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REVIEW PAPER

Composite index of anthropometric failure and conventional anthropometric indices of undernutrition among children in India – a systematic review and meta-analysis

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ABSTRACT

Introduction and aim. The high prevalence of childhood undernutrition continues to be a major public health issue in India. This systematic and meta-analysis study employed both the composite index of anthropometric failures (CIAF) and conventional to determine the magnitude of undernutrition in Indian children.

Material and methods. A comprehensive literature search was conducted from 2005 to June 2023 using electronic databases, including Google Scholar, Web of Science, SCOPUS, PubMed, J-Gate, and ScienceDirect. A random-effects model for pooled prevalence rates was generated and heterogeneity was assessed using the I^2 index and Q statistics.

Analysis of the literature. CIAF revealed a higher prevalence of undernutrition than conventional anthropometric indices in children aged 0 to 72 months. The combined prevalence of stunting and underweight was 37% (95%CI: 0.32-0.41), and wasting was 22% (95%CI: 0.18-0.25) ($p<0.01$). However, according to CIAF categorization, the pooled prevalence of undernourishment was reported to be 55% (95% CI:0.50-0.60; $p<0.01$). CIAF's higher prevalence highlights its effectiveness in capturing childhood undernutrition, accounting for children with multiple concurrent nutritional deficiencies in population.

Conclusion. This systematic review and meta-analysis investigated the assessment of undernutrition using conventional anthropometric indices compared with CIAF, which aggregate different aspects of undernutrition, especially when children have multiple undernutrition issues. Appropriate, target-specific interventions are necessary to improve the overall nutritional status of Indian children.

Keywords. child undernutrition, composite index of anthropometric failure, meta-analysis, nutritional status, public health, systematic review

Introduction

India has the world's largest population and fastest-growing economy yet continues to struggle with access to nutrition and healthcare services.[1-3] Undernutrition is a condition that occurs when an individual's nutritional requirements are out of coherence with their intake.[4] The prevalence of undernutrition becoming a severe public health issue concerns Indian children as well, classified as one of the causes of child mortality, and increasing the chances of illness burden. Despite significant economic growth, the magnitude of child mortality remains high due to undernutrition.[5] However, undernutrition is closely linked to factors such as poverty, socio-economic disparities, and demographic conditions.[6-12] The Comprehensive National Nutrition Survey (2016-2018) found that 38% of children (<5 years) are stunted and that 35% are underweight among Indian children.[13,14] The second major target of

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the Sustainable Development Goal, is to alleviate famished factors and improve nutritional status.[16,17] The conventional anthropometric indices of stunting (low height-for-age), underweight (low weight-for-age), and wasting (low weight-for height) are widely used around the world to assess the severity of childhood undernutriton.[17,18] Children who are undernourished in various undernutrition indices are not accurately represented by these conventional anthropometric indices due to the overlapping nature of assessment.[9,19-22] The Composite Index of Anthropometric Failure (CIAF) offers the overall magnitude of undernutrition as an aggregate single measure over conventional anthropometric indices, contributing to the identification of single, double or multiple anthropometric failures in children. Further, the CIAF, a typical anthropometric measure consisting of seven categories, evaluates the prevalence of stunting, wasting, and underweight in children in several combination measures and presents an additional and reliable measure to ascertain the actual degree of undernutrition.[18,23,24]

This systematic review and meta-analysis examined undernutrition status using both conventional anthropometric indices and CIAF among children in India. When a child's measurements deviated from the mean by more than minus two standard deviations (-2SD), this may indicate that they might be lacking in important nutrients and food intake in their first phase of life.[18,25-29] The included studies have examined different groups of children using both nutritional assessment approaches (i.e., conventionally used anthropometric measures and CIAF) to observe how many of them had nutritional deficiencies or undernutrition. It is interesting to note that using the CIAF method frequently showed that there were significantly more undernourished children than when using only conventional measurements.[3,9,20-21,30-42] The present study focuses on the use of both conventional anthropometric indices and CIAF as a measure of child undernutrition in India. The main objective of this study is to determine whether the CIAF provides a more accurate estimate than conventional anthropometric indices of child undernutrition. Moreover, by improving the accuracy of our assessments, target-specific interventions and policies can be made that are more effective and directly aimed at reducing child mortality, nutritional and disease burden. Nandy et al. reported that in order to address undernutrition in India, a study should ascertain the extent of the issue, which has been grossly underestimated.[5]

A newly proposed composite measure of CIAF proposed by Nandy et al. assigns a single combined value to the undernourished children in a population, which has identified that the CIAF reveals a more alarming prevalence of undernutrition after studying data from 24,396 Indian children.[5] In comparison to commonly utilized measures of stunting (45%), underweight (47%), and wasting (16%), the CIAF estimates that 60% of children show anthropometric failures in different categories of undernourishment in children. This novel method enables us to gain a deeper understanding of and recognize more children who are found to be susceptible and who require nutritional assistance.[5-9,19-22,25,34,42-49] In order to provide a more thorough understanding of the prevalence of undernutrition in India, the present study was designed around this premise. In addition, despite notable economic growth, the country continues to struggle with this significant health issue, with a high prevalence (>40.0%) of children under the age of five suffering from undernutrition in India.[3,9,20-22,24,33,35,37,42,46,48,50-58] According to the National Family Health Survey (NFHS)-4, stunting was 38.4% and decreased to 35.5% in NFHS-5, wasting was 21% in NFHS-4 and reduced to 19.3% in NFHS-5, and underweight was 35.8% in NFHS-4 and 32.1% in NFHS-5. While all three indicators of undernutrition have decreased, but the overall prevalence remains high, indicating that both chronic and acute undernourishment affect a considerable proportion of children under the age of five in India.[59]

Aim

It is imperative to investigate the relationship between undernutrition and its concomitant factors, particularly how these factors vary across nutritionally vulnerable populations. Given the foregoing, the present systematic review and meta- analysis employed both conventional anthropometric measures (i.e., stunting, underweight, and wasting) and CIAF in children to determine the magnitude of undernutrition across various geographical regions in India. Furthermore, this study compares the outcomes of conventional anthropometric indices, and the CIAF approach to determine which method is more accurate to determine the actual magnitude of undernutrition to implement any appropriate nutritional intervention in the target population. Further, this systematic review and meta-analysis also aims to contribute to the development of focused interventions that can lower morbidity and disease burden by providing a thorough understanding of undernutrition and assessments among children in India.

Material and methods

Search strategy

Between 2005 and June 2023, a thorough literature search was carried out using international search engines or databases, including Google Scholar, Web of Science, Scopus, PubMed, J-Gate, and ScienceDirect. The Medical Subject Headings (MeSH) terms CIAF, OR "Childhood Anthropometric Indices of Failure", OR "Anthropometric Failure in Children", OR "Childhood Growth Failure", OR "Malnutrition in Childhood", "Under Five Composite Index of anthropometric failure AND undernutrition" OR "Childhood undernutrition Composite Index" OR "Anthropometric Failure in Under-Five Children" OR "Under-Five Growth Failure" OR "Under-Five undernutrition", "0-72 months" OR CIAF AND "Composite Index of anthropometric failure AND undernutrition" OR "Anthropometric Failure in Children aged 0 to 72 months" OR "Growth Failure in Infants and Young Children" OR "CIAF and Nutritional Deficiency" OR "Undernutrition with Anthropometric Failure" OR "Malnutrition with Anthropometric Failure", "Childhood Undernutrition" OR "Undernutrition in Children" OR "Nutritional Deficiency in Childhood" OR "Child undernutrition" OR "Severe undernutrition in Childhood" OR "Weight-for-height deficit in Children" was combined within the search strategy along with "India." In order to find additional studies, the present systematic review and meta-analysis study applied the snowball technique to search the list of pertinent references that were cited in the published manuscripts selected for the analysis. To ensure the rationale of the studies, this systematic review excluded un-reviewed articles, conference abstracts, and dissertations and theses. The entire set of search results is then transferred, and duplicates are removed using the reference management program Endnote 21.0.1.[60] The eligibility of the remaining references was further examined by following the protocols of inclusion and exclusion.

Protocols of inclusion and exclusion

Study design

Studies included in this analysis had to offer primary information on anthropometric indices and child health parameters. Both cross-sectional and longitudinal research investigations had been taken into consideration.[42,49,57] Review articles, editorials, pieces of opinion, and studies that lacked primary data were all disqualified for the meta-analysis.

Population

The studies focused on children aged 0–72 months during the study period; priority for cross-sectional studies was considered. Studies focusing on higher age-groups or non-Indian populations with specific health conditions unrelated to the parameters of interest were excluded.

Time period

The present systematic review and meta-analysis study has included the studies published from 2005 to 2023. Search results declared zero results, which indicated that no study was found that applied both conventional and CIAF among Indian children (0–72 months) before 2005.

Anthropometric variables

In research articles that examined stunting, underweight, wasting, and CIAF, these parameters were required to be clearly defined and measured in the studies (Table 1). Studies that were not examined or examined only one of the parameters were excluded.

Data availability

The studies reported the total number of cases and provided specific values for each anthropometric measure along with the population distribution based on the age parameter (0–72 months). The research articles that did not report the total number of cases or participants or did not provide specific values for the indices were also excluded.

Eligibility criteria

Research studies that take into account the age range of 0 to 6 years and household surveys in India were included if they demonstrated the distribution of CIAF along with the conventional anthropometric measures of nutritional status (e.g., stunting, underweight, and wasting). The NFHS data have been used for selected studies that followed the above-mentioned study criteria. Articles reflecting upon only the CIAF or other single anthropometric indices were removed.

Table 1. Classification of Anthropometric failure assessed by CIAF (classification based on Nandy et al.[5])

Group name	Description	Wasting	Stunting	Underweight
A	No failure: children whose height and weight are above the age-specific norm (i.e., above – 2 z-scores) and do not suffer from any anthropometric failure.	No	No	No
B	Wasting only: children with acceptable weight and height for their age but who have subnormal weight for height.	Yes	No	No
C	Wasting and underweight: children with above-norm heights but whose weight for age and weight for height are too low.	Yes	No	Yes
D	Wasting, stunting, and underweight: children who suffer from anthropometric failure on all three measures.	Yes	Yes	Yes
E	Stunting and underweight: children with low weight for age and low height for age but who have an acceptable weight for their height.	No	Yes	Yes
F	Stunting only: children with low height for their age but who have acceptable weight, both for their age and for their short height.	No	Yes	No
Y	Underweight only: children who are only underweight.	No	No	Yes

Study selection

Two authors independently reviewed the published titles and abstracts. Both authors independently determined whether or not to include the possibly eligible research articles after acquiring their full-texts. Any disagreements among the authors were considered at each level of screening, and their consensus was used to establish the eligibility and inclusion of all listed publications. The authors, on the other hand, used risk-of-bias methodologies to meticulously analyze the quality assessments of published studies. The studies were limited to those published in English for the sake of research simplicity.

Initial screening

Following the literature search, the titles and abstracts of the retrieved references are reviewed to eliminate any unnecessary research and reduce the chance of bias and inaccuracies in the studies. The research studies that look at both conventional anthropometric indicators and CIAF are used to determine qualifying study levels. This could include studies on undernutrition in the target population. Relevant primary studies with diverse study designs, such as randomized controlled trials, cohort studies, case-control studies, or cross-sectional studies, were examined for inclusion in the study design. Studies that meet the inclusion criteria or demonstrate potential relevance go on to the next stage of the evaluation process. Full-text publications from these chosen studies are retrieved and given a more thorough evaluation before being included in the systematic review.

Full-text screening

The full-text of any potentially eligible studies is then obtained from electronic databases. Each study was thoroughly reviewed to ensure that it met the inclusion criteria. During these stages, the research articles were meticulously checked to ensure they met the requirements. The present study specifically examined whether the chosen studies took into account children aged 0-6 years, carried out household surveys, and displayed the distribution of the CIAF along with stunting, underweight, and wasting. Furthermore, researchers made certain that the studies were written in English for ease of comprehension and further analysis. The number of excluded studies and the reasons for exclusion were reported using the standard Preferred Reporting Items for systematic reviews and meta-analyses (PRISMA) guidelines (Fig. 1).[61] This stringent full-text screening process ensured that only the most relevant and high-quality studies were included in the final analysis, improving the validity and reliability of our research findings.

Data extraction

Data for this analysis were precisely and conscientiously collected from 49 studies and research articles that presented the findings of CIAF and conventional anthropometric measures focused on child undernutrition assessment and were done between 2005 and 2023. Google Scholar, J-Gate, PubMed, Science Direct, SCOPUS, and Web of Science were among the electronic databases searched; however, the search was confined to the keywords following the MeSH terms. The present investigation identified similar networking terms and built the search strategy around them. The following information was gathered from each study that followed the STROBE guidelines and basic study details are included in the Excel sheet, including the initial author, year of publication, study location, total cases, and conventional anthropometric indices, including CIAF.

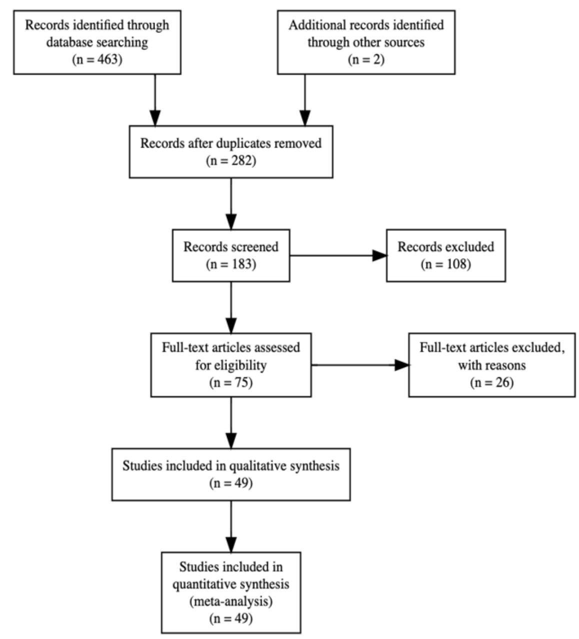

Fig. 1. The PRISMA flowchart illustrates the step-by-step process of study selection based on predefined exclusion and inclusion criteria for the systematic review

Data analysis

The R-statistical programming language was used to analyze the data.[62,63] This systematic review utilized the R-packages '*metadata*' and '*meta*', which provide a variety of functions for conducting meta-analysis, by importing the prepared Excel file and calculating the pooled prevalence rates of stunting, underweight, wasting and CIAF using a random effect model because the random effect model considers both within-study and between-study variability. A significant amount of statistical heterogeneity was also estimated. The I^2 index and Q statistics were calculated for all of the studies to quantify their heterogeneity. Stunting, underweight, wasting, and CIAF had I^2 values of 99% and 98%, respectively, indicating the degree of heterogeneity between signifying anthropometric indices across studies. This systematic review further examined potential publication bias using funnel plots. The goal of this test is to detect the small study effect, which can indicate publication bias. Finally, the present study used forest plots to visualize the results of the heterogeneity between the studies. The size of each square box in the plot corresponds to the study's sample size, and the lines extending from each side of the square boxes represent the 95% confidence interval (CI), percent weight, pooled estimate with 95% CI, significance of Chi-square statistics, and I^2 statistics. The square boxes also represent each study's 95% CI and 95% weight. The goal of the meta-analysis used in this study was to compile and produce the information contained in the CIAF and other conventional anthropometric indices.

Analysis of the literature

The results are based on research conducted on the prevalence of undernutrition in Indian children. This present study initially located 463 records in this systematic review using various electronic databases. Finally, 52 population or study groups (49 total studies) in total, including cross-sectional studies, were selected for this systematic review and meta-analysis study. The present study has identified that, of the 49 studies, 37 reported undernutrition assessments in accordance with WHO child growth standards (1995, 2006), and 12 articles reported using the National Centre for Health Statistics (1977) growth standard. This was after carefully examining the research articles in accordance with the inclusion criteria. There were 3,56,957 participants in total. There were 2,48,055 children between the ages of 0 and 72 months in the largest study.[64] The present study divided the studies into three sub-groups based on the search period, which was from 2005 to 2023. Sub-group 1 was the initial stage for conducting research on and publishing the CIAF, with studies ranging from 2005 to 2010. Sub-group 2 includes studies from 2011 to 2017 and represents the middle of publications in which researchers recognize CIAF as a valuable indicator of childhood undernutrition. The most recent stage of the investigation is Sub-group 3, which includes research from 2018 to 2023. By dividing the timeline into three groups, the present study can estimate the trend, development, and shifts in anthropometric indices over time. The present study adhered to the guidelines provided by PRISMA and the Meta-Analysis of Observational Studies in Epidemiology.[65] .

According to this systematic review analysis, the prevalence of stunting, underweight, and wasting is depicted in Figures 2–4 and Table 2, respectively. The pooled prevalence of stunting was 36.31% (95% CI: 0.3191–0.4097, I^2=98.3, H=7.59, p<0.001). In the case of underweight, it was 36.93% (95% CI: 0.3312–0.4091, I^2=98.4, H=7.86, p<0.001), while wasting was 20.52% (95% CI: 0.1765–0.2372, $I^{2=}$97.5, H=6.36, p<0.001). However, the magnitude of CIAF (Fig. 6) was observed to be significantly higher (i.e., 54.80%, 95% CI: 0.4965–0.5985, I^2=97, p<0.001) than the child undernutrition assessed utilizing conventional anthropometric measures. The test of heterogeneity analysis using Wald and the Likelihood Ratio Test (LRT) both yielded highly significant values, indicating substantial variability across studies in both conventional anthropometric measures and CIAF (p<0.01).

Based on a random-effects model, the analysis between six geographical regions revealed significant heterogeneity, with I^2=99.6% (tau^2 values: 0.0272 and 0.0007). The Q-test yielded a significant value of 809.59, indicating significant variation across regions. The Q-value for the between-group analysis was 21.04 (d.f., 6; p<0.01), indicating significant regional variability. The overall findings revealed 59% (95% CI: 0.56–0.62, I^2=100), indicating a significant difference among the reported studies (p<0.01) (Table 3). However, region-specific analysis revealed that the northern region had a 60% (95% CI: 0.48–0.72, I^2=96, p<0.01) distribution, the central region had a 47% (95% CI: 0.26–0.68, I^2=100, p<0.01) distribution, the eastern region had a 51% (95% CI: 0.44–0.57, I^2=96, p<0.01) distribution, and the western region had a 60% (95% CI: 0.32–0.68, I^2=97, p<0.01).

The results showed significant variations in prevalence rates of CIAF across the regions of India. The large variation in most countries highlights the importance of taking regional variables into account when managing childhood undernutrition and single, double, or multiple anthropometric failures. This systematic review and meta-analysis has derived that four of the forty nine studies were designated as "India," with four studies conducted in the Northern region of India (Region 1),[38,40,66,67] five in the Central region (Region 2)[20,45,47,51,68] nineteen in the Eastern region (Region 3),[19,31-34,42,43,49,50,53-56,58,69-73] two in the North Eastern region (Region 4)[9,22] nine in the Western region (Region 5)[35-37,39,41,46,74-76] and six in the Southern region (Region 6).[2,23,59,77-79]

Table 2. This table presents the results of quantifying heterogeneity and conducting tests of heterogeneity for four anthropometric indices (stunting, underweight, wasting, and CIAF) in a systematic review with 52 included studies and a total of 356,957 observations. The proportion is represented with 95% CI for each index

(a) No of studies 'K'=52, (b) No of Observation 'o'=356957, (c) Proportion=95% CI										
	Quantifying Heterogeneity						Test of Heterogeneity			
Anthropometric indices	No of Event (e)	Random	tau^2	tau	I^2	H		Q	d.f.	p
Stunting	142834.5	0.3631	0.4969	0.7049	98.3%	7.59	Wald	2941.44	51	0.001
							LRT	3162.60	51	0.001
Underweight	134893.2	0.3693	0.3693	0.5985	98.4%	7.86	Wald	3154.01	51	0.001
							LRT	3226.58	51	0.001
Wasting	73206.73	0.2052	0.4388	0.6624	97.5%	6.36	Wald	2059.81	51	0.001
							LRT	2084.60	51	0.001
CIAF	201887	0.5480	0.5573	0.7465	97.4%	6.24	Wald	1982.66	51	0.001
							LRT	2452.17	51	0.001

Table 3. This table presents the results of the meta-analysis conducted in different regions, analyzing the prevalence of the CIAF index. The table includes information on the number of studies (K) in each region, the estimated proportion value, the 95% CI, and measures of heterogeneity (tau² and tau)

Regions	K proportion	95% CI	tau²	tau	Q	I²	Between groups
India	4	0.5889	0.0007	0.0272	809.59	99.6	
Region 1 (North)	4	0.6014	0.0131	0.1146	72.15	95.8	
Region 2 (Central)	5	0.4721	0.0559	0.2365	951.90	99.6	Q =21.04
Region 3 (East)	21	0.5058	0.0218	0.1476	558.93	96.4	d.f.,=6
Region 4 (N. East)	2	0.4987	0	0	0.43	0.0	p=0.0018
Region 5 (West)	9	0.6014	0.0131	0.1143	309.04	97.4	
Region 6 (South)	7	0.6034	0.0382	0.1954	596.45	99.0	

Table 4 shows that sub-group 1 (2005–2010) included a total of seven investigations. The CIAF was observed to have a proportionate value of 0.5613 (95% CI: 0.0517 to 0.2275). The tau² and tau values were 0.2275 and 0.0517, respectively, indicating the level of variation or heterogeneity among the investigations. The heterogeneity test yielded a statistically significant Q-value of 1993.88 and an I² score of 99.7. These results indicate that there was a lot of variation among the trials in this sub-group. The present study examined 18 studies in the second sub-group (2011–2017). The calculated proportion value for the CIAF was 0.5839, with a 95% CI ranging from 0.0121 to 0.1098. Tau² and tau were both 0.1098 and 0.0121, respectively. The heterogeneity test revealed a Q value of 328.68 and an I² value of 94.8. These findings indicate that there was significant diversity among the studies in this sub-group as well. Sub-group 3 (2018–2023) had 27 studies and the calculated proportion value for the CIAF index was 0.5163, with a 95% CI of 0.0231 to 0.1519. Tau² and tau were both 0.1519 and 0.0231, respectively. The heterogeneity test yielded a Q-value of 1787.24 and an I² value of 98.5. The sub-group results show variable proportion values for the CIAF throughout time periods. For between-group heterogeneity, the Q-value was 2.82 (d.f., 2; $p>0.05$). As a result, while each sub-group exhibits high heterogeneity within itself, there is an insignificant difference in heterogeneity between sub-groups, showing that the variability reported in the research is unaffected by time periods (Fig. 5–7).

Eggers' test was used for each anthropometric measure to quantify publication bias, as shown in (Table 5). The publication bias indicates a nominal result that was statistically insignificant for all outcomes ($p>0.05$). Each anthropometric index's p-value is greater than the significance level of 0.05. To clarify further, the present study has calculated and plotted a funnel plot (Fig. 8), which highlights any potential publication bias or small study impacts. The funnel plot displays the effect size or bias, on the horizontal axis and the standard error of the effect size on the vertical axis.

Table 4. The results of the meta-analysis conducted on three sub-groups based on studies conducted in different time periods (2005-2023), which were majorly categorized as initial, mid, and advanced, referring to the research and publication phase, sub-group 1 (2005–2010), sub-group 2 (2011–2017), and sub-group 3 (2018–2023). Each sub-group consists of a specific number of studies (K) and a proportion value with a 95% CI for the CIAF.

Sub-groups	K proportion	95% CI	tau²	tau	Q	I²	Between groups
Sub-group 1 (2005–2010)	7	0.5613	0.0517	0.2275	1993.88	99.7	Q=2.82,
Sub-group 2 (2011–2017)	18	0.5839	0.0121	0.1098	328.68	94.8	d.f.,=2,
Sub-group 3 (2018–2023)	27	0.5163	0.0231	0.1519	1787.24	98.5	p=0.2437

Table 5. Anthropometric indices and publication bias assessment using Egger's test

Anthropometric Indices	Bias (95% CI)	p
Stunting	-0.1601 (1.1823–0.0293)	0.8928
Underweight	1.2230 (1.2127–0.0303)	0.3181
Wasting	0.2911 (0.9870–0.0296)	0.7693
CIAF	0.1327 (0.9681–0.0236)	0.8916

Discussion

Child undernutrition remains a serious public health issue in low-to middle-income countries, which has a significant adverse impact on health status by increasing morbidity, mortality and disease burden.[23,75,80] According to the findings, children utilizing CIAF showed a significantly greater prevalence of undernourishment than children using conventional anthropometric indicators such as stunting, underweight, and wasting in India (Fig. 9). The present study also found that the proportion of children facing undernutrition was notably higher in various Indian regions (Fig. 10): among urban, rural, slum and tribal children less than 6 years old, 59.8%, 5.9%, 58.64%, 61.8%, and 55.32% respectively,[24,30,44,48,51] under 6 years old slum children in Tamil Nadu 68.6%[23], Gujrat, 60.5% and 73.4%,[35,74] Jammu and Kashmir 73.2%,[66] Maharashtra 47.8%,[36] West Bengal 41.2%,[55] 43.5%,[52] and 24.16%,[41] Telangana 39.6%[4]: under 6 years of age, tribal children of Assam is 28.6%, 51.0%,[9,22] Kerala 41.1% and 66.9%,[57] Maharashtra, 38% and 66%,[75,76] Odisha 54.4%,[73] West Bengal 66.3% and 69.6%[33,49]: among the urban children's younger than 6 years, the CIAF proportions in Andhra Pradesh 56%,[78] Chhattisgarh 54.16%,[47] Delhi 62% and 60.5%,[38,40] Kar-

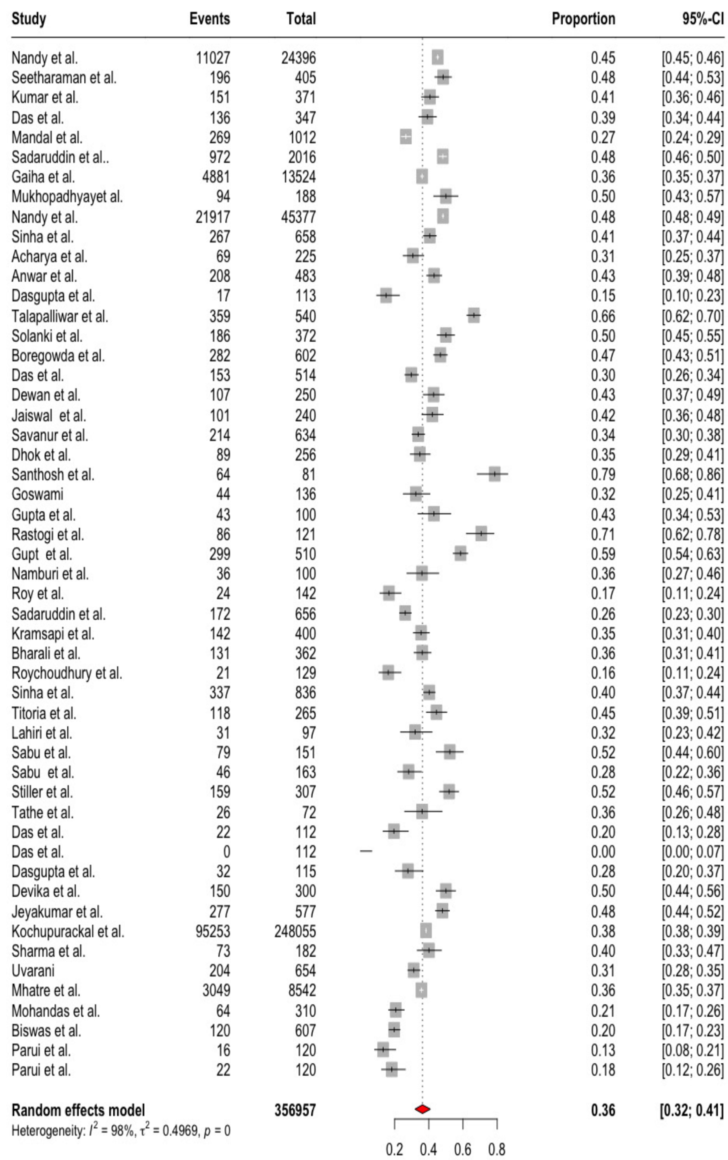

Fig. 2. The forest plot presents the results of the meta-analysis conducted on the variable stunting using a random-effect model. The plot displays individual study estimates (represented by squares) of the effect size, along with their corresponding 95%CI represented by horizontal lines.

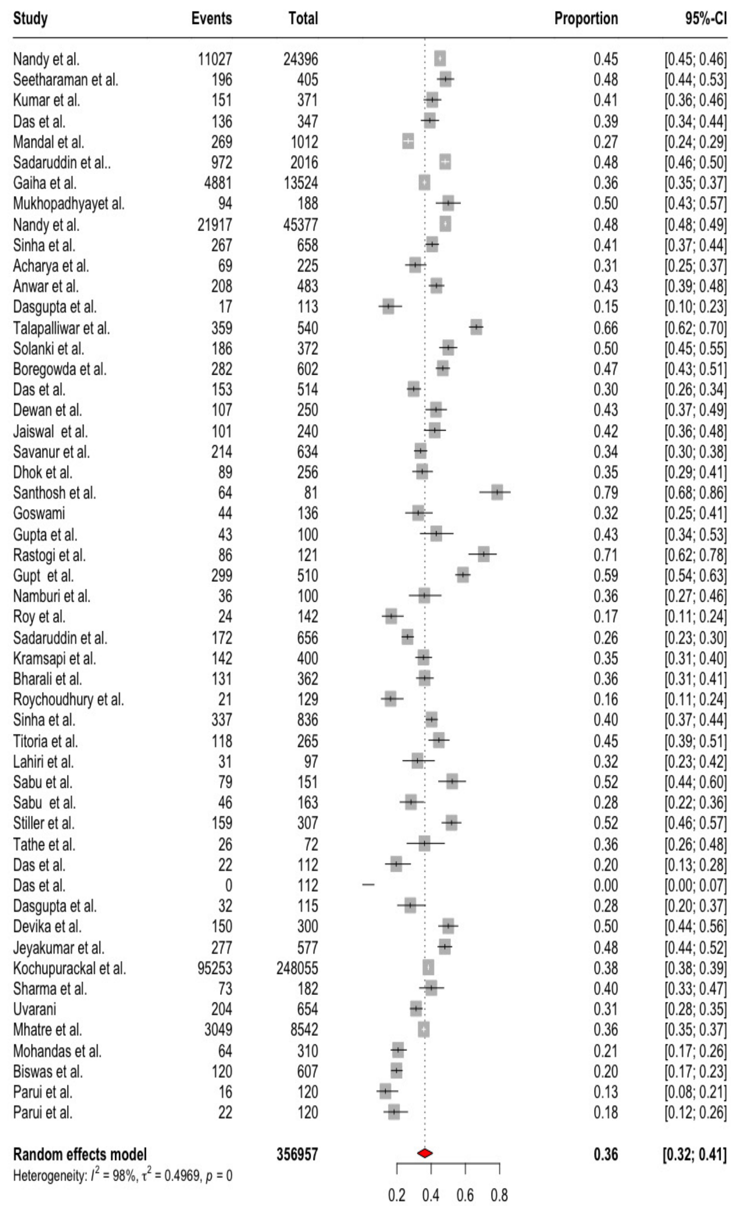

Fig. 3. The forest plot presents the results of the meta-analysis conducted on the variable underweight using a random-effect model. The plot displays individual study estimates (represented by squares) of the effect size, along with their corresponding 95%CI represented by horizontal lines

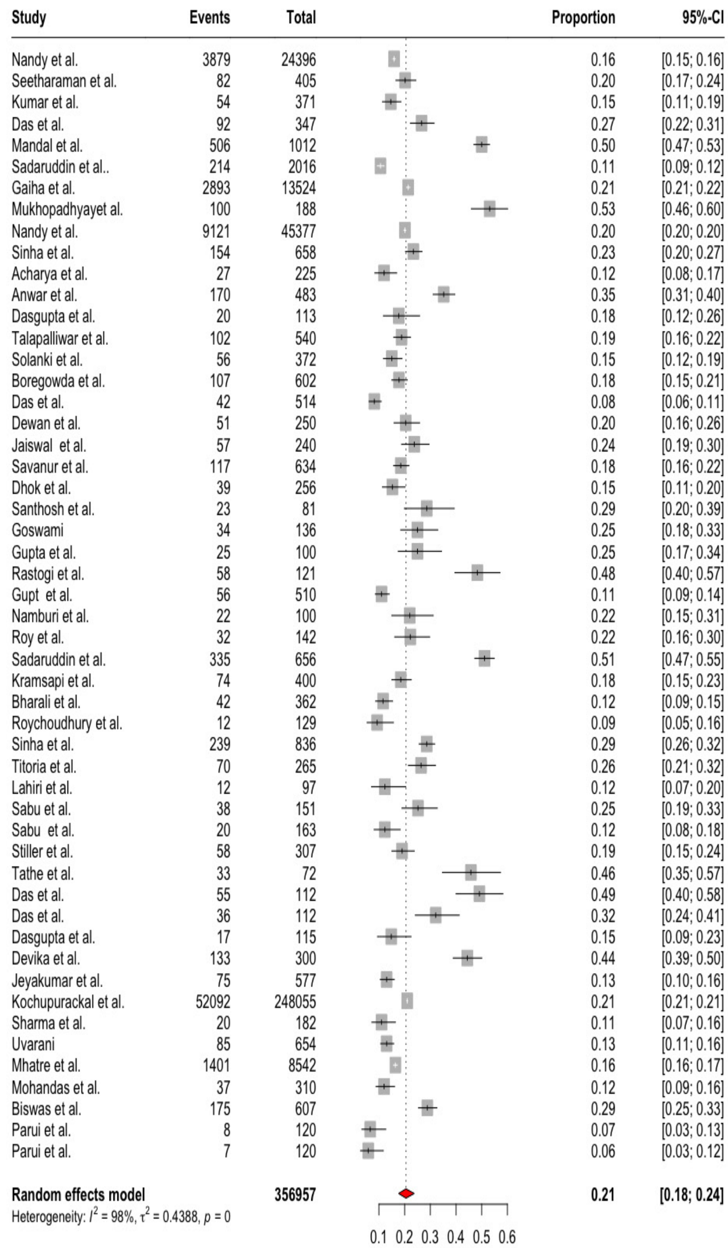

Fig. 4. The forest plot presents the results of the meta-analysis conducted on the variable wasting using a random-effect model. The plot displays individual study estimates (represented by squares) of the effect size, along with their corresponding 95%CI represented by horizontal lines

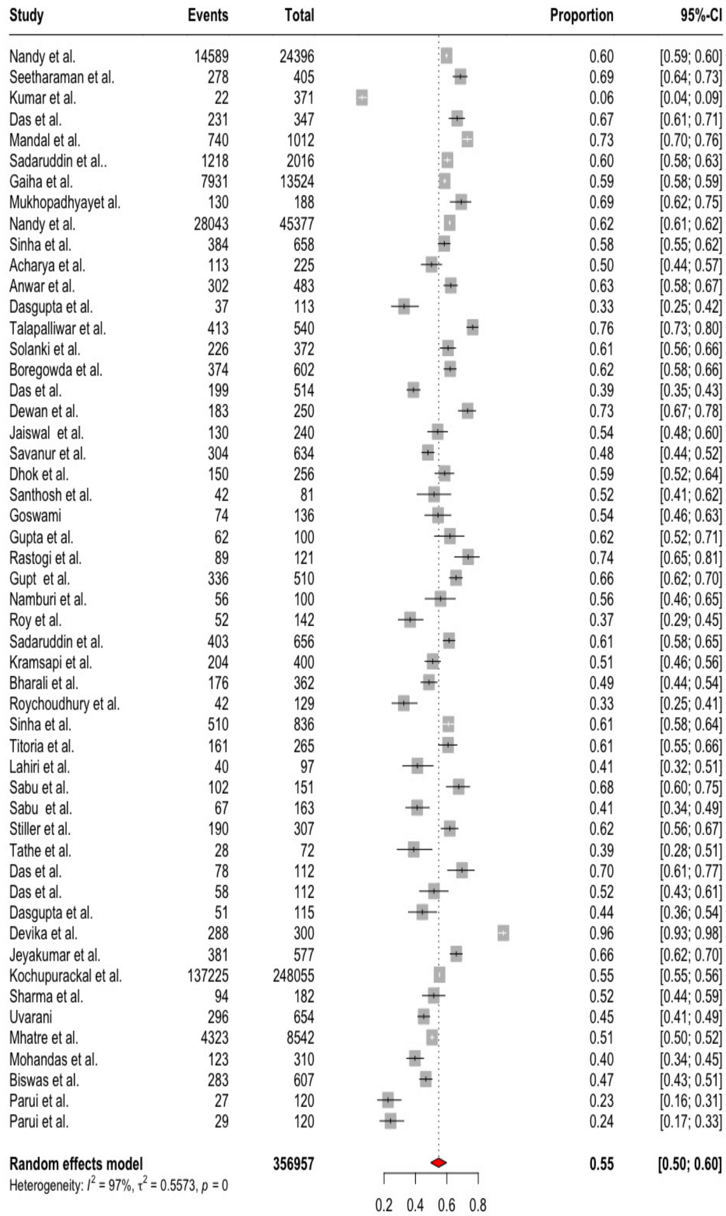

Fig. 5. The forest plot illustrates the results of the meta-analysis conducted on the CIAF using a random-effect model. The plot provides a visual representation of the effect sizes and their 95% CI from individual studies included in the systematic review

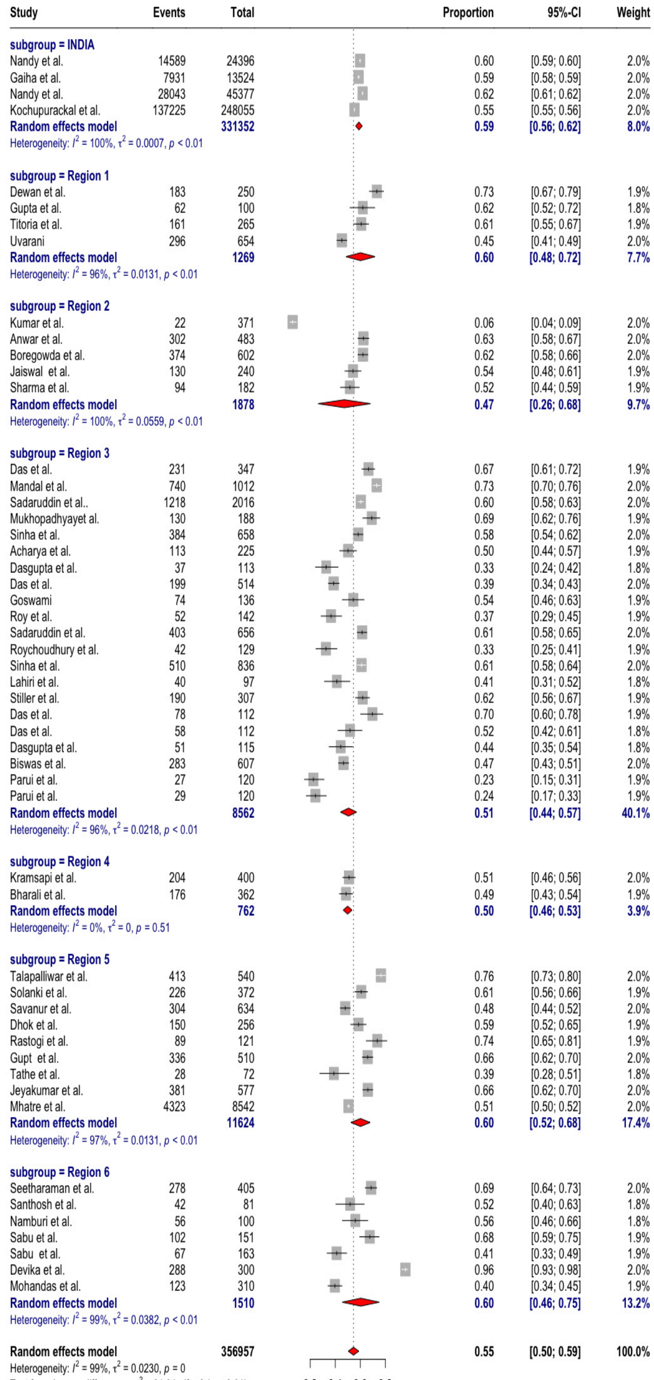

Fig. 6. This forest plot presents the results of the meta-analysis conducted on different regions to assess the proportion of CIAF. Each row in the plot represents a separate region, and the size of the squares corresponds to the weight of the individual studies within the region (Region: North=1, Central=2, East=3, Northeast=4, West=5, South=6)

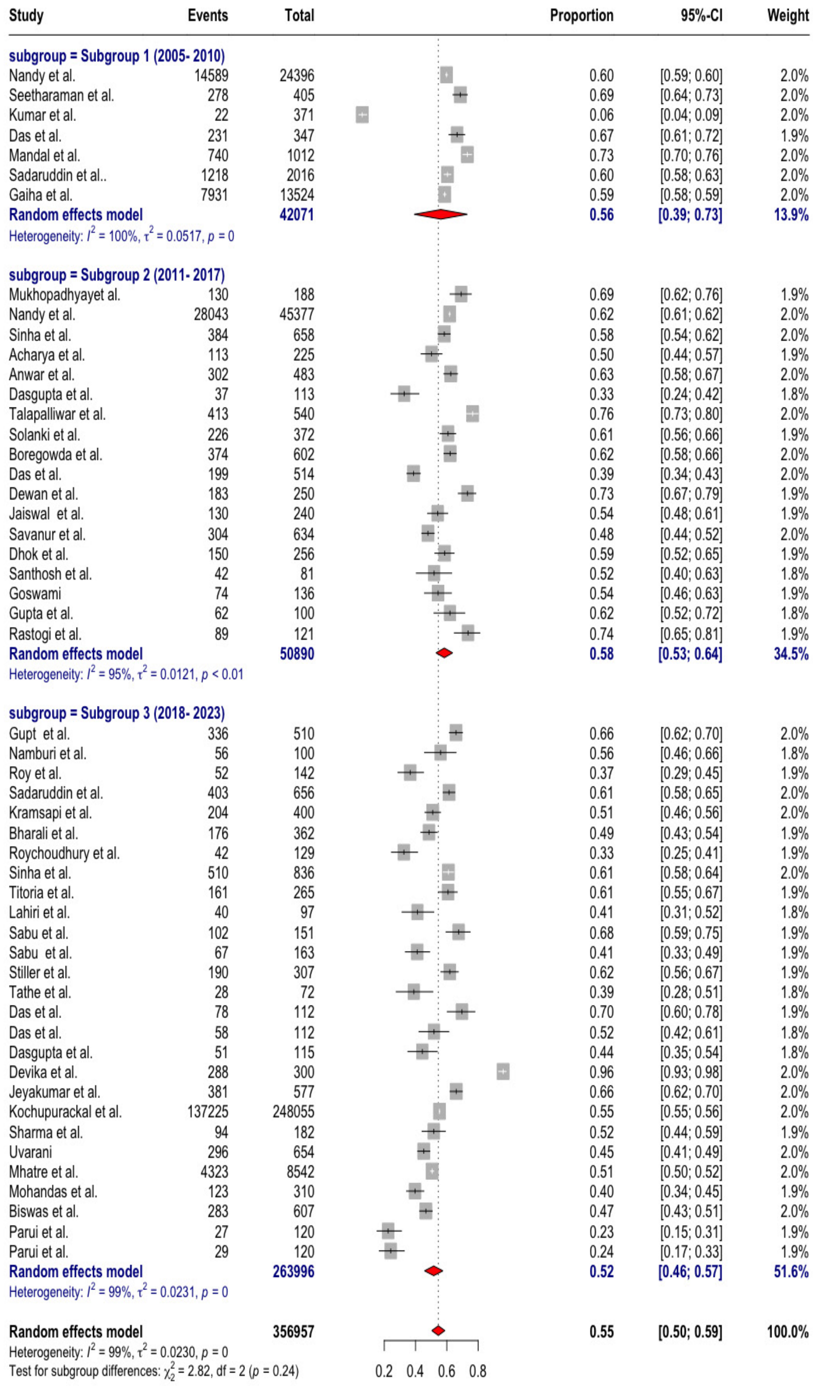

Fig. 7. This forest plot presents the results of the meta-analysis conducted on three sub-groups, representing different time periods (2005–2010, 2011–2017, and 2018–2023), to assess the proportion of CIAF. Each row in the plot represents a separate sub-group, and the size of the squares corresponds to the weight of the individual studies within the sub-group

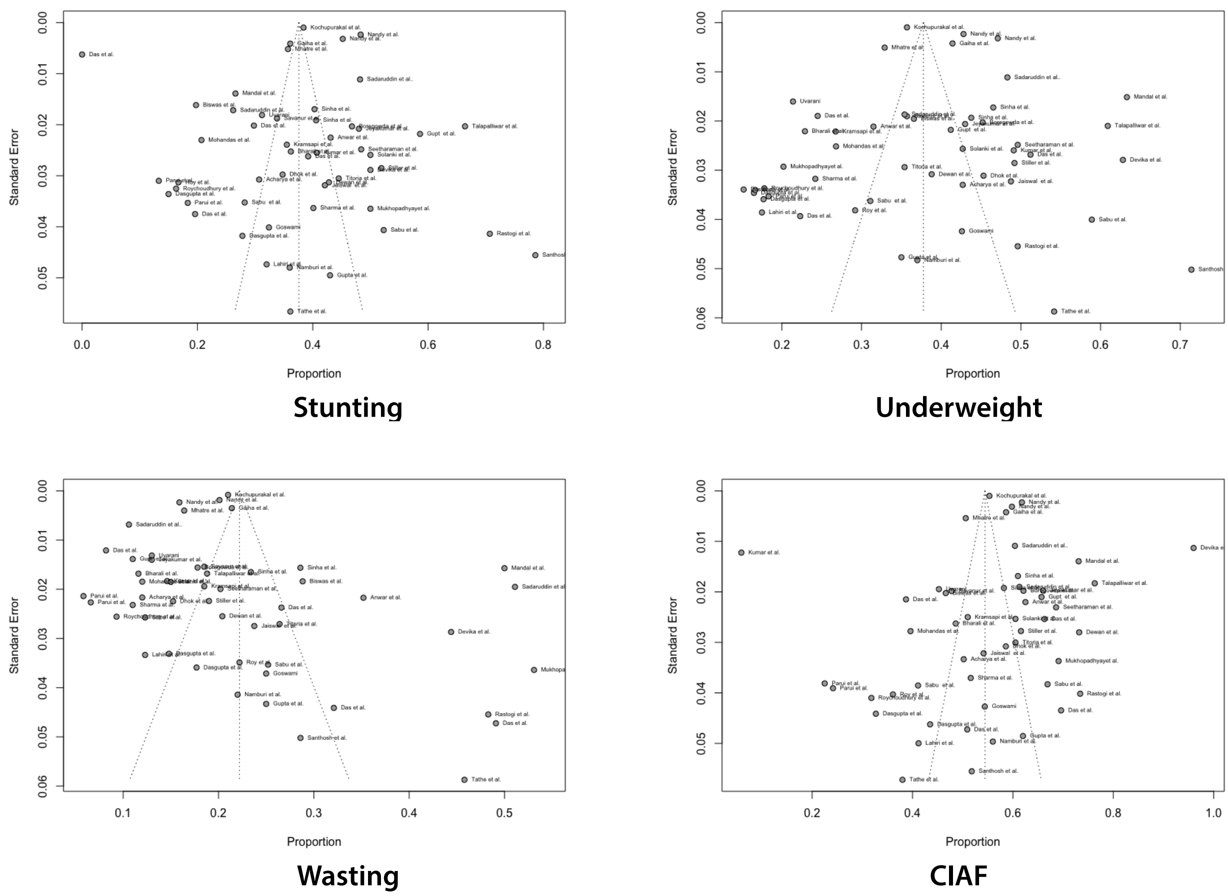

Fig. 8. Funnel plot illustrating the distribution of selected research articles examining publication bias in measured anthropometric indices (stunting, underweight, wasting, and CIAF), the analysis was conducted using generalized linear mixed models methodology

nataka 51.8%,[77] Maharashtra 58.59% and 65.7%,[37,39] Tamil Nadu 96%,[79] Uttar Pradesh 62.5%,[45] West Bengal 31.8% and 22.5%.[42,70] Under 6 years, rural children reflect a proportion in Chhattisgarh 62.1% and 51.6%,[20,68] Haryana 76.3%,[67] Maharashtra 76.3% and 50.6%,[41,46] West Bengal 73.1%, 60.4%, 69.1%, 58.21%, 50.2%, 32.7%, 38.7%, 36.1%, 61.3%, 61%, 61.6%, 50.9% and 46.62%.[19,31,32,34,43,49,50,53-55,69,71,72] Several populations based investigations have suggested that the CIAF may accurately determine the cause-specific mortality and co-morbidity in health records.[19,22,24,31,33,41,42,44,45,48,49,68,69] This specialized ability is beyond the reach of conventional anthropometric indicators, which struggle to distinguish groups of populations facing multiple anthropometric failures related to health and nutritional challenges. The CIAF along with its detailed sub-categories (i.e., B-Y), provides a clear and precise understanding of undernutrition, where conventional indices are unable to determine the actual magnitude due to their overlapping outcomes.[24,31,39,42,66,71,76] However, many children from less privileged backgrounds tend to experience multiple health challenges in their respective measurements.[19,20,30,32,51,70] These children are likely to be susceptible to health risks due to their poor socio-economic conditions, belonging to underprivileged segments, inadequate resource allocation at intra-household level and being unable to utilize appropriate healthcare facilities.[52,54,72,75,78,81] To find out the effects of various determinant variables, including income, education, occupation, demographics and lifestyle, on CIAF, in-depth analysis becomes necessary at population levels.[9,54,72,75] Several studies have reported the connections between different types of anthropometric failures or nutritional deficiency related issues and socio-economic, demographic, and lifestyle factors in the population.[31,36,49,42,52,72,73,75] This valuable information can be helpful to guide government agencies and policymakers in constructing effective policies and/or appropriate nutritional intervention programmes.[26,82-84] The present investigation has carried out a systematic review and meta-analysis utilizing standard anthropometric measures and CIAF to describe the magnitude of undernutrition among Indian children (below 6 years old) during an 18-year period (2005–2023). The preva-

Fig. 9. Graphs depict trends among urban, rural, tribal, and slum children from 2005 to 2023 for conventional anthropometric indices and CIAF reporting, providing insights into the evolving undernutrition trend

lence of wasting was found to be 22% (95% CI: 0.18–0.25, p<0.001), and the combined prevalence of stunting and underweight was 37% (95% CI: 0.32–0.41, p<0.01). According to CIAF categorization, the pooled prevalence of undernourishment was reported to be 55% (95% CI: 0.50–0.60, p<0.001). The majority of children scored a higher magnitude of undernutrition on the CIAF, and stunted and underweight children were more common, which suggested the existence of long-term chronic rather than acute undernutrition.[4,9,17,52] Stunting, underweight, wasting, and CIAF are among the more severe types of undernutrition in Indian children under the age of six, according to several studies.[21,25,30,52,83,85-88] The high burden of infectious diseases, recent food insecurity, socio-economic status, and/or the high prevalence of childhood undernutrition all point to a scenario of both chronic and acute undernutrition.[21,24,35,36,43,45,54,71,73,75] It is believed that intra-household food or resource allocation, cultural customs, social influences, environmental factors, and restricted access to healthcare services remain the main contributors to such severe nutritional manifestations in the population.[10,72,85]

In addition to affecting dietary intake, socio-economic status, food preferences or feeding practices, these factors are considered to be crucial for maintaining adequate nutritional status throughout physical growth and development.[35,36,75] Further, food taboos, low hemoglobin levels, and literature was located using electronic databases like PubMed, PMC, Google Scholar, and Scopus. The present investigation did not include any grey literature, theses, dissertations, or research manuscripts from other print or online databases. The time frame for the literature search was limited to June 2005 through June 2023. Only reports which studied Indian children were included in this analysis, and the magnitude of undernutrition was evaluated using both conventional an-

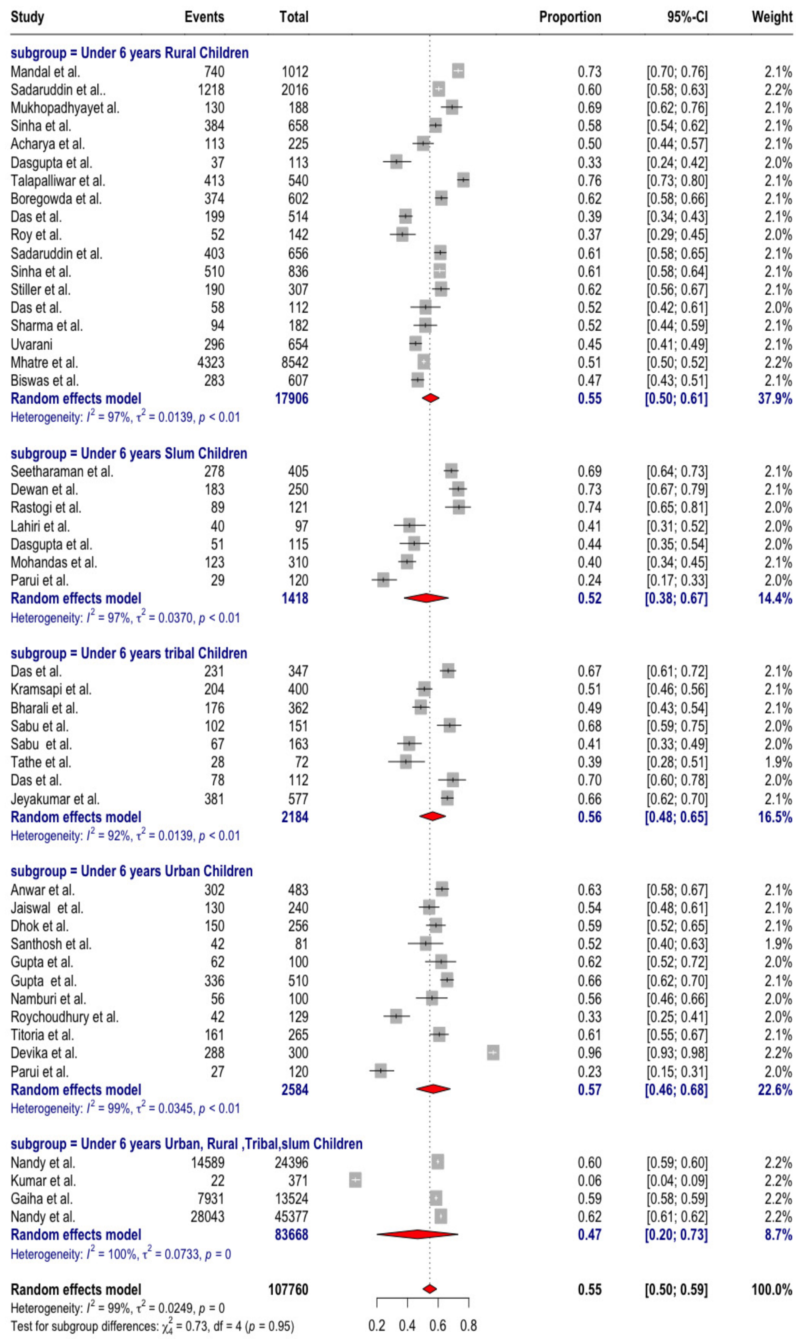

Fig. 10. This forest plot presents the results of the meta-analysis conducted on five sub-groups, representing different study groups that consist of urban, rural, slum, and tribal children, to assess the proportion of CIAF. Each row in the plot represents a separate sub-group, and the size of the squares corresponds to the weight of the individual studies within the sub-group

thropometric measurements and the CIAF. Since only a significant portion of studies were presented in the analysis's use of only English-language published articles, publications on non-Indian children published during the study period and children not found within the considered age groups (e.g., 0–6 years) were not considered for this study. The study's time frame was only between June 1 and July 20, 2023, when the published manuscripts were searched.

Conclusion

India is not an exception to the fact that undernutrition is one of the most serious public health problems in children. Due to demographic disparities, inadequate nutritional status, educational attainment, and food security, children suffer disproportionately from undernutrition in India. The present investigation has utilized both conventional anthropometric measurements and the CIAF to highlight the magnitude of undernutrition in children. Undernutrition was significantly higher in children who received CIAF. The findings shed light on the prevalence and relationships of stunting, underweight, wasting, and CIAF in children. This information can be used to develop evidence-based interventions and policies to combat undernutrition and anthropometric assessment related investigations. It is impossible to overstate the importance of adequate healthcare facilities and maternal education on optimal nutrition for pregnancy and breastfeeding, marriage age, and family planning

Declarations

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Author contributions

Conceptualization, S.S.R. and N.M.; Methodology, S.S.R; Software, S.S.R; Validation, S.S.R. and N.M.; Formal Analysis, S.S.R. and N.M.; Resources, S.S.R; Writing – Original Draft Preparation, S.S.R.; Writing – Review & Editing, N.M.; Visualization, S.S.R and N.M.; Supervision, N.M.; Funding Acquisition, S.S.R.

Conflicts of interest

The authors declare that there are no conflicts of interest.

Data availability

Data supporting the results of this study shall, upon appropriate request, be available from the corresponding author.

Ethics approval

This systematic review and meta-analysis did not involve direct human participation or interaction; hence, ethics approval and consent to participate were not required. However, research ethical guidelines and best practices were adhered to in the selection, review, and reporting of the studies included in this analysis.

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