specificity	Youden's J	AUC (95% CI)
101.5	32	24	4	1093	0.889	0.979	0.868	0.993 (0.984–0.999)

Notes: Sensitivity, specificity, and Youden's index quantify the cutoff's diagnostic performance. Note: The chosen threshold (103.5) achieved high specificity (0.981) and acceptable sensitivity (0.829), with an AUC of 0.983.
Abbreviations: TP, true positives; FP, false positives; FN, false negatives; TN, true negatives; AUC, area under the ROC curve; CI, confidence interval.

Table 4 Comparison of Dimension-specific and Total Nomophobia Scores, as Well as State-trait Anxiety Levels, Between Children Classified as Low-to-Moderate versus Severe Nomophobia (Cutoff > 101.5)

Factors		NMP Predicted Classification (Cut-Off > 103,5 for Positive Cases)			
		Low-to-Moderate Nomophobia (n=1181)	Severe Nomophobia (n=52)	p_value	Effect_Size
Nomophobia – Total: Mean (SD)		64.53 (16.49)	111.88 (10.62)	<0.001	Cohen's d = 2.91
Nomophobia - Psychological Dimension: Mean (SD)		34.09 (10.01)	62.23 (7.64)	<0.001	Cohen's d = 2.9
Nomophobia - Social Dimension: Mean (SD)		24.21 (7.28)	39.18 (4.59)	<0.001	Cohen's d = 2.21
Nomophobia - Physiological Dimension: Mean (SD)		6.23 (1.92)	10.46 (4.92)	<0.001	Cohen's d = 3.01
STAIC State Anxiety: Mean (SD)		36.83 (4.84)	38.68 (5.64)	0.019	Cohen's d = 0.38
Gender	Male (n)	95.79% (n=525)	4.21% (n=23)	0.393	Cramer's V = 0.03
	Female (n)	94.55% (n=572)	5.45% (n=33)	0.393	Cramer's V = 0.03

Notes: Means (SD) are shown for continuous variables, with p-values and effect sizes (Cohen's d or odds ratios) indicating differences between the groups.

further supports the idea that the 101.5 cutoff can differentiate participants with clinically relevant anxiety levels. The significant correlation between nomophobia severity and anxiety aligns with earlier findings.[4,29,30]

Overall, these checks affirm that our 101.5 cutoff identifies children with elevated subdimension scores and higher anxiety, confirming its utility for distinguishing those most susceptible to severe nomophobia.

Summary of Findings

The combination of hierarchical clustering and ROC analysis singled out a small but distinctly severe-nomophobia group (3.12% by clustering, 4.86% by ROC) among children aged 9–13. Those meeting or surpassing the 101.5 cutoff scored considerably higher on measures of state anxiety, underscoring that even in a predominantly mild-to-moderate sample, a small subset may face serious psychological detriments. Absence of gender disparities suggests nomophobia risk is broadly similar for boys and girls at this age, at least in urban Spanish settings.

Overall, these results highlight the practicality of a data-driven cutoff (NQC $\geq$ 101.5) for identifying children who might benefit from prompt intervention, thereby facilitating targeted prevention and support strategies during a pivotal phase of their developmental trajectory.

Discussion

This study provides a refined classification for nomophobia in a crucial but understudied demographic: pre-adolescent children. A key contribution of our work is its specific focus on nomophobia, rather than the broader construct of 'smartphone addiction'. Nomophobia uniquely captures the affective dimension of digital dependency, including the anxiety and emotional distress tied to separation from the device—a concept closely linked to attachment theory.[19] By

concentrating on nomophobia, our research addresses a critical gap, as previous literature has not applied this specific framework to the 9–13 age group, thereby offering a more nuanced understanding of children's emotional relationship with their smartphones.

Our two-step approach—hierarchical clustering followed by ROC analysis—established a high-specificity cutoff (NQC ≥ 101.5) that identified a small subset (4.86%) of children facing severe risk. This data-driven method adds precision to prior literature, which often uses broad percentile-based or multi-tiered (mild/moderate/severe) classifications that can overeste intervention needs. Our finding of a ~5% prevalence for severe nomophobia is modest compared to rates in adolescents and university students, which can exceed 17%.[4,15–18] However, this figure must be interpreted through a developmental lens, where its clinical significance is amplified. The 9-to-13-year-old period is a formative window for social and emotional maturation, where attachment patterns evolve and solidify. The emergence of severe nomophobia is particularly concerning at this stage, as it may signal a nascent, maladaptive attachment to the smartphone itself, potentially perturbing the development of secure interpersonal bonds. Therefore, even a 5% prevalence identifies a small but highly vulnerable subgroup for whom early monitoring and intervention are not just beneficial, but critical to fostering healthy emotional regulation and social development.The validity of our cutoff was strengthened by its association with external measures. The link between the severe nomophobia group and higher state anxiety (d=0.38) corroborates findings from numerous studies in other populations,[4,29,30] reinforcing the view of nomophobia as a genuine anxiety-related construct.

The absence of gender differences (4.66% boys vs 5.07% girls, p=0.671) suggests nomophobia severity in this age range is not sex-driven, possibly reflecting uniform smartphone exposure or environmental influences in urban settings. This result contrasts with previous studies in older cohorts that find higher nomophobia in females.[16,17] This could indicate that at ages 9–13, smartphone integration into social life is more uniform between genders, with differences emerging later in adolescence.

While dichotomizing a continuous psychological phenomenon inevitably loses information, clinical practice often requires binary decisions (intervene/monitor). For practitioners, this NQC ≥ 101.5 cutoff can be integrated into routine school-based mental health screenings as a first-line tool to identify children who may require a more thorough clinical assessment and targeted support, such as digital wellness workshops or individual counseling. However, the substantial variability within the low-to-moderate cluster (SD = 17.28) suggests a continuum of risk, and children scoring just below the threshold may still benefit from preventive attention.

The study's limitations include its cross-sectional design, which prevents tracking the evolution of nomophobia, and its urban focus, which may limit generalizability to rural contexts. Future studies could employ latent profile analysis to explore subgroups, particularly as children age into adolescence, where moderate nomophobia might warrant lighter intervention. Further exploration of environmental factors—such as parenting styles or school phone policies—could clarify risk pathways. Despite these limitations, the NQC ≥ 101.5 cutoff offers a practical tool for detecting urban Spanish children aged 9–13 most likely to benefit from early intervention, enhancing targeted prevention efforts. For practitioners, this NQC ≥ 101.5 cutoff can be integrated into routine school-based mental health screenings. School psychologists or counselors could use it as a first-line tool to identify children who may require a more thorough clinical assessment and targeted support strategies, such as digital wellness workshops or individual counseling.

Conclusion

Combining hierarchical clustering and ROC analysis, this study defined a conservative threshold (NQC ≥ 101.5) to identify severe nomophobia in urban Spanish children aged 9–13. Though only 4.86% exceeded this cutoff, their moderately higher State Anxiety (p=0.019, d=0.38) underscores the psychological stakes of severe smartphone-related fears. Unlike multi-tiered approaches, this binary cutoff isolates a small at-risk group for focused action, proving robust for this pre-adolescent cohort. Future research should not only validate this cutoff cross-culturally but also explore its utility in rural populations where smartphone access patterns may differ. Longitudinal studies are crucial to track whether children in the 'severe' group continue on this trajectory and to identify protective factors, such as specific parenting styles or school-based digital literacy programs, that could mitigate risk Ultimately, this benchmark provides a valuable tool for digital mental health surveillance in schools and health services, enabling early, tailored responses to curb maladaptive digital behaviors.

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Disclosure

The authors declare that they have no conflicts of interest to declare.

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