REVIEW ARTICLE

Prevalence of smartphone addiction among undergraduate medical students in India- A systematic review and meta-analysis

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ABSTRACT

Background: Smartphone addiction is an emerging public health issue worldwide, affecting individuals across age groups, including undergraduate medical (MBBS) students. **Aim:** This systematic review and meta-analysis aimed to estimate the pooled prevalence of smartphone addiction among MBBS students in India and to explore variations based on the demographic, regional, and methodological factors.

Methods: A comprehensive search was conducted in PubMed, Scopus, Web of Science, EBSCO, and Embase for studies published up to October 01, 2024, following a PROSPERO-registered protocol (CRD42024607941). Studies reporting the prevalence of smartphone addiction among MBBS students in India were included. Two reviewers independently screened studies, extracted data, and assessed quality using the joanna brings institute (JBI) critical appraisal checklist. Meta-analysis was performed using R version 4.4.2 (2024-10-31 ucrt). Single arcsine transformation with maximum likelihood estimator was used for pooled prevalence calculation. Subgroup analyses examined differences based on the geographic region, sampling method, academic year, and type of scale used. Meta-regression assessed the influence of potential moderators. Leave one out sensitivity analysis was conducted. Publication bias was evaluated using Doi plot and luis furuya- kanamori (LFK) index.

Results: Twenty-four studies were included in the analysis. The pooled prevalence of smartphone addiction among MBBS students was 60% (95% CI 45% to 73%; number of studies = 24), with high heterogeneity ($I^2 = 99.4\%$, $P < 0.001$). The overall prevalence of smartphone addiction among undergraduate medical students (evaluated using screening instruments for smartphone addiction) in India is 60%. Although some subgroup differences (regarding region studied, sampling method used and batch of MBBS studied) were found to be statistically significant, it is important to interpret these findings with caution, as these differences may still be influenced by chance occurrences, random error, or underlying study-level biases.

Conclusion: The high prevalence of smartphone addiction among Indian MBBS students underscores the need for targeted awareness, preventive strategies, and support systems within medical institutions. Addressing this issue is critical to safeguard students' mental health and academic performance.

Key words: Behavioral addiction, India, medical students, smart phone, smart phone addiction

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Submitted: 29-Apr-2025, **Revised:** 23-Jun-2025, **Accepted:** 10-Aug-2025, **Published:** 16-Sep-2025

Access this article online	
Website: https://journals.lww.com/indianjpsychiatry	Quick Response Code
DOI: 10.4103/indianjpsychiatry_419_25	

How to cite this article: Pradeep C, Sahoo S, Singla N, Gandhi AP, Padhi BK. Prevalence of smartphone addiction among undergraduate medical students in India- A systematic review and meta-analysis. Indian J Psychiatry 2025;67:842-51.

INTRODUCTION

Smartphone addiction refers to a person's dependence on their smartphones, uncontrollable fear of being without a mobile phone, or of not having contact with the mobile phone.[1–3] It is one of the fastest growing forms of behavioral addiction in the current era, highly prevalent in across all age groups and across the globe.[2,4] Smartphone addiction has emerged as a significant public health concern, particularly among university students, who are among the most frequent users of digital devices. Mobile learning has found to increase student clinical competency and confidence, improve the acquisition and enhance of students' theoretical knowledge.[5,6] However, the increasing reliance on smartphones for communication, socialization, academic activities, and entertainment has raised concerns about excessive usage patterns leading to problematic behaviors. Several studies have come up with many psychological, as well as physical consequences of smartphone addiction, such as anxiety, agitation, creativity blocks, disorientation, impaired relationships, loneliness, lower concentration, perspiration, poor grades, psychological disorders, reduced cognition, respiratory alterations, sleep deficit, tachycardia, and nervousness.[7–12]

Among medical students, the risk of smartphone addiction may be even higher due to intensive academic demands, high levels of stress, and the integration of smartphones into medical education. A very recent meta-analysis has reported the global prevalence of smartphone addiction among medical students to be around 39%,[13] which is quite alarming. Similarly, its prevalence in medical students of Asia was found to be 41.93% in another meta-analysis focused on Asian countries.[14] There have been several studies conducted in India on this problematic condition in the medical student population, too, with prevalence ranging from 15% to 100%,[3,15] wide variation owing to the use of different assessment instruments.

A rapid literature review involving major databases revealed a scarcity of systematic reviews and meta-analyses of published studies that have investigated the prevalence of smartphone addiction among Indian medical undergraduates. While the previous individual studies provide useful insights, a systematic synthesis of data through meta-analysis is necessary to derive a pooled prevalence estimate and examine variations based on factors such as region/zone, gender, study year, or batch-wise prevalence. Furthermore, given the high heterogeneity in study findings, an investigation into the potential causes of variability is crucial for designing targeted interventions.

Understanding the burden of smartphone addiction in medical students is essential for policy development, academic interventions, and mental health support strategies. With this background, the current systematic review and meta-analysis (SRMA) was designed to estimate the pooled prevalence of smartphone addiction among undergraduate medical students in India. Additionally, we also explored if there existed any difference in overall prevalence about region, sample size, year of study, gender, and batch-wise distribution.

The findings of this review can help medical institutions implement preventive measures and digital well-being programs to mitigate the negative effects of excessive smartphone use on students' academic performance, mental health, and overall well-being.

METHODS

Search strategy

The PICO [Patient/participants, Intervention, Comparison, Outcome] criteria [Table S1] and the research question "What is the prevalence of smartphone addiction among undergraduate medical students in India?" was the focal point of our search. The study was registered with the "International Prospective Register of Systematic Reviews (PROSPERO)," as CRD42024607941.

We searched in following five databases: "PubMed, Scopus, Embase, EBSCO, Web of Science." Additional suitable studies were identified by conducting a thorough search of the references and citations of the selected papers, as well as relevant review articles. A systematic search was performed of entire databases for studies published till 01/10/2024 using a combination of search keywords (*indicates truncation), which included "student*," "medical student*," "Medical trainee," "medical undergraduate," "nomophobia," "smartphone addiction*," "mobile addiction," "cellphone addiction," and "India" [Table S2]. Mendeley Desktop V1.19.5 software was used to filter and manage selected studies, and further coordinate the review/selection process.

Selection criteria

The study population was medical students pursuing undergraduate medical education (MBBS) in India of any gender and belonging to all age groups. We included those studies that reported the prevalence of smartphone addiction as primary outcome as well as secondary outcome. The studies providing complete information for calculating the prevalence were included. The study designs and other eligibility criteria are presented in Table S1.

Initially, the 1st author and 3rd author independently went through the title and abstract of the article based on the inclusion and exclusion criteria and selected or omitted the article. If there was a difference of opinion the 2nd author resolved it. Following this full text review was also undertaken by two authors, independently. Studies with no full text, lack of standardized tools/measurement scales, unclear methodology or results were excluded. Any discrepancies regarding the final eligibility of the study for the inclusion in the SRMA were resolved by 4th and 5th author. All the decisions were recorded in the Microsoft Excel spread sheet.

Data extraction

From the studies that were selected based on the inclusion and exclusion criteria, data was extracted independently by 1st author and 3rd author. For any extra data, the corresponding author of some of the articles was also contacted for clarification. Data was collected under the following headings: author, type of sampling used, region where the study was done, publication year, type of scale used, sample size, total participants with smartphone addiction, gender wise participants, and number addicted among them, smartphone addiction among the different batches of medical students. Any difference in data extraction was discussed, and the other three authors (2nd, 4th, and 5th authors) resolved any discrepancies.

"Preferred Reporting Standard of Systematic Reviews and Meta-Analysis (PRISMA)" was adhered to in the SRMA, to maintain scientific accuracy[16] [PRISMA Figure 1 and Table S3].

Study outcomes

Pooled prevalence of smartphone addiction among undergraduate medical students in India was the primary outcome. Additional outcomes were region, sampling technique, gender based, batch-wise prevalence of smartphone addiction.

Quality assessment

Two authors (1st and 2nd authors) independently assessed the studies chosen for meta-analysis using the joanna brings institute (JBI) critical appraisal checklist for studies reporting prevalence data. If there was a disagreement, the 4th and 5th authors resolved it. After excluding the studies rated as poor quality, the authors did a sensitivity analysis.

Statistical analysis

Single arcsine transformation with maximum likelihood estimator was used for pooled prevalence calculation and all further analysis, except for Doi plot and meta regression, which were performed with logit transformation. Using I^2 statistic the heterogeneity between the studies was calculated. An $I^2 > 50\%$ was used as the cut-off for high heterogeneity in our present

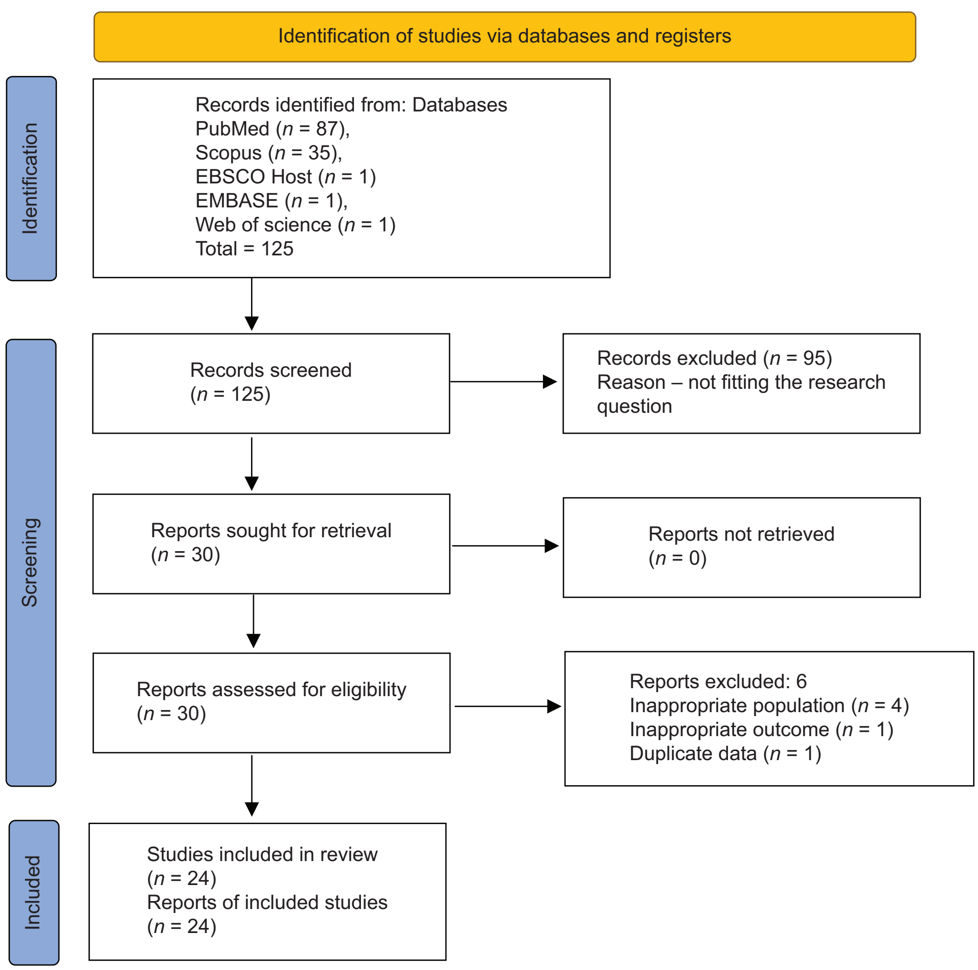

Figure 1: PRISMA 2020 flow diagram. PRISMA: Preferred Reporting Standard of Systematic Reviews and Meta-Analysis. From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al*. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

study, and a random effects model was planned if it exceeded that level.[17] A forest plot was constructed to show the overall prevalence along with 95% confidence interval (CI), and *P* value. The $P < 0.05$ was set as the statistical significance level.

Doi plot and LFK index were used to evaluate the publication bias. A meta-regression was conducted using a logit transformation to analyze the effects of potential moderators on the overall outcome estimate and the heterogeneity. The moderators that were assessed were the sample size, gender, and year of publication. Subgroup analysis was conducted for gender, type of assessment tool used, MBBS batch-wise estimates of prevalence, region of India where the study was done (states to be included for zonal division was based on a previously published National Family Health Survey-3 i.e. NFHS-3 study)[18] and sampling method used. Leave one out sensitivity analysis was used to find the effect on the pooled prevalence after excluding each study. Meta-analysis was performed using R version 4.4.2 (2024-10-31 ucrt) was used to conduct all the relevant analyses in the SRMA.[19] The images and plots were generated by the R studio software. The packages used were "readxl," "meta," "metafor," "metasens," "ggplot2," and "dplyr."[20,21]

RESULTS

Eligible studies

The systematic search yielded 125 unique records. Based on the title-abstract screening and full text review 24 studies were found eligible for data collection.[1,3,15,22–42] [Figure 1]

Characteristics of the included studies

The studies were conducted from 2010 to 2024. The studies had sample sizes ranging from 93 to 626 medical students. Seven studies were from northern part of India,[22–24,35–37,40] 4 from western part,[1,28,29,33] five each from southern[27,31,38,41,42] and eastern part of India.[3,15,26,32,34] Only three studies were from the central India.[25,30,37] No eligible studies were found from the North-Eastern part of India suggesting an eminent need for research from this part of the country.

For assessing smartphone addiction, 13 studies[22,25,27–29,31,33,34,37,42] had used the Smart Phone Addiction Scale - short version (SAS-SV) and nine studies had used Nomophobia Questionnaire (NMP-Q).[1,3,23,26,30,32,35,36,40] Only one study each had used the Mobile Phone Addiction Scale (MPAS)[24] and Mobile Phone Dependence Questionnaire (MPDQ)[15] [Table 1].

Risk of bias assessment

Based on the JBI tool for prevalence studies, all the 24 studies qualified for assessment with more than 50% cut off scores that is, were of good quality [Table S4].

Prevalence of smartphone addiction

The prevalence of smart phone addiction among medical students as reported by different studies ranged from 15% to 100%. By using the single arcsine transformation with maximum likelihood estimator, the pooled prevalence was estimated to be 60% (95% CI 45% to 73%; no of studies = 24; I^2-99.4%; $P < 0.001$). The heterogeneity was

Table 1: Characteristics of the studies included in the index study

Author, year	Sample	Region/zone in India	No of students addicted	No of Males addicted	No of females addicted	Scale used for assessment of
Dixit *et al*., 2010[30]	200	Central	37	20	17	NMP-Q (cutoff 24)
Sharma *et al*., 2019[36]	164	North	106	57	49	NMP-Q (cutoff 24)
Mengi *et al*., 2020[35]	600	North	241	169	72	NMP-Q (cutoff 24)
Dasgupta *et al*., 2017[26]	303	East	129	66	63	NMP-Q Mean score
Farooqui *et al*., 2018[1]	145	West	145	66	79	NMP-Q
Bartwal and Nath, 2020[23]	451	North	451	171	280	NMP-Q
Kundu *et al*., 2022[32]	338	East	338	170	168	NMP-Q
Yadav *et al*., 2022[40]	363	North	363	191	172	NMP-Q
Ranjan *et al*., 2023[3]	374	East	373	-	-	NMP-Q
Zeerak *et al*., 2024[41]	481	South	211	97	114	NMP-Q
Mangot *et al*., 2018[33]	93	West	37	-	-	SAS-SV
Basu *et al*., 2018[24]	388	West	155	96	59	MPAS
Choudhury *et al*., 2019[15]	247	East	37	22	15	MPDQ
Dharmadhikari *et al*., 2019[29]	195	West	90	45	45	SAS-SV
Kumar *et al*., 2019[42]	150	South	67	31	36	SAS-SV
Awasthi *et al*., 2020[22]	395	North	173	76	97	SAS-SV
Chatterjee and Kar, 2021[25]	224	North	88	48	40	SAS-SV
Dhamija *et al*., 2021[28]	499	West	257	110	147	SAS-SV
Jahagirdar *et al*., 2021[31]	626	South	372	123	249	SAS-SV
Solanki *et al*., 2021[37]	395	Central	166	-	-	SAS-SV
Devi *et al*., 2022[27]	253	South	137	-	-	SAS-SV
Manna *et al*., 2023[34]	204	East	60	-	-	SAS-SV
Verma *et al*., 2023[39]	402	North	140	83	57	SAS-SV
Vengadessin *et al*., 2024[38]	383	South	194	-	-	SAS-SV

SAS-SV=Smartphone Addiction scale; NMP-Q=Nomophobia Questionnaire; MPDQ=Mobile Phone Dependence Questionnaire; MPAS=Mobile Phone Addiction Scale high (I^2-99.4%). The prediction interval varied between 1% and 100% [Figure 2a].

Similarly, using single arcsine transformation with maximum likelihood estimator, the pooled prevalence of smartphone addiction in males and females was estimated to be 63% (95% CI 46% to 78%; no of studies = 18; I^2 - 98.9%; $P < 0.001$) [Figure 2b] and 60% (95% CI 42% to 77%; no of studies = 18; I^2 - 99.1%; $P < 0.001$) [Figure 2c], respectively; heterogeneity being high in both cases. The meta-regression of year when the study was published (beta = 0.1898; $P = 0.248$; $R^2 = 0.56\%$) [Figures S1a], the sample size (beta = 0.0015; $P = 0.661$; $R^2 = -5.97\%$) [Figures S1b] of studies. Either gender that is, male gender (beta = −0.0016; $P = 0.817$; $R^2 = -9.67\%$) and female gender (beta = 0.0018; $P = 0.78$; $R^2 = -9.1\%$) did not have any significant effect on the prevalence of smartphone addiction [Figure S2a, b].

For estimating batch-wise prevalence, when the year of the medical students at the time of assessment was checked, it was available for only few studies.[1,3,22,27,29,31–33,35,36,40,42] While only two studies had included all batches, including interns,[22,35] three had looked into all batches except the interns[3,29,31] and two studies took information from interns only.[33,42] While one study included 1st, 2nd, 3rd year students,[40] others had included either 2nd and 3rd years,[27] or 1st year only[1] or 2nd year students only.[36] The remaining studies did not mention the batch-wise distribution of numbers. Based on these data, it was found that 1st year students had the highest prevalence 80% (95% CI 51% to 98%; no of studies = 7; I^2 - 98.7%; $P < 0.0001$) [Figure S4a], which was followed by 3rd year 72% (95% CI 47% to 91%; no of studies = 7; I^2 - 98.2%; $P < 0.001$) [Figure S4c] and 2nd year 70% (95% CI 48% to 89%; no of studies = 8; I^2 - 98.1%; $P < 0.001$) [Figure S4b], 4th year 64% (95% CI 34% to 89%; no of studies = 5; I^2 - 98.2%; $P < 0.001$) [Figure S4d]. The interns had the lowest prevalence that is, 33% (95% CI 22% to 44%; no of studies = 4; I^2 - 86.7%; $P < 0.001$) [Figure S4e]. Heterogeneity remained high for all for all batches.

Subgroup analysis based on the sampling method used showed that the studies that used random sampling methods (no of studies 6)[24,26,30,34,38,41] had low pooled prevalence of 37% (95% CI 29% to 46%; no of studies = 6; I^2 93.6%; $P < 0.001$) as compared to those that had convenience sampling[1,3,22,23,25,27–29,31,33,35–37,39,40,42] which was 67% (95% CI 49% to 82%; no of studies = 16 studies; I^2 99.4%; $P < 0.001$). Only two studies[15,32] had not defined any sampling methodology used, the pooled prevalence for them was 69% (95% CI 3% to 100%; no of studies = 2; I^2-99.9%; $P < 0.0001$) [Figure S3]. Subgroup differences, assessed using Cochran's Q-test for subgroup differences in R, were statistically significant ($P = 0.0104$), indicating that the type of sampling method used in the studies accounts for a substantial portion of the observed heterogeneity.

Subgroup analysis based on the type of scale used to assess the prevalence of smartphone addiction revealed that the studies that used NMP-Q (cut-off score of 21 or more as nomophobia) showed nil heterogeneity, but the prevalence of smartphone addiction was 100% (95% CI 100% to 100%; no of studies = 5; $I^2 = 0\%$; $P = 0.540$). The studies that had used the NMP-Q scale but had taken either cut-off score of 24 or more[1,3,23,32,40] or had used the NMP-Q mean score to classify addiction, had prevalence rates 40% (95% CI 20% to 63%; number of studies = 3; I^2 97.7%; $P < 0.0001$) and 43% (95% CI 37% to 48%; number of studies = 1), respectively. When the studies that had used other scales (SAS-SV-13 studies; MPAS-1 study; MPDQ-1 study)[15,22,24–31,33,35–39,41,42] were analyzed as sub-groups, prevalence of smartphone addiction varied that is, SAS-SV that is, 45% (95% CI 40% to 49%; no of studies = 13; I^2 89.7%; $P < 0.0001$), MPAS - 40% (95% CI 35% to 45%; no of studies = 1) and MPDQ that is, 15% (95% CI 11% to 20%; no of studies = 1) [Figure 3a]. Heterogeneity was high, which ranged from 89.7% to 97.7% [Figure 3a]. Test for subgroup differences was significant ($P < 0.001$) showing high heterogeneity can be explained by the type of scale used.

When the subgroup analysis based on the geographical regions, the studies belonged to were carried out, Central Indian studies[25,30,39] had the lowest prevalence 31% (95% CI 21% to 41%; no of studies = 3; I^2 92.4%; $P < 0.001$), followed by Southern India[27,31,38,41,42] 51% (five studies; 95% CI 46% to 56%; no of studies = 5; I^2 87%; $P < 0.001$), Western India[1,28,29,33] 66% (95% CI 32% to 93%; no of studies = 4; I^2 99.1%; $P < 0.001$), Eastern Indian studies - 67% (95% CI 25% to 97%; no of studies = 5; I^2 99.7%; $P < 0.001$).[3,15,26,32,34] and Northern India 69% (95% CI 41% to 91%; no of studies = 7; I^2 99.6%; $P < 0.001$).[22–24,35–37,40] No eligible studies were found from the North-Eastern part of India suggesting an eminent need for research from this part of the country. I^2 of the different regions varied between 87% to 99.7% and test for subgroup differences was significant ($P = 0.0046$). All the South Indian studies had used SAS-SV scale, and the studies conducted in the Western, Eastern and Northern regions had mostly used NMP-Q with 21 as cutoff showed 100% prevalence. This may explain the difference in prevalence between regions [Figure 3b]. However, study design and sampling technique which varied across different studies within same region, as well as in different regions can affect the prevalence rate, hence these findings should be interpreted with caution.

Publication bias was assessed using Doi plot. The Doi plot, which visualizes the deviation from the mean proportion, showed that the deviations were balanced, suggesting no extreme outliers and that no single study appeared to be excessively skewing the results [Figure 4]. The LFK index was found to be −1.44, which was very small, suggesting minor asymmetry and publication bias.[43] Possible reasons for publication bias in this review may include selective publication of significant results, suppression of grey literature, and small-study effects.

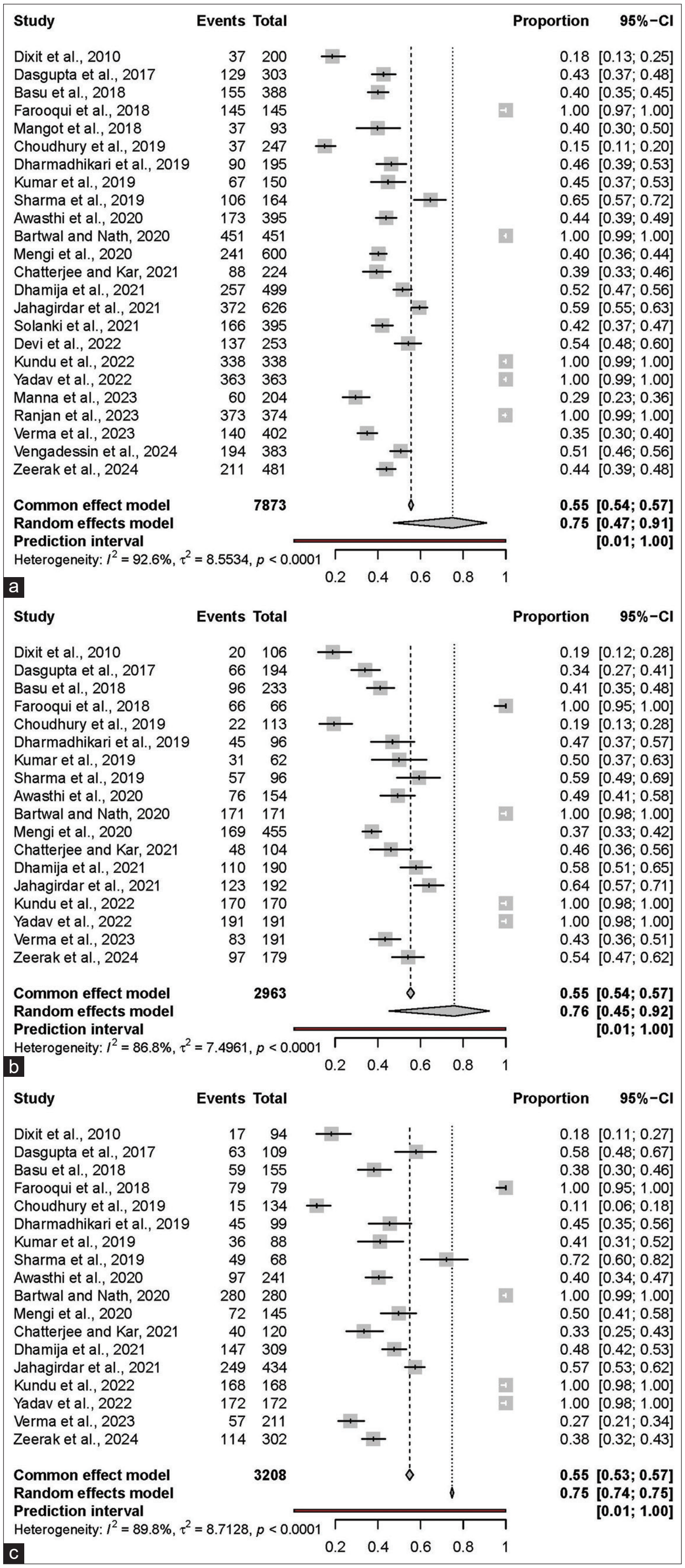

Figure 2: (a) Forest plot of the pooled prevalence of smartphone addiction. (b) Forest plot of prevalence of smartphone addiction in males. (c) Forest plot of prevalence of smartphone addiction in females

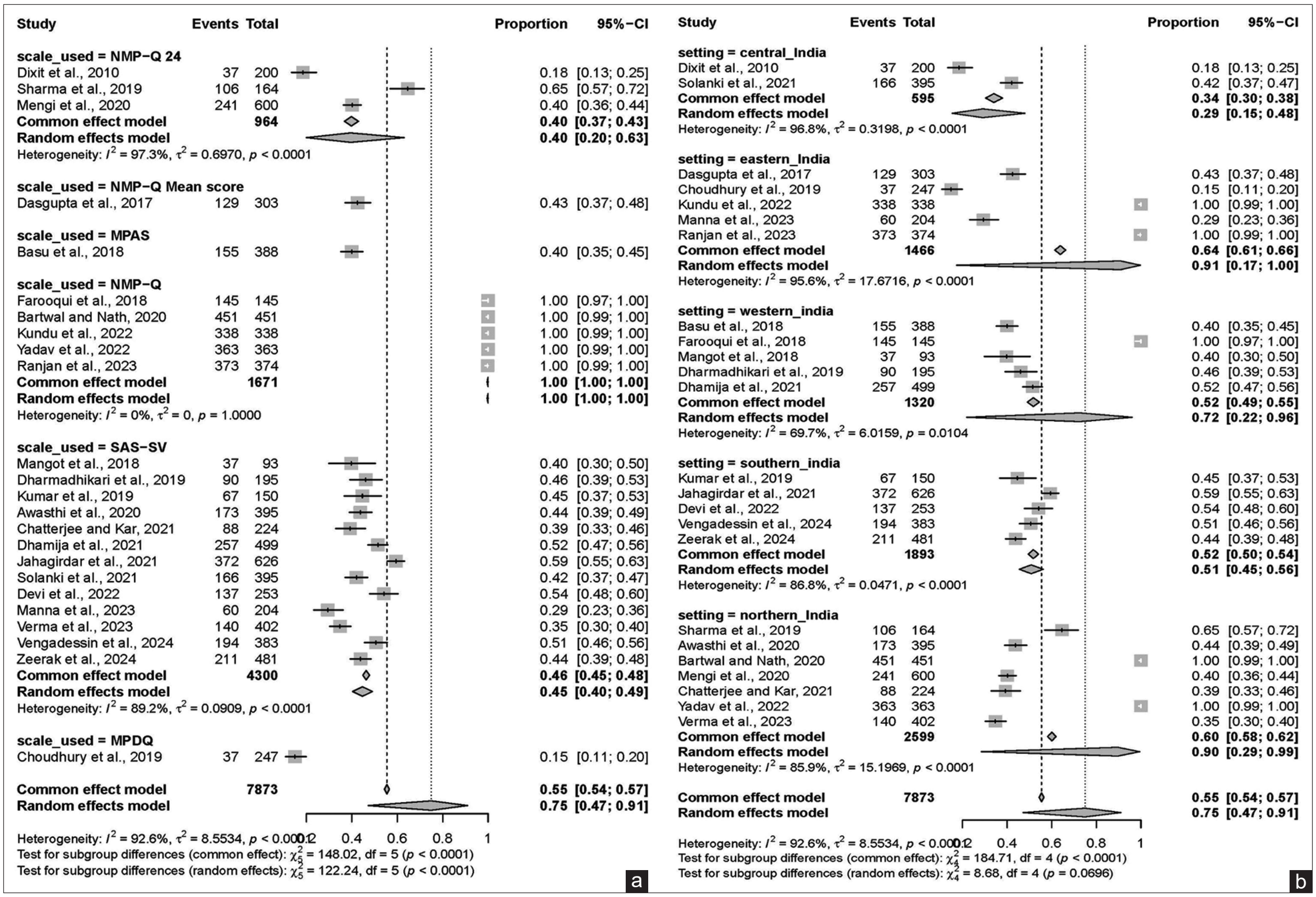

Figure 3: (a) Forest plot of prevalence of smartphone addiction as per different assessment scales used. (b) Forest plot of prevalence of smartphone addiction with region as subgroup

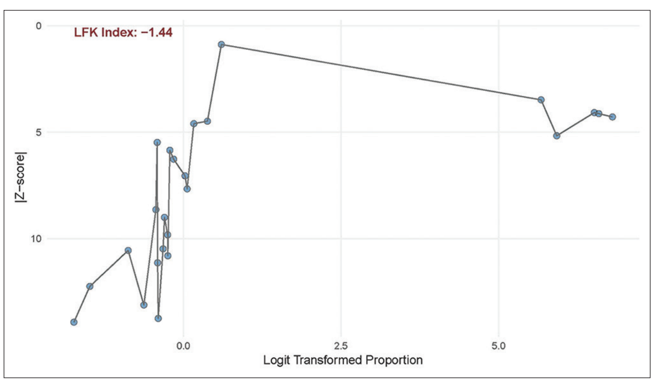

Figure 4: Doi plot to assess for publication bias. LFK index- -1.44

When leave-one-out sensitivity analysis was conducted, no single study dominated the overall estimate [Figure S4]. In most studies, when the prevalence was omitted, it ranged between 59.34% and 61.62%. The following studies, when omitting the prevalence were Bartwal and Nath 2020 (56.6%),[23] Kundu *et al*., 2011 (56.6%),[32] Yadav *et al*., 2022 (56.6%),[40] Farooqui *et al*., 2018 (56.63%),[1] and Ranjan *et al*., 2023 (56.62%),[3] which was significantly less than the other studies. When these five studies were left out and forest plot was re-drawn with the remaining studies, the pooled prevalence reduced to 42% (95% CI 36% to 47%; no of studies = 19; I^2 94.5%; $P < 0.001$) [Figures S5 and S6; Table S5].

DISCUSSION

Smartphone addiction has been in the limelight of research for the last decade. With the growing applications of smartphones in daily lives, the nuances of the adverse effects of excessive smartphone use are likely to occur soon. The more accepted terminology is problematic smartphone use, which also falls under the broad rubric of behavioral addiction.[2] However, most of the studies had used scales that assess smartphone addiction rather than problematic use; therefore, we used the term smartphone addiction for all descriptive purposes.

The present review estimated the prevalence of smartphone addiction in medical undergraduates in India, the pooled prevalence of which (single arcsine transformation with maximum likelihood estimator) came out to be 60%. This review found substantial heterogeneity (I^2-99.4%), indicating significant variability across the studies. Leave one out (LOO) sensitivity analysis suggested that the studies that had close to 100% prevalence rates may have disproportionately influenced the pooled estimate.

The previous meta-analysis, which estimated the prevalence of smartphone addiction among Asian medical students, found smartphone addiction to be 41.93%, which was less than the present review.[14] However, this meta-analysis had over-representation of study participants from India as compared to other Asian countries (India – 11 studies and other Asian countries – 8 studies). Further, it represented only those studies which had one specific scale, that is, SAS-SV.[14] The present review also reported almost similar pooled prevalence when analysis was limited to only those studies that had used SAS-SV, that is, 45% (95% CI 40% to 49%; number of studies = 13; I^2 89.7%; $P < 0.001$). However, the present review took into account all the studies that had estimated prevalence using other scales used for assessing smartphone addiction [such as NMP-Q, The MPAS, and MPDQ]. Hence, the present review findings can be regarded as having more weightage than the previous findings and had a greater representation of medical students from India.

As evident from the review findings, the prevalence values varied significantly based on the scale used for assessment of smartphone addiction. While the studies that used NMP-Q with 21 as the cut-off showed 100% prevalence, studies that used 24 as the cut-off for smartphone addiction showed a pooled prevalence of 40% (95% CI 20% to 63%; number of studies = 3; I^2 97.7%; $P < 0.0001$). This was closer to the pooled prevalence estimate obtained from studies using SAS-SV, which was 45% (95% CI 40% to 49%; no of studies = 13; I^2 89.7%; $P < 0.0001$) and 40% for the study which used MPAS (95% CI 35% to 45%; no of studies = 1).[24] Hence, for accurate estimation of smartphone addiction in Indian context, a standardized scale covering all aspects of smartphone addiction needs to be prepared, which should be validated in Indian population in different age groups/populations (elderly, children, adolescents, adults etc.), as specific age group has different usage of smartphone for different needs. It would be too simplistic to use a single scale in all age groups to justify smartphone addiction. Additionally, several concerns have been raised on the assessment tools developed to measure smartphone addiction, which possibly lead to significant variation in estimating prevalence rates.[44] While some of the scales are Likert scales, others have used a dichotomous format to assess different symptoms suggestive of smartphone addiction. The majority of the scales used in the studies (as mentioned in the present study) have only reported internal consistency and not temporal stability (which is an essential construct to determine test-retest reliability); therefore, suggesting inadequate psychometric properties of the used scales.[44] Further, the concept of smartphone addiction is undergoing rapid change with regard to its nosologically construct and conceptualization of over-pathologizing everyday life phone usage versus smartphone excessive usage/problematic use vis-à-vis addiction.[45]

In the index review, the prevalence did not differ between the male and female gender in our review as was in the previous meta-analysis.[14] This finding was unlike the findings of another meta-analysis which solely focused on smartphone addiction in Chinese medical students ($n = 20$ studies, 36,365 students), which demonstrated higher incidence in males.[46]

The batch-wise prevalence estimates revealed a decreasing prevalence from 1st year to interns. Since only few studies have reported batch-wise prevalence and even those studies have covered different batches its am difficult to draw a definitive conclusion.

Region-wise analysis demonstrated that studies from central India had the lowest prevalence, and those from northern and eastern Indian regions had the highest prevalence estimates. However, it would be difficult to comment on any relationship between the region of study/study sample and smartphone addiction. Rather, the high prevalence rates in the northern and eastern regions of India could have been because of more studies from these regions, and due to the usage of specific common scales used in these studies. Further there is no eligible study from the North-eastern part of India. Hence, there is a need to have a national survey of smartphone addiction with a representative sample from all states using one standardized scale with good psychometric properties to be able to decipher any relationship on this aspect.

The subgroup analysis has shown that there were significant group differences between studies when sub-grouped in terms of sampling method, type of scale used, and region of India. All these might also explain the issue of high heterogeneity.

Strengths and limitations

The pooled estimate of smartphone addiction among medical undergraduates in India was assessed systematically for the first time across all published studies in the index meta-analysis. The included studies were assessed for risk of bias using standard tools, and a sensitivity analysis was conducted by using LOO analysis, and those studies that contributed a little more to the effect size than others were removed, and the analysis was conducted to improve the robustness of the results. However, a major limitation of the study was the high heterogeneity among the included studies in the pooled prevalence. To address this, subgroup analysis and meta-regression was conducted based on the available social and demographic factors. Nevertheless, heterogeneity was still high. This could be due to the methodology used, that is, type of scale used, sampling methods used, region where the study was conducted, and MBBS batches/year of medical education included in the studies. Additionally, there could be several other potential confounders that could have affected the study results. Although we attempted to improve the study findings by doing a sensitivity analysis, the overall heterogeneity remained high. Finally, one should be more cautious in drawing conclusions based on such a small number of studies with no certainty regarding the methodological robustness of these studies, and these studies had used only screening tools, which are not confirmatory tools or diagnostic tools or any interview methods which are gold standard methods to detect smartphone addiction. Under-reporting or providing socially desirable answers in the scales used could be other important limitations that could have affected the study estimates. Moreover, some of the study findings need to be interpreted with caution due to the limited number of studies in the sub-groups.

CONCLUSIONS

The overall prevalence of smartphone addiction among undergraduate medical students (evaluated using screening instruments for smartphone addiction) in India is 60%. Although some subgroup differences (regarding region studied, sampling method used and batch of MBBS studied) were found to be statistically significant, it is important to interpret these findings with caution, as these differences may still be influenced by chance occurrences, random error, or underlying study-level biases. Therefore, conclusions should be drawn carefully, considering the potential for spurious associations. However, despite these issues, since the prevalence is quite high, a concerted nationwide effort is needed to educate the students and to develop intervention strategies to overcome smartphone addiction, as there is strong evidence of its detrimental effects on mental health and productivity of the budding medical fraternity.

Implications of the study

Our study findings suggest that prevalence of smartphone addiction is high among medical students. The prevalence seems to vary in terms of scales used for assessment. Hence there is a need to develop standardized tools of assessment with good psychometric properties. Additionally, there is a need to carry out a nationwide survey with representative samples from all states.

Declaration regarding the use of generative AI

The author(s) attest that there was no use of generative artificial intelligence (AI) technology in the generation of text, figures, or other informational content of this manuscript.

Ethical statement

As it was a systematic review and meta-analysis of the data from published literature an ethical review was not needed.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Acknowledgements

The authors would like to acknowledge Global Centre for Evidence Synthesis and the Technical Resource Centre, Centre for Evidence based Guidelines at the Department of Community Medicine, All India Institute of Medical Sciences, Nagpur, India for providing a platform to learn, teach, collaborate, and perform the systematic review and meta-analysis.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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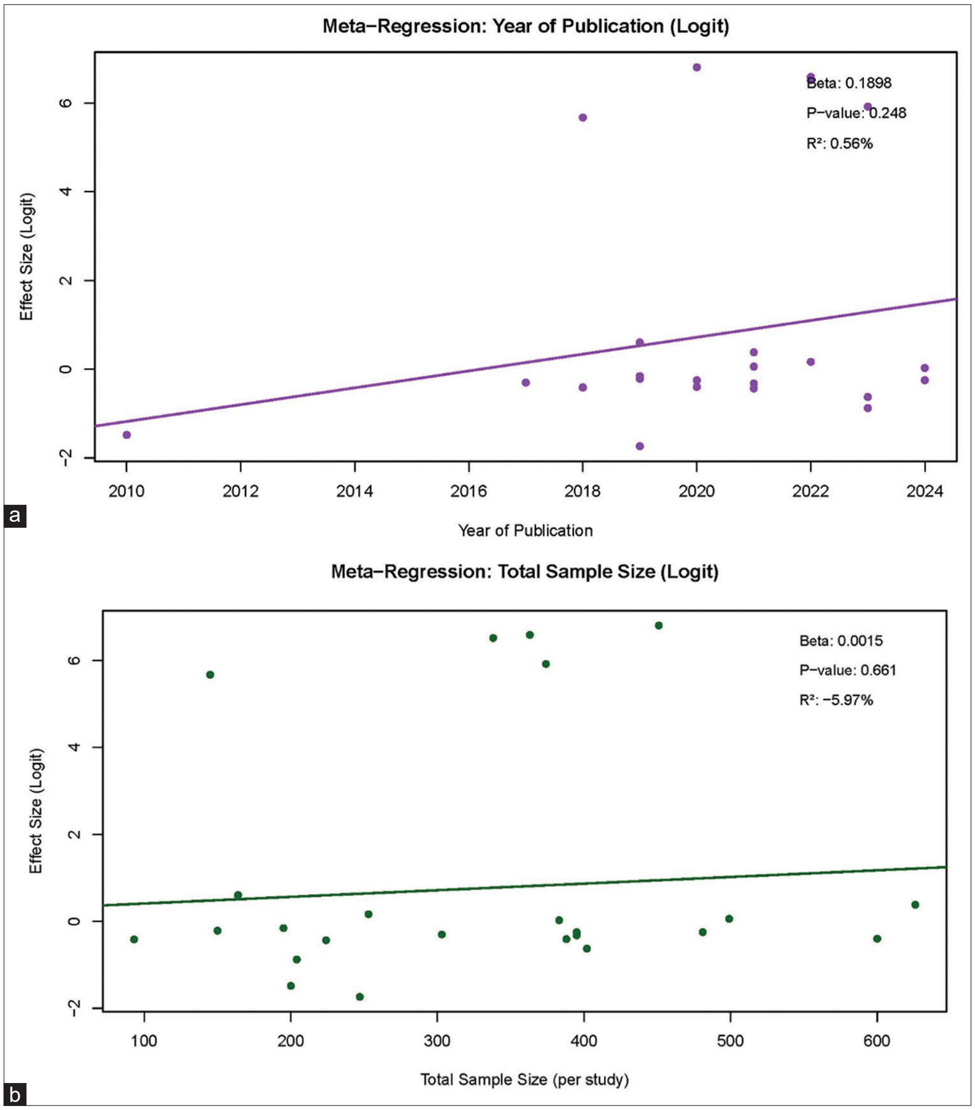

Figure S1: (a) Meta-Regression plot with publication year as moderator, (b) Meta-Regression plot with sample size as moderator

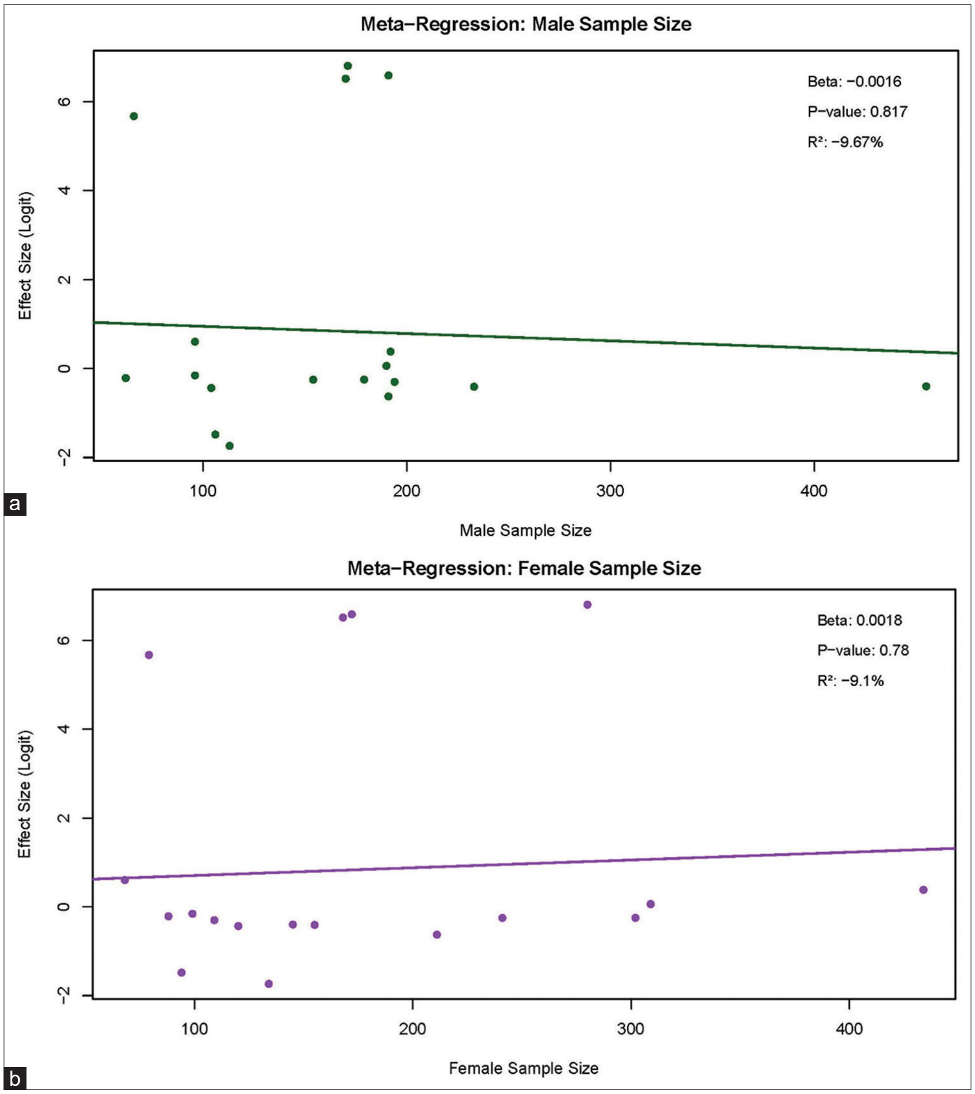

Figure S2: (a) Meta-Regression plot with male as moderator. (b) Meta-Regression plot with female as moderator

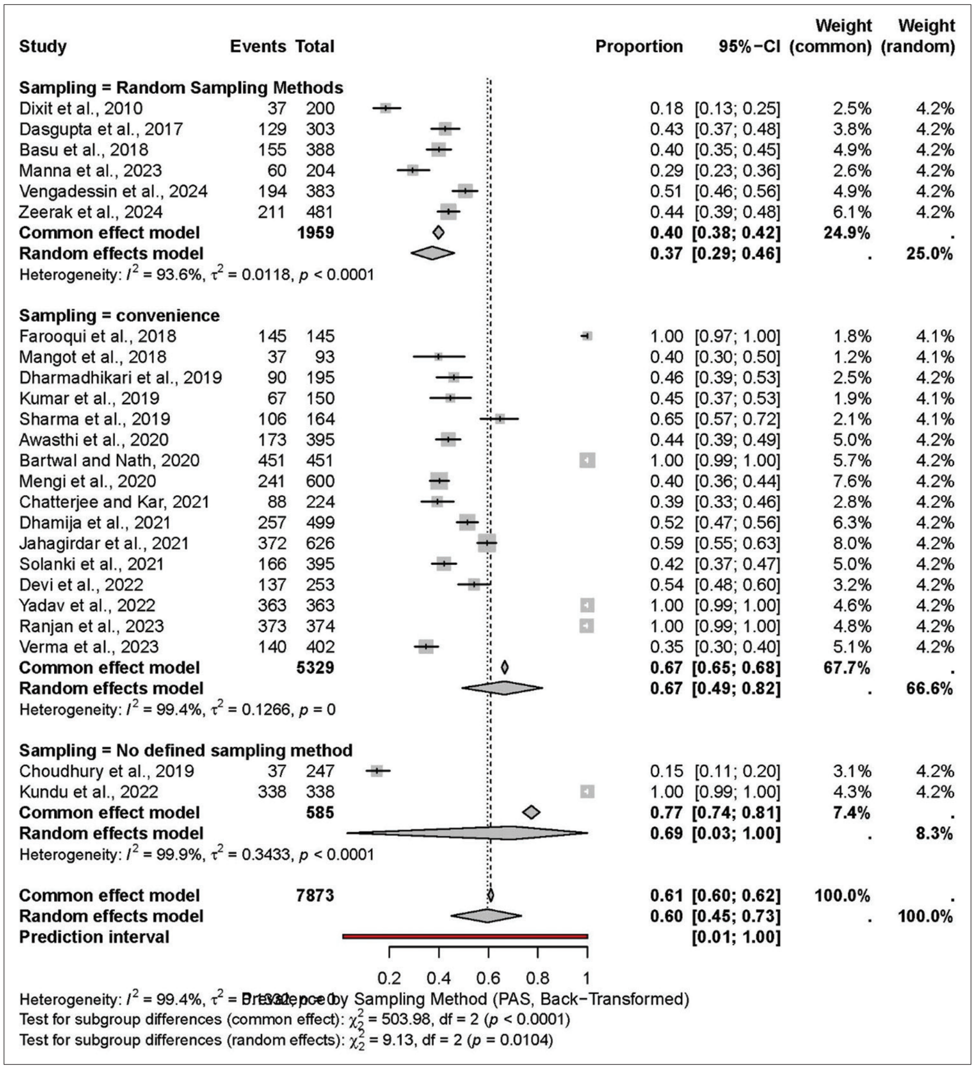

Figure S3: Forest plot of prevalence of smartphone addiction with regard to the Sampling method used

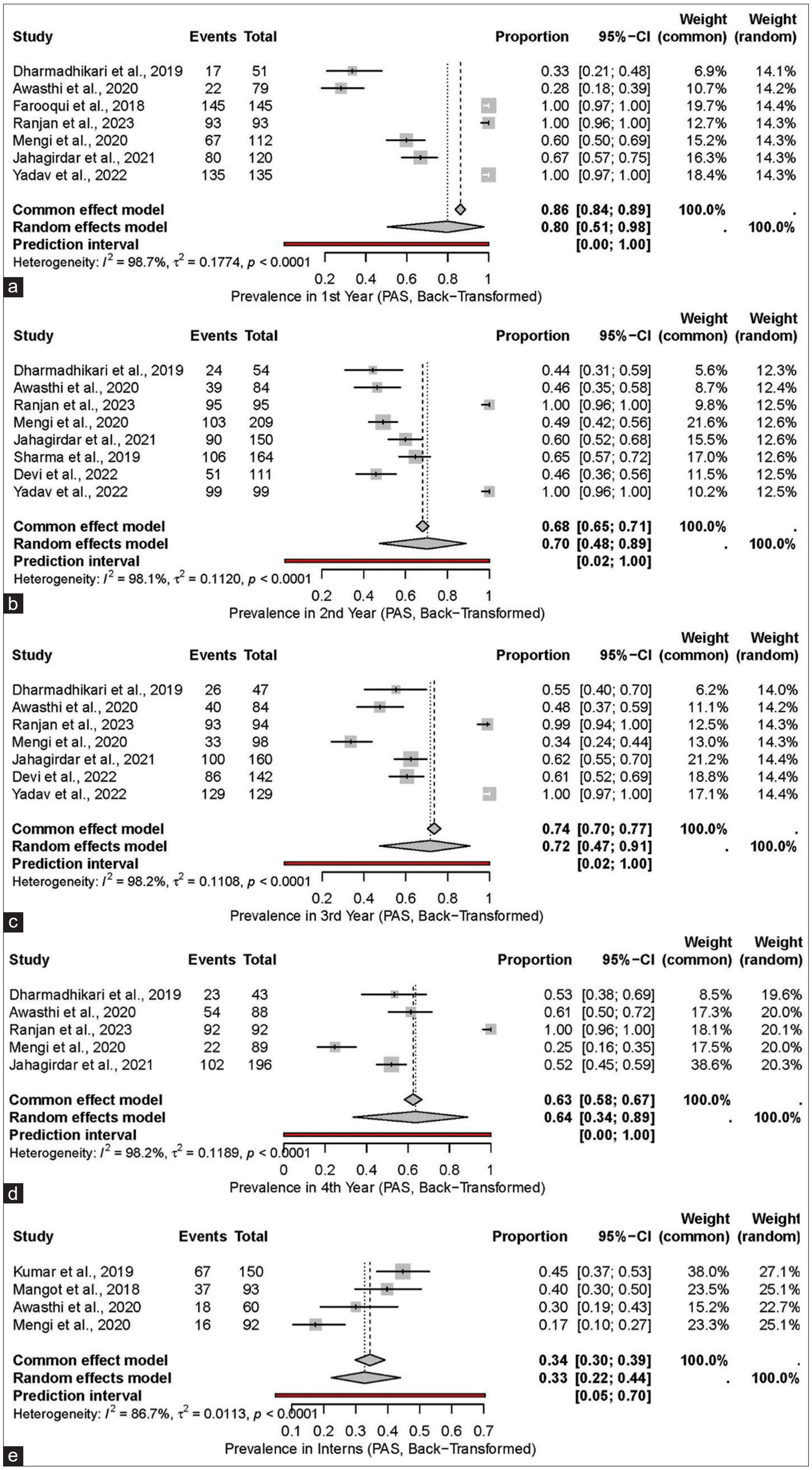

Figure S4: (a) Forest plot of prevalence of smartphone addiction in 1st year MBBS students. (b) Forest plot of prevalence of smartphone addiction in 2nd year MBBS students. (c) Forest plot of prevalence of smartphone addiction in 3rd year MBBS students. (d) Forest plot of prevalence of smartphone addiction in 4th year MBBS students. (e) Forest plot of prevalence of smartphone addiction in interns

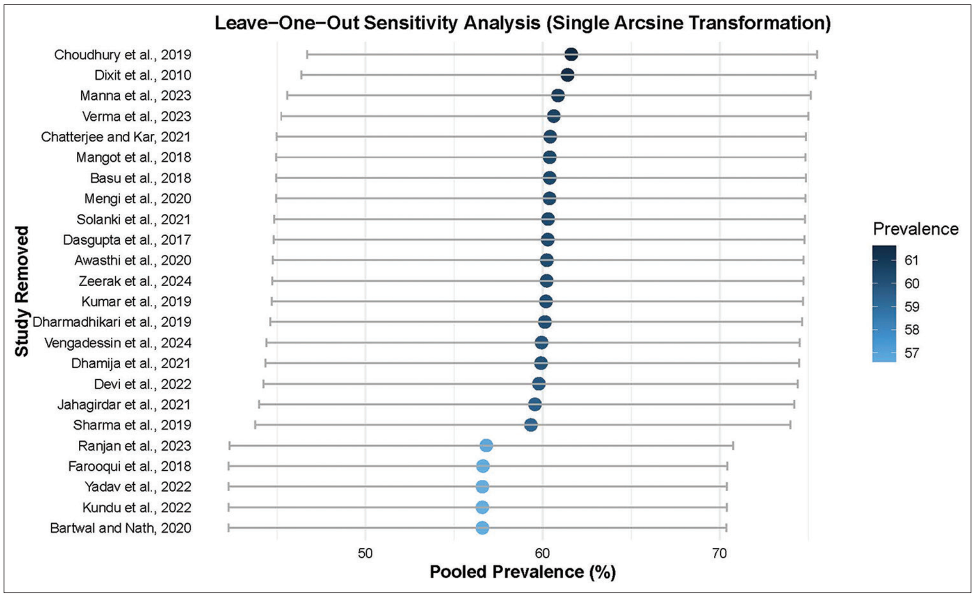

Figure S5: Leave one out sensitivity analysis

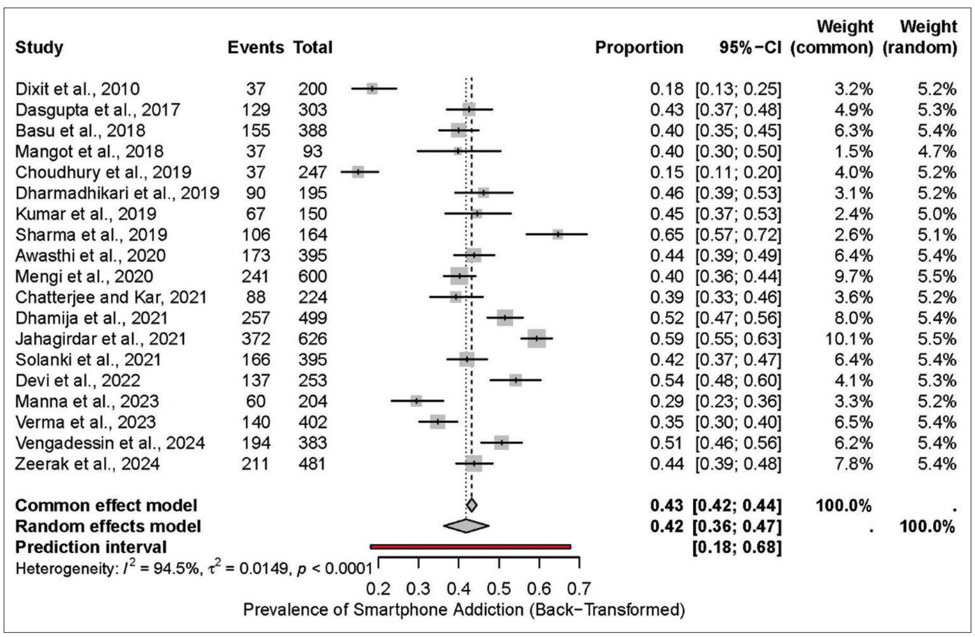

Figure S6: Forest plot after removing studies identified from Leave one out sensitivity analysis

Research Question: What is the prevalence smartphone addiction among medical students in India?

Table S1: PICO criteria

	Inclusion Criteria	Exclusion Criteria
Participants	Medical students pursuing undergraduate (MBBS) education All gender All age groups	Nursing students Dental undergraduates
Disease	Smart phone addiction/ Problematic smartphone use/ Nomophobia -measured using validated scales	Validated scales not used
Outcome	Prevalence of smart phone addiction	Risk factors, impact
Study designs	Prevalence studies, cross sectional studies, cohort studies published in indexed journals Geography- India Date of search- all included English language Human studies	Qualitative, policy, case reports, case series, review, meta-analysis, Opinion reports

Table S2: Search strategy in different databases (Date of Search: 01/10/2024)

No	Search query	Results
	Pubmed	
#1	((((((((((((“Students, Medical”[Mesh]) OR (“Education, Medical, Graduate”[Mesh])) OR (Clinical student*[Title/Abstract])) OR (Med student*[Title/Abstract])) OR (Medical student*[Title/Abstract])) OR (Medical trainee*[Title/Abstract])) OR (Preclinical student*[Title/Abstract])) OR (Student doctor*[Title/Abstract])) OR (Student physician*[Title/Abstract])) OR (Undergraduate medic*[Title/Abstract])) OR (Education, medical[MeSH Terms])) OR (medical undergraduate*[Title/Abstract]))	2,36,161
#2	((((((((((“Technology Addiction”[Mesh]) OR (nomophobia*[Title/Abstract])) OR (mobile phone addiction*[Title/Abstract])) OR (cell phone addiction*[Title/Abstract])) OR (mobile addiction*[Title/Abstract])) OR (smartphone addiction*[Title/Abstract])) OR (no mobile phobia*[Title/Abstract]))) OR (mobile phone*)) OR (smartphone*))	47,634
#3	(((“India”[Mesh]) OR (India*[Title/Abstract]))) OR (India[Affiliation])	8,90,796
#4	#1 AND #2 AND #3	87
	Scopus	
#1	(TITLE-ABS-KEY (medical AND students) OR TITLE-ABS-KEY (medical AND undergraduate AND students) OR TITLE-ABS-KEY (preclinical AND students) OR TITLE-ABS-KEY (medical AND trainee))	230,638
#2	(TITLE-ABS-KEY (technology AND addiction) OR TITLE-ABS-KEY (nomophobia) OR TITLE-ABS-KEY (mobile AND phone AND addiction) OR TITLE-ABS-KEY (cell AND phone AND addiction) OR TITLE-ABS-KEY (no AND mobile AND phobia) OR TITLE-ABS-KEY (smartphone AND addiction))	8225
#3	(TITLE-ABS-KEY (india) OR TITLE-ABS-KEY (indian))	904439
#4	#1 AND #2 AND #3	35
	EBSCO	
#1	TI medical students OR TI medical undergraduates OR TI preclinical students OR TI medical trainees OR AB medical students OR AB medical undergraduates OR AB medical trainees	3899
#2	TI Technology addiction OR AB Technology addiction OR TI Nomophobia OR AB Nomophobia OR TI Mobile phone addiction OR AB mobile phone addiction OR TI smart phone addiction OR TI cell phone addiction OR no mobile phobia	44
#3	TI India OR AB India	9730
#4	#1 AND #2 AND #3	1
	EMBASE	
#1	‘medical student’:ab,ti OR ‘medical undergraduates’:ab,ti OR ‘preclinical students’:ab,ti OR ‘medical trainees’:ab,ti	20,824
#2	‘computer addiction’:ab,ti OR ‘technology addiction’:ab,ti OR ‘nomophobia’:ab,ti OR ‘no cell phobia’:ab,ti OR ‘mobile phone addiction’:ab,ti OR ‘smart phone addiction’:ab,ti	566
#3	‘india’:ab,ti	207,536
#4	#1 AND #2 AND #3	1
	Web of science	
#1	((((((TI=(medical students)) OR AB=(medical students)) OR TI=(medical undergraduates)) OR AB=(medical undergraduates)) OR TI=(preclinical students)) OR TI=(medical trainees)) OR AB=(medical trainee)	72,953
#2	(((((((TI=(Technology addiction)) OR AB=(technology addiction)) OR TI=(nomophobia)) OR AB=(nomophobia)) OR TI=(no cell phobia)) OR TI=(mobile phone addiction)) OR AB=(mobile phone addiction)) OR TI=(smart phone addiction)	1330
#3	(TI=(India)) OR AB=(India)	217,251
#4	#1 AND #2 AND #3	1

Table S3: PRISMA Checklist			
Section and Topic	**Item #**	**Checklist item**	**Location where item is reported**
		Title	
title	1	Identify the report as a systematic review.	Page 1
		Abstract	
abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 2
		Introduction	
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 3-4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 4
		Methods	
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 5 and table S1
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 4
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Table S2
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 5
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 5, Figure 1
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 5
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 5
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 6
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page 6
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 6-7
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page 5-6
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Table 1
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 6
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page 6
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Page 6
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 7, Table S4
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	NA
		Results	
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 6-7, Figure 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page 7
Study characteristics	17	Cite each included study and present its characteristics.	Page 7
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page 7, Table S4
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Page 7-9 Figure 2a,2b, 3a,3b, S2,S3, S4atoe
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 7 to 9

Contd...

Table S3: Contd...

Section and Topic	Item #	Checklist item	Location where item is reported
Results			
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Page 7 to 9
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Page 7 to 9
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Page 7 to 9
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	NA
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	NA
Discussion			
discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 9-12
	23b	Discuss any limitations of the evidence included in the review.	Page 9-12
	23c	Discuss any limitations of the review processes used.	Page 11-12
	23d	Discuss implications of the results for practice, policy, and future research.	Page 12
Other information			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 4
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 4
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	NA
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 13
Competing interests	26	Declare any competing interests of review authors.	Page 13
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Page 13

Table S4: Quality assessment of prevalence studies using JBI critical appraisal checklist

Author	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Rating
Dixit *et al*., 2010	y	y	y	y	y	y	y	y	y	Good
Dasgupta *et al*., 2017	y	y	y	y	y	y	y	y	y	Good
Basu *et al*., 2018	y	y	y	y	y	y	y	y	y	Good
Farooqui *et al*., 2018	y	n	y	y	y	y	y	y	y	Good
Mangot *et al*., 2018	y	y	y	y	y	y	y	y	y	Good
Choudhury *et al*., 2019	y	n	y	y	y	y	y	y	y	Good
Dharmadhikari *et al*., 2019	y	n	y	y	y	y	y	y	y	Good
Kumar *et al*., 2019	y	n	y	y	y	y	y	y	y	Good
Sharma *et al*., 2019	y	y	y	y	y	unclear	y	y	y	Good
Awasthi *et al*., 2020	y	n	y	y	y	y	y	y	y	Good
Bartwal and Nath, 2020	y	n	y	y	y	y	y	y	y	Good
Mengi *et al*., 2020	y	n	y	y	y	y	y	y	y	Good
Chatterjee and Kar, 2021	y	n	y	y	y	y	y	y	y	Good
Dhamija *et al*., 2021	y	y	y	y	y	y	y	y	y	Good
Jahagirdar *et al*., 2021	y	y	y	y	y	y	y	y	y	Good
Solanki *et al*., 2021	y	y	y	y	y	y	y	y	y	Good
Devi *et al*., 2022	y	y	y	y	y	y	y	y	y	Good
Kundu *et al*., 2022	y	y	y	y	y	y	y	y	y	Good
Yadav *et al*., 2022	y	y	y	y	y	y	y	y	y	Good
Manna *et al*., 2023	y	y	y	y	y	y	y	y	y	Good
Ranjan *et al*., 2023	y	n	y	y	y	y	y	y	y	Good
Verma *et al*., 2023	y	n	y	y	y	y	y	y	y	Good
Vengadessin *et al*., 2024	y	y	y	y	y	y	y	y	y	Good
Zeerak *et al*., 2024	y	y	y	y	y	y	y	y	y	Good

y-Yes, n-no. Q1- Was the sample frame appropriate to address the target population? Q2- Were study participants sampled in an appropriate way? Q3- Was the sample size adequate? Q4- Were the study subjects and the setting described in detail? Q5- Was the data analysis conducted with sufficient coverage of the identified sample? Q6- Were valid methods used for the identification of the condition? Q7- Was the condition measured in a standard, reliable way for all participants? Q8- Was there appropriate statistical analysis? Q9- Was the response rate adequate, and if not, was the low response rate managed appropriately?

Table S5: Leave one out results						
Study_Left_Out	**TE_logit**	**Lower_logit**	**Upper_logit**	**Prevalence**	**Lower**	**Upper**
Dixit *et al*., 2010	0.900556745	0.749113931	1.05199956	61.41	46.37	75.41
Dasgupta *et al*., 2017	0.889022271	0.733407742	1.044636799	60.29	44.81	74.78
Basu *et al*., 2018	0.890194739	0.734825057	1.04556442	60.4	44.95	74.86
Farooqui *et al*., 2018	0.851843892	0.707888223	0.995799561	56.63	42.28	70.42
Mangot *et al*., 2018	0.890141083	0.734853579	1.045428588	60.4	44.95	74.85
Choudhury *et al*., 2019	0.90264474	0.75234918	1.052940299	61.62	46.7	75.5
Dharmadhikari *et al*., 2019	0.887434429	0.731557564	1.043311294	60.13	44.63	74.66
Kumar *et al*., 2019	0.888064627	0.732309959	1.043819295	60.19	44.7	74.71
Sharma *et al*., 2019	0.879325505	0.723069283	1.035581727	59.34	43.78	73.99
Awasthi *et al*., 2020	0.888494248	0.73276885	1.044219646	60.24	44.75	74.74
Bartwal and Nath, 2020	0.851550298	0.707791901	0.995308694	56.6	42.27	70.38
Mengi *et al*., 2020	0.890111691	0.734712137	1.045511244	60.39	44.94	74.85
Chatterjee and Kar, 2021	0.890459831	0.735174686	1.045744977	60.43	44.99	74.87
Dhamija *et al*., 2021	0.885131564	0.728927966	1.041335162	59.91	44.36	74.49
Jahagirdar *et al*., 2021	0.881651119	0.72527428	1.038027958	59.57	44	74.2
Solanki *et al*., 2021	0.889274784	0.733702658	1.044846911	60.31	44.84	74.8
Devi *et al*., 2022	0.883966434	0.727692959	1.040239909	59.79	44.24	74.4
Kundu *et al*., 2022	0.851597319	0.707807112	0.995387526	56.6	42.27	70.39
Yadav *et al*., 2022	0.851584414	0.707802929	0.995365898	56.6	42.27	70.39
Manna *et al*., 2023	0.894977203	0.74105892	1.048895487	60.87	45.57	75.15
Ranjan *et al*., 2023	0.853831282	0.708166025	0.999496539	56.82	42.31	70.76
Verma *et al*., 2023	0.892505991	0.737744596	1.047267385	60.63	45.24	75.01
Vengadessin *et al*., 2024	0.885498369	0.72933855	1.041658187	59.94	44.41	74.52
Zeerak *et al*., 2024	0.888469329	0.732734007	1.044204651	60.23	44.74	74.74