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**Staphylococcus aureus** (S. aureus) is an important pathogen responsible for a wide range of human infections, including minor skin infections, pimples, impetigo, boils, cellulitis, folliculitis, carbuncles, scalded skin syndrome, and abscesses, including life-threatening diseases.\(^1,2\) **S. aureus** is an important pathogen of many nosocomial and community-related infections leading to high morbidity and mortality.\(^3\) **S. aureus** possesses various antibiotic resistance mechanisms, including resistance to methicillin known as methicillin-resistant **S. aureus** (MRSA), which consequently becomes difficult in managing infections. Over the last 50 years, antibiotics have reduced the rate of mortality; nevertheless, bacteria have been known to develop maximum resistance to most of the available antimicrobial agents.\(^4\)

The methicillin resistance expressed by **S. aureus** is contributed by the *mecA* gene that is harbored by the mobile segments of the MRSA strains, which encodes the penicillin-binding protein 2a that has a low affinity for β-lactam and allows MRSA strains to survive in different concentrations of these antimicrobial agents.\(^5\) It is known that MRSA is endemic in India with variation in the antimicrobial susceptibility patterns based on geographical region.\(^6\) Early detection of MRSA and its susceptibility pattern becomes vital for the treatment of the condition as very few antimicrobial agents can be used to manage the ailment. Hence, it is imperative to review the prevalence of MRSA in India.
to study the overall prevalence of MRSA in India to develop improved and efficient treatment methods for its management.

Our study concentrates on systematic review and meta-analysis to estimate the pooled prevalence of MRSA in India and state-wise, zone-wise, and year-wise analysis was conducted using statistical tools, viz., meta-analysis.

**METHODS**

**Literature search**

We performed a systematic search for articles using the following keywords in various combinations: ‘Staphylococcus aureus’, ‘S. aureus’, ‘MRSA’, ‘prevalence’, ‘India’, and ‘Humans’. We used various search engines such as J-Gate Plus, PubMed, Google Scholar, and Indian journals. The search was limited to articles published from 2015 to 2020. In addition, manual searches on citations retrieved from original studies and review articles were also performed. Finally, the articles were chosen by screening through the titles and abstracts for relevance based on the inclusion and exclusion criteria.

**Study selection criteria**

The results after searching were tabulated into Excel, duplicates were removed, and relevant studies were examined. Our preliminary inclusion criteria were to include all articles having the title keyword “prevalence of MRSA in India” from 2015 to 2020 only. Selected papers were subjected to abstract screening for titles. Studies were read in full for which they had reported on: (a) the prevalence of MRSA, (b) sample size data, (c) events (positive), (d) year of study, (e) geographical location of the study, and (f) diagnostic tests used as confirmatory tool for identification of MRSA. Those articles that did not satisfy the above screening criteria were excluded from the study. Articles containing a large number of samples/events were also not included in the study. Studies that did not report the MRSA prevalence included reviews, reports, editorial articles and outbreak reports, and studies that were duplicates of included studies were excluded. The articles that were selected included humans of all age groups. The searches, scrutiny, and methodology were in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocol (http://www.prisma-statement.org).

**Data extraction**

The data was extracted from qualified studies that included first author, year of publication, study setting/sampling location, number of investigated cases, number of MRSA isolates, sources of isolates, diagnostic methods employed for confirmation, antiogram results, and considered for meta-analysis. We were also interested in the year of publication and the location of the study setting to stratify the studies based on the year of publication, zone-wise, and state-wise. Studies were independently extracted by two investigators and discussed to arrive at a consensus.

**Risk of bias and quality assessment**

The quality assessment of different studies was done on a fixed rating scale. The scoring was on a scale of 0 to 5, which included evaluation of author and year of study, representativeness of the sample used in the study, ascertainment of the exposure, comparability, and outcome.

**Meta-analysis**

Meta-analysis was performed using the R Open Source Scripting Software (version 3.4.3, R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/). Metafor, Metaprop, and Meta of this software were statistical packages used. Tau square, $\tau^2$ (Higgins’ $\tau^2$), and

![Figure 1: Systematic review and meta-analysis.](image-url)
| Study                          | Events | Total | Proportion | 95% CI       | Weight, (fixed) | Weight, (random) |
|-------------------------------|--------|-------|------------|--------------|----------------|-----------------|
| Abbas et al., 2015            | 201    | 500   | 0.4        | 0.36–0.45    | 240.0          | 1.1             |
| Agarwal et al., 2015          | 28     | 96    | 0.29       | 0.20–0.39    | 0.5            | 1               |
| Agarwala et al., 2016         | 7      | 1550  | 0          | 0.00–0.01    | 7.6            | 1.1             |
| Akhtar et al., 2016           | 85     | 250   | 0.35       | 0.29–0.41    | 1.2            | 1.1             |
| Ambika et al., 2017           | 15     | 39    | 0.38       | 0.23–0.55    | 0.2            | 1               |
| Arunkumar et al., 2017        | 5      | 100   | 0.05       | 0.02–0.11    | 0.5            | 1               |
| De Backer et al., 2019        | 5      | 9     | 0.56       | 0.21–0.86    | 0              | 0.7             |
| Banerjee et al., 2018         | 12     | 26    | 0.46       | 0.27–0.67    | 0.1            | 0.9             |
| Baruah et al., 2019           | 13     | 190   | 0.07       | 0.04–0.11    | 0.9            | 1               |
| Bhat et al., 2016             | 54     | 89    | 0.61       | 0.50–0.71    | 0.4            | 1               |
| Bhatt et al., 2015            | 103    | 510   | 0.20       | 0.17–0.24    | 2.5            | 1.1             |
| Bhattacharya et al., 2015     | 47     | 100   | 0.47       | 0.37–0.57    | 0.5            | 1               |
| Bhattacharya et al., 2017     | 20     | 122   | 0.16       | 0.10–0.24    | 0.6            | 1               |
| Bhavana et al., 2017          | 89     | 200   | 0.44       | 0.37–0.52    | 1              | 1.1             |
| Bhavana et al., 2019          | 70     | 187   | 0.37       | 0.30–0.45    | 0.9            | 1               |
| Bhavsar et al., 2015          | 65     | 150   | 0.43       | 0.35–0.52    | 0.7            | 1               |
| Bhowmik et al., 2019          | 71     | 127   | 0.56       | 0.47–0.65    | 0.6            | 1               |
| Bhutta et al., 2015           | 53     | 150   | 0.35       | 0.28–0.44    | 0.7            | 1               |
| Bouchiat et al., 2015         | 48     | 92    | 0.52       | 0.42–0.63    | 0.4            | 1               |
| Chaudhary et al., 2015        | 77     | 178   | 0.43       | 0.36–0.51    | 0.9            | 1               |
| Choudhury et al., 2016        | 311    | 724   | 0.43       | 0.39–0.47    | 3.5            | 1.1             |
| Cugati et al., 2017           | 92     | 161   | 0.57       | 0.49–0.65    | 0.8            | 1               |
| Dass et al., 2016             | 64     | 100   | 0.64       | 0.54–0.73    | 0.5            | 1               |
| Datta et al., 2019            | 5      | 26    | 0.19       | 0.07–0.39    | 0.1            | 0.9             |
| Deepika et al., 2015          | 25     | 29    | 0.86       | 0.68–0.96    | 0.1            | 0.9             |
| Dhiman et al., 2017           | 24     | 150   | 0.16       | 0.11–0.23    | 0.7            | 1               |
| Dixit, 2018                   | 21     | 42    | 0.5        | 0.34–0.66    | 0.2            | 1               |
| Farooq et al., 2016           | 210    | 343   | 0.61       | 0.56–0.66    | 1.7            | 1.1             |
| Geetha et al., 2014           | 44     | 166   | 0.27       | 0.20–0.34    | 0.8            | 1               |
| Ghosh et al., 2016            | 11     | 46    | 0.24       | 0.13–0.39    | 0.2            | 1               |
| Govindan et al., 2015         | 17     | 441   | 0.04       | 0.02–0.06    | 2.2            | 1.1             |
| Gupta and Sinha, 2017         | 344    | 450   | 0.76       | 0.72–0.80    | 2.2            | 1.1             |
| Gupta et al., 2015a           | 19     | 60    | 0.32       | 0.20–0.45    | 0.3            | 1               |
| Gupta et al., 2015b           | 12     | 30    | 0.4        | 0.23–0.59    | 0.1            | 0.9             |
| Gupta et al., 2016            | 69     | 174   | 0.4        | 0.32–0.47    | 0.8            | 1               |
| Gupta et al., 2017            | 408    | 505   | 0.81       | 0.77–0.84    | 2.5            | 1.1             |
| Hemamalini et al., 2015       | 14     | 40    | 0.35       | 0.21–0.52    | 0.2            | 1               |
| Hussain et al., 2015          | 53     | 80    | 0.66       | 0.55–0.76    | 0.4            | 1               |
| Jana et al., 2015             | 23     | 122   | 0.19       | 0.12–0.27    | 0.6            | 1               |
| Jindal et al., 2016           | 161    | 248   | 0.65       | 0.59–0.71    | 1.2            | 1.1             |
| John et al., 2019             | 18     | 100   | 0.18       | 0.11–0.27    | 0.5            | 1               |
| Joshi et al., 2017            | 34     | 231   | 0.15       | 0.10–0.20    | 1.1            | 1.1             |
| Kaur et al., 2019             | 83     | 162   | 0.51       | 0.43–0.59    | 0.8            | 1               |
| Kavitha et al., 2017          | 22     | 207   | 0.11       | 0.07–0.16    | 1              | 1.1             |
| Kogekar et al., 2015          | 16     | 30    | 0.53       | 0.34–0.72    | 0.1            | 0.9             |
| Kulhreshta et al., 2017       | 82     | 161   | 0.51       | 0.43–0.59    | 0.8            | 1               |
| Kulhreshta et al., 2019       | 73     | 214   | 0.34       | 0.28–0.41    | 1              | 1.1             |
| Kumar et al., 2016            | 79     | 147   | 0.54       | 0.45–0.62    | 0.7            | 1               |
| Kumari et al., 2016           | 88     | 291   | 0.3        | 0.25–0.36    | 1.4            | 1.1             |
| Study                  | Events | Total | Proportion | 95% CI     | Weight, (fixed) % | Weight, (random) % |
|-----------------------|--------|-------|------------|------------|------------------|--------------------|
| Majhi et al,9 2016    | 129    | 209   | 0.62       | 0.55–0.68  | 1                | 1.1                |
| Mamporta et al,26 2019 | 310    | 1041  | 0.3        | 0.27–0.33  | 5.1              | 1.1                |
| Mehta,7 2017         | 145    | 250   | 0.58       | 0.52–0.64  | 1.2              | 1.1                |
| Mendem et al,9 2016  | 24     | 62    | 0.39       | 0.27–0.52  | 0.3              | 1                  |
| Mohanty et al,9 2019 | 127    | 284   | 0.45       | 0.39–0.51  | 1.4              | 1.1                |
| Mokta et al,40 2015  | 82     | 350   | 0.23       | 0.19–0.28  | 1.7              | 1.1                |
| Mondal et al,44 2016 | 16     | 87    | 0.18       | 0.11–0.28  | 0.4              | 1                  |
| Mundhada et al,42 2017 | 14    | 112   | 0.12       | 0.07–0.20  | 0.5              | 1                  |
| Mushraq et al,46 2016 | 58     | 140   | 0.41       | 0.33–0.50  | 0.7              | 1                  |
| Nadimpalli et al,46 2016 | 63    | 2040  | 0.03       | 0.02–0.04  | 10               | 1.1                |
| Nagamadhavi et al,48 2016 | 2    | 91    | 0.02       | 0.00–0.08  | 0.4              | 1                  |
| Nagaraju et al,48 2017 | 41    | 274   | 0.15       | 0.11–0.20  | 1.3              | 1.1                |
| Nagasundaram et al,49 2019 | 114  | 200   | 0.57       | 0.50–0.64  | 1                | 1.1                |
| Negi et al,48 2015    | 11     | 70    | 0.16       | 0.08–0.26  | 0.3              | 1                  |
| Pai et al,50 2015     | 7      | 33    | 0.21       | 0.09–0.39  | 0.2              | 0.9                |
| Pai et al,50 2017     | 9      | 100   | 0.09       | 0.04–0.16  | 0.5              | 1                  |
| Pal et al,51 2019     | 34     | 121   | 0.28       | 0.20–0.37  | 0.6              | 1                  |
| Pandya et al,52 2015  | 104    | 180   | 0.58       | 0.50–0.65  | 0.9              | 1                  |
| Patil et al,53 2017   | 23     | 57    | 0.4        | 0.28–0.54  | 0.3              | 1                  |
| Patil et al,53 2019   | 11     | 47    | 0.23       | 0.12–0.38  | 0.2              | 1                  |
| Peral et al,54 2016   | 132    | 386   | 0.34       | 0.29–0.39  | 1.9              | 1.1                |
| Perween et al,55 2015 | 80     | 141   | 0.57       | 0.48–0.65  | 0.7              | 1                  |
| Phukan et al,57 2015  | 160    | 215   | 0.74       | 0.68–0.80  | 1                | 1.1                |
| Radhakrishna et al,58 2016 | 9   | 78    | 0.12       | 0.05–0.21  | 0.4              | 1                  |
| Raigar et al,59 2019  | 208    | 400   | 0.52       | 0.47–0.57  | 2                | 1.1                |
| Rana-Khara et al,60 2016 | 52     | 100   | 0.52       | 0.42–0.62  | 0.5              | 1                  |
| Recma et al,61 2016   | 23     | 50    | 0.46       | 0.32–0.61  | 0.2              | 1                  |
| Rengaraj et al,62 2016 | 54     | 109   | 0.5        | 0.40–0.59  | 0.5              | 1                  |
| Routray et al,63 2019 | 13     | 17    | 0.76       | 0.50–0.93  | 0.1              | 0.9                |
| Roy,64 2018           | 9      | 38    | 0.24       | 0.11–0.40  | 0.2              | 1                  |
| Rudresh et al,65 2015 | 22     | 98    | 0.22       | 0.15–0.32  | 0.5              | 1                  |
| Sankaran et al,66 2018 | 13    | 30    | 0.43       | 0.25–0.63  | 0.1              | 0.9                |
| Selvabai et al,67 2019 | 114   | 468   | 0.24       | 0.21–0.29  | 2.3              | 1.1                |
| Sengupta et al,68 2016 | 19    | 19    | 1          | 0.82–1.00  | 0.1              | 0.9                |
| Senthilkumar et al,69 2015 | 46   | 98    | 0.47       | 0.37–0.57  | 0.5              | 1                  |
| Shinde et al,70 2016  | 9      | 26    | 0.35       | 0.17–0.56  | 0.1              | 0.9                |
| Singh et al,71 2015   | 15     | 200   | 0.08       | 0.04–0.12  | 1                | 1.1                |
| Singh et al,72 2018   | 87     | 248   | 0.35       | 0.29–0.41  | 1.2              | 1.1                |
| Singh et al,73 2018   | 9      | 49    | 0.18       | 0.09–0.32  | 0.2              | 1                  |
| Swathirajan et al,74 2020 | 262   | 380   | 0.69       | 0.64–0.74  | 1.9              | 1.1                |
| Talwar et al,75 2016  | 38     | 111   | 0.34       | 0.25–0.44  | 0.5              | 1                  |
| There et al,76 2016   | 50     | 114   | 0.44       | 0.35–0.55  | 0.6              | 1                  |
| Thomas et al,77 2018  | 14     | 43    | 0.33       | 0.19–0.49  | 0.2              | 1                  |
| Tiewsoh et al,78 2017 | 24     | 432   | 0.06       | 0.04–0.08  | 2.1              | 1.1                |
| Tripathi,79 2015      | 70     | 210   | 0.33       | 0.27–0.40  | 1                | 1.1                |
| Trivedi et al,80 2015 | 47     | 232   | 0.2        | 0.15–0.26  | 1.1              | 1.1                |
| Vasuki et al,81 2016  | 45     | 83    | 0.54       | 0.43–0.65  | 0.4              | 1                  |
| Veluswamy et al,82 2017 | 120   | 182   | 0.66       | 0.59–0.73  | 0.9              | 1                  |
| Venkatesan et al,83 2017 | 23    | 43    | 0.53       | 0.38–0.69  | 0.2              | 1                  |

Fixed effect model: 20493, 0.29, 0.28–0.29, 100%  
Random effect model: 0.37, 0.32–0.41, 100%

Heterogeneity: F = 99%, τ² = 0.0571, p < 0.001.
p-values were computed to determine the percentage of variation due to heterogeneity among various reports included in this study. The random-effect and fixed-effect models were used to calculate the pooled prevalence of individual diseases. This analysis facilitates generating a weighted average proportion of prevalence of various studies, providing a way forward for proper planning. Graphical representation of the data was depicted as forest plots. The restricted maximum-likelihood estimator was used to determine between-study variance ($\tau^2$). The prevalence estimates for MRSA were expressed as a percentage with 95% CI.

Subgroup analysis was performed to investigate the significance of heterogeneity among the studies. The studies were stratified based on zones of the country, year of publication, and state-wise. Subgroup meta-regression analysis was performed to identify the stratified prevalence of MRSA in different regions, study periods, sample size, and diagnostic tests.
RESULTS

Study details
Articles reporting the prevalence of MRSA were thoroughly screened, and irrelevant ones were excluded. A total of 1831 of 2717 articles identified were excluded following the exclusion criteria described above; 886 potential articles were selected using a combination of keywords. A total of 98 articles were selected suitable for systematic review and meta-analysis [Figure 1]. All the articles described the prevalence of MRSA in India and were published between 2015 and 2020. The

Table 3: Year-wise prevalence of methicillin-resistant *Staphylococcus aureus* in India during 2015–2020.

| Year | Pooled prevalence, % (95% CI) | I² | τ² | p-value |
|------|------------------------------|----|---|--------|
| 2015 | 38 (30–45)                   | 97 | 0.0414 | < 0.01 |
| 2016 | 39 (29–50)                   | 99 | 0.0797 | < 0.01 |
| 2017 | 31 (20–44)                   | 99 | 0.0835 | < 0.01 |
| 2018 | 35 (26–43)                   | 62 | 0.0091 | 0.02 |
| 2019 | 37 (28–46)                   | 95 | 0.0343 | < 0.01 |
| 2020* | 69 (64–74)                   | -  | -  | -  |

*Single article

Table 4: Zone-wise prevalence of methicillin-resistant *Staphylococcus aureus* in India during 2015–2020.

| Sl No | Region | Pooled Prevalence, % (95% CI) | I² | τ² | Heterogeneity test | Egger test (predictor = ninv*) | Chi-square test |
|-------|--------|------------------------------|----|---|-------------------|-------------------------------|-----------------|
| 1     | North  | 41 (33–50)                   | 98 | 0.0446 | 991.31 | < 0.01 | -1.55 | 0.14 | 1000.57 |
|       | (Uttar Pradesh, Haryana, Jammu and Kashmir, Himachal Pradesh, Punjab, New Delhi, and Uttarakhand) |
| 2     | South  | 34 (26–42)                   | 98 | 0.0614 | 1351.91 | < 0.01 | 1.19 | 0.24 | 1369.91 |
|       | (Tamil Nadu, Telangana, Karnataka Andhra Pradesh, Kerala, and Puducherry) |
| 3     | West   | 33 (24–43)                   | 99 | 0.0514 | 2551.24 | < 0.001 | 2.3 | 0.030 | 2559.54 |
|       | (Rajasthan, Maharashtra, and Gujarat) |
| 4     | East   | 43 (20–68)                   | 96 | 0.01401 | 193.14 | < 0.01 | 0.57 | 0.58 | 209.95 |
|       | (West Bengal and Odisha) |
| 5     | North East | 40 (23–58)                  | 98 | 0.0601 | 260.52 | < 0.01 | -0.27 | 0.8 | 264.06 |
|       | (Assam, Tripura, and Sikkim) |
| 6     | Central | 36 (25–47)                   | 78 | 0.0112 | 13.3 | < 0.01 | 0.58 | 0.62 | 13.54 |
|       | (Madhya Pradesh) |
| 7     | Overall | 37 (32–41)                   | 99 | 0.0571 | 6901.21 | < 0.01 | 2.44 | 0.02 | 1031.2 |

**Figure 3:** Zone analysis.
prevalence data for this study were extracted and tabulated as per the requirement of the statistical software. Twenty-two states of India had reports of the prevalence of MRSA. Six zones of the country, namely; North (Uttar Pradesh, Haryana, Jammu and Kashmir, Himachal Pradesh, Punjab, New Delhi, and Uttarakhand), East (West Bengal and Odisha), West (Rajasthan, Maharashtra, and Gujarat), South (Tamil Nadu, Telangana, Karnataka, Andhra Pradesh, Kerala, and Puducherry), Central (Madhya Pradesh), and Northeast (Assam, Tripura, and Sikkim) zones had a varied pooled prevalence of MRSA.

**Risk of bias and quality assessment**

Risk of bias and quality assessment were awarded a maximum of two stars, and the score given was on a scale of 0 to 5. Hence, the overall quality assessment has a maximum score of 5 and a minimum score of 3.

**Meta-analysis of the prevalence of MRSA**

The percentage prevalence of MRSA in India was estimated statistically using R Open source Scripting software. The overall prevalence of MRSA using 17,525 samples in 98 studies was 37% (95% CI: 32–41) in India during 2015–2020 ($I^2$ = -99%, $\tau^2$ = 0.0571, $p$ < 0.001) [Table 1]. The pooled data were stratified into state-wise and zone-wise.

**Year-wise prevalence of MRSA**

Heterogeneity assessment was performed year-wise [Figure 2]. It was found that the studies published in 2015, 2016, 2017, 2018, and 2019 have independent significant heterogeneity; hence subgroup analysis is
Table 7: Pooled prevalence of methicillin-resistant *Staphylococcus aureus* in community settings.

| Study                  | Events | Total | Proportion | 95% CI     | Weight, % |
|------------------------|--------|-------|------------|------------|-----------|
| **Community**          |        |       |            |            |           |
| Abbas et al., 2015     | 201    | 500   | 0.4        | 0.36–0.45  | 1.1       |
| Agarwal et al., 2015   | 28     | 96    | 0.29       | 0.20–0.39  | 1         |
| Ambika et al., 2017    | 15     | 39    | 0.38       | 0.23–0.55  | 1         |
| Banerjee et al., 2019  | 12     | 26    | 0.46       | 0.27–0.67  | 0.9       |
| Bhavana et al., 2017   | 89     | 200   | 0.44       | 0.37–0.52  | 1.1       |
| Bhutia et al., 2015    | 53     | 150   | 0.35       | 0.28–0.44  | 1         |
| Bouchiar et al., 2015  | 48     | 92    | 0.52       | 0.42–0.63  | 1         |
| Deepika et al., 2015   | 25     | 29    | 0.86       | 0.34–0.66  | 0.9       |
| Dixit, 2018            | 21     | 42    | 0.5        | 0.68–0.96  | 1         |
| Govindan et al., 2015  | 17     | 441   | 0.04       | 0.02–0.06  | 1.1       |
| Jana et al., 2015      | 23     | 122   | 0.19       | 0.12–0.27  | 1         |
| John et al., 2019      | 18     | 100   | 0.18       | 0.11–0.27  | 1         |
| Kogekar et al., 2015   | 16     | 50    | 0.33       | 0.24–0.43  | 0.9       |
| Kulshreshtha et al., 2017 | 73    | 214   | 0.34       | 0.43–0.59  | 1.1       |
| Mondal et al., 2016    | 16     | 87    | 0.18       | 0.11–0.28  | 1         |
| Mundhada et al., 2017  | 14     | 112   | 0.12       | 0.07–0.20  | 1         |
| Nagaraju et al., 2015  | 41     | 274   | 0.15       | 0.11–0.20  | 1         |
| Patil et al., 2019     | 11     | 47    | 0.23       | 0.12–0.38  | 1         |
| Radhakrishna et al., 2016 | 9    | 78    | 0.12       | 0.05–0.21  | 1         |
| Roy, 2018              | 9      | 38    | 0.24       | 0.11–0.40  | 1         |
| Shinde et al., 2016    | 9      | 26    | 0.35       | 0.17–0.56  | 0.9       |
| Singh et al., 2017     | 15     | 200   | 0.08       | 0.04–0.12  | 1.1       |
| Tiewsoh and Dias, 2017 | 24     | 432   | 0.06       | 0.04–0.08  | 1.1       |
| **Hospital**           |        |       |            |            |           |
| Agarwala et al., 2016  | 7      | 1550  | 0          | 0.00–0.01  | 1.1       |
| Akhtar et al., 2016    | 87     | 250   | 0.35       | 0.29–0.41  | 1.1       |
| Arunkumar et al., 2017 | 5      | 100   | 0.05       | 0.02–0.11  | 1         |
| De Backer et al., 2019 | 5      | 9     | 0.56       | 0.21–0.86  | 0.7       |
| Baruah et al., 2019    | 13     | 190   | 0.07       | 0.04–0.11  | 1         |
| Bhat et al., 2016      | 54     | 89    | 0.61       | 0.50–0.71  | 1         |
| Bhatt et al., 2015     | 103    | 510   | 0.2        | 0.17–0.24  | 1.1       |
| Bhattacharya et al., 2015 | 47   | 100   | 0.47       | 0.37–0.57  | 1         |
| Bhattacharya et al., 2017 | 20   | 122   | 0.16       | 0.10–0.24  | 1         |
| Bhavana et al., 2019   | 70     | 187   | 0.37       | 0.30–0.45  | 1         |
| Bhavas et al., 2015    | 65     | 150   | 0.43       | 0.35–0.52  | 1         |
| Bhowmik et al., 2019   | 71     | 127   | 0.56       | 0.47–0.65  | 1         |
| Chaudhary et al., 2015 | 77     | 178   | 0.43       | 0.36–0.51  | 1         |
| Choudhury et al., 2016 | 311    | 724   | 0.43       | 0.39–0.47  | 1.1       |
| Cagati et al., 2017    | 92     | 161   | 0.57       | 0.49–0.65  | 1         |
| Das et al., 2016       | 64     | 100   | 0.64       | 0.54–0.73  | 1         |
| Datta et al., 2019     | 5      | 26    | 0.19       | 0.07–0.39  | 0.9       |
| Dhiman et al., 2017    | 24     | 150   | 0.16       | 0.11–0.23  | 1         |
| Farooq et al., 2016    | 210    | 343   | 0.61       | 0.56–0.66  | 1.1       |
| Geccha et al., 2015    | 44     | 166   | 0.27       | 0.20–0.34  | 1         |
| Ghosh et al., 2016     | 11     | 46    | 0.24       | 0.13–0.39  | 1         |
| Gupta et al., 2017     | 344    | 450   | 0.76       | 0.72–0.80  | 1.1       |
| Gupta et al., 2015     | 19     | 60    | 0.32       | 0.20–0.45  | 1         |
| Gupta et al., 2015     | 12     | 30    | 0.4        | 0.23–0.59  | 0.9       |

Heterogeneity: \( I^2 = 99\%, \tau^2 = 0.0521, p = 0.01 \)
continued.

| Study                        | Events | Total | Proportion | 95% CI      | Weight, % |
|------------------------------|--------|-------|------------|-------------|-----------|
| Gupta et al.\(^{20}\) 2016  | 69     | 174   | 0.4        | 0.32–0.47   | 1         |
| Gupta et al.\(^{21}\) 2017  | 408    | 505   | 0.81       | 0.77–0.84   | 1.1       |
| Hemamalini et al.\(^{22}\) 2015 | 14   | 40    | 0.35       | 0.21–0.52   | 1         |
| Hussain et al.\(^{23}\) 2015 | 53     | 80    | 0.66       | 0.55–0.76   | 1         |
| Jindal et al.\(^{24}\) 2016  | 161    | 248   | 0.65       | 0.59–0.71   | 1.1       |
| Joshi et al.\(^{25}\) 2017   | 34     | 231   | 0.15       | 0.10–0.20   | 1.1       |
| Kaur et al.\(^{26}\) 2019    | 83     | 162   | 0.51       | 0.43–0.59   | 1         |
| Kavirha et al.\(^{27}\) 2017 | 22     | 207   | 0.11       | 0.07–0.16   | 1.1       |
| Kulsbrotha et al.\(^{28}\) 2019 | 82    | 161   | 0.51       | 0.28–0.41   | 1         |
| Kumar et al.\(^{29}\) 2016   | 79     | 147   | 0.54       | 0.45–0.62   | 1         |
| Kumar et al.\(^{30}\) 2016   | 88     | 291   | 0.3        | 0.25–0.36   | 1.1       |
| Majhi et al.\(^{31}\) 2016   | 129    | 209   | 0.62       | 0.55–0.68   | 1.1       |
| Mantora et al.\(^{32}\) 2019 | 310    | 1041  | 0.3        | 0.27–0.33   | 1.1       |
| Mehra,\(^{33}\) 2017         | 145    | 250   | 0.58       | 0.52–0.64   | 1.1       |
| Mendem et al.\(^{34}\) 2016  | 24     | 62    | 0.39       | 0.27–0.52   | 1         |
| Mohanty et al.\(^{35}\) 2019 | 127    | 284   | 0.45       | 0.39–0.51   | 1.1       |
| Mokta et al.\(^{36}\) 2015   | 82     | 350   | 0.23       | 0.19–0.28   | 1.1       |
| Mushraq et al.\(^{37}\) 2016  | 58     | 140   | 0.41       | 0.33–0.50   | 1         |
| Nadimpalli et al.\(^{38}\) 2016 | 63    | 2040  | 0.03       | 0.02–0.04   | 1         |
| Nagasundaram et al.\(^{39}\) 2019 | 114   | 200   | 0.57       | 0.50–0.64   | 1.1       |
| Negi et al.\(^{40}\) 2015    | 11     | 70    | 0.16       | 0.08–0.26   | 1         |
| Pai et al.\(^{41}\) 2015     | 7      | 33    | 0.21       | 0.09–0.39   | 0.9       |
| Pai et al.\(^{42}\) 2017     | 9      | 100   | 0.09       | 0.04–0.16   | 1         |
| Pal et al.\(^{43}\) 2019     | 34     | 121   | 0.28       | 0.20–0.37   | 1         |
| Pandya et al.\(^{44}\) 2015  | 104    | 180   | 0.58       | 0.50–0.65   | 1         |
| Patil et al.\(^{45}\) 2017   | 23     | 57    | 0.4        | 0.28–0.54   | 1         |
| Peral et al.\(^{46}\) 2016   | 132    | 386   | 0.34       | 0.29–0.39   | 1.1       |
| Perween et al.\(^{47}\) 2015 | 80     | 141   | 0.57       | 0.48–0.65   | 1         |
| Phukan et al.\(^{48}\) 2015  | 160    | 215   | 0.74       | 0.68–0.80   | 1.1       |
| Raigar et al.\(^{49}\) 2019  | 208    | 400   | 0.52       | 0.47–0.57   | 1.1       |
| Rana-Khara et al.\(^{50}\) 2016 | 52    | 100   | 0.52       | 0.42–0.62   | 1         |
| Reema et al.\(^{51}\) 2016   | 23     | 50    | 0.46       | 0.32–0.61   | 1         |
| Rengaraj et al.\(^{52}\) 2016 | 54    | 109   | 0.5        | 0.40–0.59   | 1         |
| Routray et al.\(^{53}\) 2019 | 13     | 17    | 0.76       | 0.50–0.93   | 0.9       |
| Rudresh et al.\(^{54}\) 2015 | 22     | 98    | 0.22       | 0.15–0.32   | 1         |
| Sankaran et al.\(^{55}\) 2018 | 13     | 30    | 0.43       | 0.25–0.63   | 0.9       |
| Selvabai et al.\(^{56}\) 2019 | 114    | 468   | 0.24       | 0.21–0.29   | 1.1       |
| Sengupta et al.\(^{57}\) 2016 | 19     | 19    | 1          | 0.82–1.00   | 0.9       |
| Senthil Kumar et al.\(^{58}\) 2015 | 46   | 98    | 0.47       | 0.37–0.57   | 1         |
| Singh et al.\(^{59}\) 2018   | 87     | 248   | 0.35       | 0.29–0.41   | 1.1       |
| Singh et al.\(^{60}\) 2018   | 9      | 49    | 0.18       | 0.09–0.32   | 1         |
| Swahitaj et al.\(^{61}\) 2020 | 262    | 380   | 0.69       | 0.64–0.74   | 1.1       |
| Talwar et al.\(^{62}\) 2016   | 38     | 111   | 0.34       | 0.25–0.44   | 1         |
| There et al.\(^{63}\) 2016   | 50     | 114   | 0.44       | 0.35–0.53   | 1         |
| Thomas et al.\(^{64}\) 2018   | 14     | 43    | 0.33       | 0.19–0.49   | 1         |
| Triparhi\(^{65}\) 2015        | 70     | 210   | 0.33       | 0.27–0.40   | 1.1       |
| Trivedi et al.\(^{66}\) 2015  | 47     | 232   | 0.2        | 0.15–0.26   | 1.1       |
| Vasuki et al.\(^{67}\) 2016   | 45     | 83    | 0.54       | 0.43–0.65   | 1         |
| Velayudham et al.\(^{68}\) 2017 | 120   | 182   | 0.66       | 0.59–0.73   | 1         |
| Venkatesan et al.\(^{69}\) 2017 | 23    | 43    | 0.53       | 0.38–0.69   | 1         |
| Random effects model         | 17027  | 4     | 0.4        | 0.35–0.45   | 75.8      |

Heterogeneity: F = 99%, \(\tau^2 = 0.0542, p < 0.001\)
Random effects model

Heterogeneity: F = 99%, \(\tau^2 = 0.0571, p < 0.001\)
Residual heterogeneity: F = 99%, p < 0.001
more appropriate using the random effect model to deal with heterogeneity.

In 2015, 27 articles showed the prevalence of MRSA as 38% (95% CI: 30–45) with $I^2 = -97$, $\tau^2 = -0.0414$, $p < 0.01$. In 2016, 27 articles showed the prevalence of MRSA as 39% (95% CI: 29–50) with $I^2 = -99$, $\tau^2 = -0.0797$, $p < 0.01$. In 2017, 20 articles showed the prevalence of MRSA as 31% (95% CI: 20–44) with $I^2 = -99$, $\tau^2 = -0.0835$, $p < 0.001$. In 2018, 7 articles showed the prevalence of MRSA as 35% (95% CI: 26–43) with $I^2 = -62$, $\tau^2 = -0.0091$, $p = 0.02$. In 2019, 16 articles showed the prevalence of MRSA as 37% (95% CI: 28–46) with $I^2 = -99$, $\tau^2 = -0.0343$, $p < 0.01$. In 2020, a single article showed prevalence of MRSA as 69% (95% CI: 64–74) [Table 3].

**Zone-wise prevalence of MRSA**

In zone-wise analysis [Table 4 and Figure 3], the east zone with nine articles (West Bengal and Odisha) showed the highest pooled prevalence of 43% (95% CI: 20–68) with $I^2 = -96$, $\tau^2 = 0.01401$, $p < 0.01$. The lowest prevalence of MRSA was recorded in the west zone with 20 articles (Rajasthan, Maharashtra, and Gujarat) as 33% (95% CI: 24–43) with $I^2 = -99$, $\tau^2 = -0.0514$, $p < 0.01$, and these states are geographically large and densely populated. Twenty-four articles in the north zone comprising Uttar Pradesh, Haryana, Jammu and Kashmir, Himachal Pradesh, Punjab, New Delhi, and Uttarakhand had a pooled prevalence of 41% (95% CI: 33–50) with $I^2 = -98$, $\tau^2 = -0.0446$, $p < 0.01$. Thirty-four articles in the south zone consisting of Tamil Nadu, Telangana, Karnataka, Andhra Pradesh, Kerala, and Puducherry revealed a pooled prevalence of MRSA as 34% (95% CI: 26–42) with $I^2 = -98$, $\tau^2 = -0.0614$, $p < 0.01$. Four articles in central zone (Madhya Pradesh) showed a pooled prevalence of 36% (95% CI: 25–47) with $I^2 = -78$, $\tau^2 = -0.0112$, $p < 0.01$. Assam, Tripura, and Sikkim are part of the northeast zone (seven articles) which showed a pooled prevalence of MRSA as 40% (95% CI: 23–58) with $I^2 = -98$, $\tau^2 = -0.0601$, $p < 0.01$.

**Meta-regression analysis**

Meta-regression is a tool used to examine the effect of moderators on MRSA prevalence rates. In this study, the year of publications, sample size, geographical regions, and confirmatory tests used for the diagnosis of samples are the moderators. After conducting the meta-regression, sample size was found significant ($R^2 = 7.03; p = 0.005$). The heterogeneity contribution of the moderator variables ranged from 0 to 7.03%. Further investigation of subgroup analysis of sample size was performed, dividing the sample size moderator into two groups viz., less than median and more than median, using a mixed-effect model, which yielded $I^2 = 99\%$, $p = 0.990$. The results of the tests for residual heterogeneity and parameter estimation by meta-regression are presented in Tables 5 and 6.

The study included 74 hospitals and 24 community settings (total of 98 articles). Further investigation of subgroup analysis of hospital and...
community settings was conducted. The pooled prevalence of MRSA for community settings was 27% (95% CI: 19–35) ($F = -96, \tau^2 = -0.0521, p < 0.01$) and that for hospital setting was 49% (95% CI: 35–45) ($F = -99, \tau^2 = -0.0542, p < 0.001$) [Table 7].

To assess the heterogeneity between study reports, we generated a Galbraith plot [Figure 4]. The standardized effect estimates against inverse standard error were shown as scattered points in the plot. The points representing the study reports outside confidence bounds may be contributing to the heterogeneity. In the absence of heterogeneity, all points (reports) are expected to lie within the confidence limits centering around the line.

**DISCUSSION**

Antibiotic resistance is one of the foremost health concerns of India. There has been an alarming increase in the prevalence of *S. aureus* resistant to methicillin in India in recent years, especially community-associated MRSA. MRSA is now endemic in India, and its incidence is varied. The current policy shows a growing political commitment at the highest levels to take strong action on antimicrobial resistance and provide adequate support for nationwide surveillance and stewardship to mitigate the resistance problem.

Our meta-analysis study reveals the pooled prevalence of MRSA in India at 37% (95% CI: 32–41) during 2015–2020. The epidemiology of MRSA in humans is changing gradually in India and the prevalence has increased over the years due to lack of awareness, overuse of antimicrobial medicines in human health, increase in the infections caused due to lack of sanitation and hygiene, and the paucity of stringent rules and regulations for use of antibiotics. Although the cost of antibiotics is high, the consumption rate has increased due to inappropriate prescribing, indiscriminate use of antibiotics, and sales of antibiotics without prescription. Self-medication with antibiotics bought without prescription is also a serious concern in India.

A pooled prevalence of MRSA varied between 31%–39% from 2015 to 2019 (69% in 2020) against a total prevalence of 37% across India. Jammu and Kashmir showed the highest prevalence of MRSA (55%), which shares a border with Pakistan, though illegal movement may not be ruled out alongside borders. On the other hand, Maharashtra has the lowest prevalence of MRSA (21%) and has more sophisticated hospitals.

In zone-wise analysis, the east zone has shown the highest prevalence of MRSA (43%), including West Bengal and Odisha. West Bengal shares a porous border with Bangladesh, and there is no restriction on the movement of men and material between them. The north zone, which included Uttar Pradesh, Haryana, Jammu and Kashmir, Himachal Pradesh, Punjab, New Delhi, and Uttarakhand states, had the second-highest (41%) MRSA prevalence. The northeast zone, which comprises Assam, Tripura, and Sikkim, has shown the third-highest prevalence of MRSA (40%). Assam has a porous border with Bhutan and Bangladesh; Tripura shares a porous border with Bangladesh whereas Sikkim shares with Bhutan, Tibet, and Nepal. There is no restriction on the movement of men and materials. In a similar study, 104 46% and 54% of prevalence of MRSA among females and males, respectively, was recorded in the west zone of Iran. Eighty-four isolates from the intensive care unit of a hospital in Iran were antimicrobial-resistant, which is quite alarming.

In year-wise analysis, the pooled prevalence of MRSA was more (39%) during 2016, followed by 38% prevalence in 2015. The reports on the prevalence of MRSA (35%) were more homogenous ($F = 62\%$). There was a consistency in reporting of prevalence rate of MRSA in all zones of India.

The moderate heterogeneity may be due to the size’s total variability effect, which might not have been caused by sampling error. Further, the heterogeneity between studies can be attributed to the different study settings and study populations since the studies on MRSA prevalence from different regions are limited. Heterogeneity between studies could also be due to different population settings under investigation, type of samples used, geographical locations, and hospital/community practices. However, the weight (fixed) assigned to 24 studies under community settings did not exhibit outlier features upon scrutinizing the forest plots. Therefore, the effect of two settings (hospital and community) on pooled prevalence of MRSA was not found to have a large difference. The subgroup analysis of studies revealed that the pooled prevalence of MRSA in the hospital setting was 49% and 27% in the community setting.

Further to meta-analysis, barring selection bias, systematic reviews helps the revision of all
the scientific evidence on a given topic. Based on the output, the summarized information can be used to propose hypotheses that explain the data’s behavior and identify areas of gaps where further research is needed. However, it is a controversial tool because several conditions are critical, and even small violations of these can lead to misleading conclusions. While designing and performing a meta-analysis, several decisions concerning personal judgment and expertise need to be made that may eventually create bias or expectations that influence the result.

**CONCLUSION**

The overall pooled prevalence of MRSA in India was very high (37%). Studies comprising large populations in different locations with rapid tests would be of much help in computing the prevalence of MRSA. This increase in the prevalence of MRSA builds more emphasis on the need to develop more stringent policies and regulations for the use of antibiotics in the human healthcare system. Strict adherence to hand hygiene and judicious use of any antibiotics will greatly reduce the incidence of MRSA. Awareness of the indiscriminate use of antibiotics and preventive strategies should be introduced to combat the epidemic spread of drug-resistant bacteria in India.

**Disclosure**

The authors declared no conflicts of interest.

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