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Systematic Review Article

Trends in Nutrition Assessment of Adult Population of India: A Systematic Literature Review

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ABSTRACT

Background and Objectives: Nutrition assessment of individuals and populations has been used in itself and as a part of health statistics for a long time. It is used to judge and predict malnutrition, deficiency disorders, disease and treatment outcomes etc. There are continuous and many on going studies being conducted at various parts of India to assess nutrition status. The study aimed to analyze the ongoing trends in nutritional assessment of seemingly-disease-free Indian Adult population in India.

Materials and Methods: A systematic literature review according to PRISMA guidelines was conducted. The database was collected from PubMed. The database included studies from the year 2020. 4 search queries related to nutrition assessments specific to India were made. Studies that met the eligibility criteria i.e., methods and tools used in India for nutrition assessment of general, healthy adult population; were shortlisted and studied. Analytical representations were done with aid of VoS viewer and R Studio.

Results: A total of 736 results of the queries were identified. While focusing on the aim and objectives of the study these were screened and sieved down to eighteen. These were then studied for the tools used, the frequency and repetitiveness of these tools, and how these tools were used singly and in combination to produce better interpretation of the sample population's nutrition status.

Conclusions: As initially predicted, there was a lack in assessments and studies concerning normal adult population. The studies generally focus on specific age groups, physiological conditions, disease conditions or particular nutrients while studying nutritional assessment. Also, even in these studies, there is a lack of a generalised format or tool for nutritional assessment. There lies a need for a standardised format or a tool universal for nutritional assessment of the seemingly healthy adult population of India, so as to ease prediction and prevention of malnutrition of any kind.

Keywords: Nutrition Assessments, Nutritional Assessment, Public Health, Quality of Health Care

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Introduction

Nutritional assessment is the first step to identify nutrition-related problems that arise from nutrient deficiency and lead to chronic disease or result in malnutrition. Assessment of nutrition status can be considered a foundation for assessing and rectifying the diet patterns, coming up with new public policies in the concerned aspects. The aim of this review was to analyze the methods and tools used for assessment of nutritional status of Indians.

Nutritional status assessment can be done by Anthropometric, Biochemical, Clinical, Dietary Assessment (ABCD) methods, however, while Anthropometric assessments lack conciseness/accuracy, biochemical assessment can be expensive to conduct at a large scale, & usually of a specific nutrient. Clinical assessment requires a team of trained individuals for assessing the population, which leads to dietary intake assessment as the most appropriate method for mass study. [1] While searching for a tool that is most suitable for nutritional assessment of Indian population, the researcher came across a lack of a standardized tool available that

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would be appropriate for the universal population of India, and one tool that was used universally. On the quest to understand the pattern of nutrition assessment and tools used for nutrition assessment for Indian adults, focusing on the seemingly healthy population, this study reviewed the database of past works done on seemingly healthy (not diseased) adult population of India.

Exposure & Outcome: The review aimed to study the frequency, patterns, and tools used in nutritional status assessment of the seemingly healthy adult population of India. The endpoint was the trends in the current nutrition assessment scenario in India for this population and the frequency of recent studies concerning this population, as depicted in Fig. 1. The review highlights the lack of work done to assess the nutritional status of this population and the lack of a standardized tool available to evaluate dietary quality and nutritional status assessment in the Indian adult population.

2. Methods

2.1 Inclusion & Exclusion Criteria: The aim was to assess the variety and frequency of tools used to assess the nutrition status of the general adult population of India. Since the intention was to study the tools used to assess nutrition status of general Indian adult population. Studies concerning infants, children, adolescents, older population and studies concerning specific diseases were not included in the review. Also, studies specific for pregnant and lactating mothers were excluded. Studies with samples that included normal (seemingly healthy) adult population who are not diagnosed with any disease, even if only as a part of the sample population, were included in the review.

2.2 Information Sources: The literatures were sourced from PubMed. Searches with 4 different but topic concerned queries/keywords were made and literatures were collected in November 2024.

2.3 Search strategy: Since we aimed to study Nutrition Assessment tools and **current** trends in Nutrition Assessment, all the literatures from 01/01/2020 till the date the database was accessed, i.e. 22/11/2024, were collected to be a part of the review. 2 preliminary filters were used – (1.) Publication date – "From 2020"; (2.) Language – "English".

2.4 Study Selection and Extraction Process: Only one of the researchers was involved in collection and sorting of the works. A literature search across Pubmed with 6 keywords 'nutrition assessment, India - 188', 'nutritional assessment, India - 201', 'dietary assessment, India - 204', 'adult, nutrition assessment, India - 40', 'adult, nutritional assessment, India - 42', 'adult, dietary assessment, India - 61' was done to gain results from the year 2020. We collected 188, 201, 204, 40, 42, and 61 results from the above searches respectively and a total of 736 results were collected. The studies were scrutinised by the researcher manually for their compliance with the inclusion criteria. After manually sorting through these, 328 duplicates were removed and 163 were found irrelevant. Out of 245 remaining, on further sorting 131 more were found irrelevant. Out of 114 remaining relevant works. 59 works dealt with old or too young people, 28 dealt with one or more diseases, 6 were concerned with pregnant or lactating women, which left us with 21. 3 [2–4] out of these were not available in open access, therefore, 18 works dealing with nutrition assessment of normal, seemingly healthy adult population were studied in this review. No automation tool was used for these sorting and sieving processes. The proportion distribution of published works according to their target population is depicted in Fig 1.

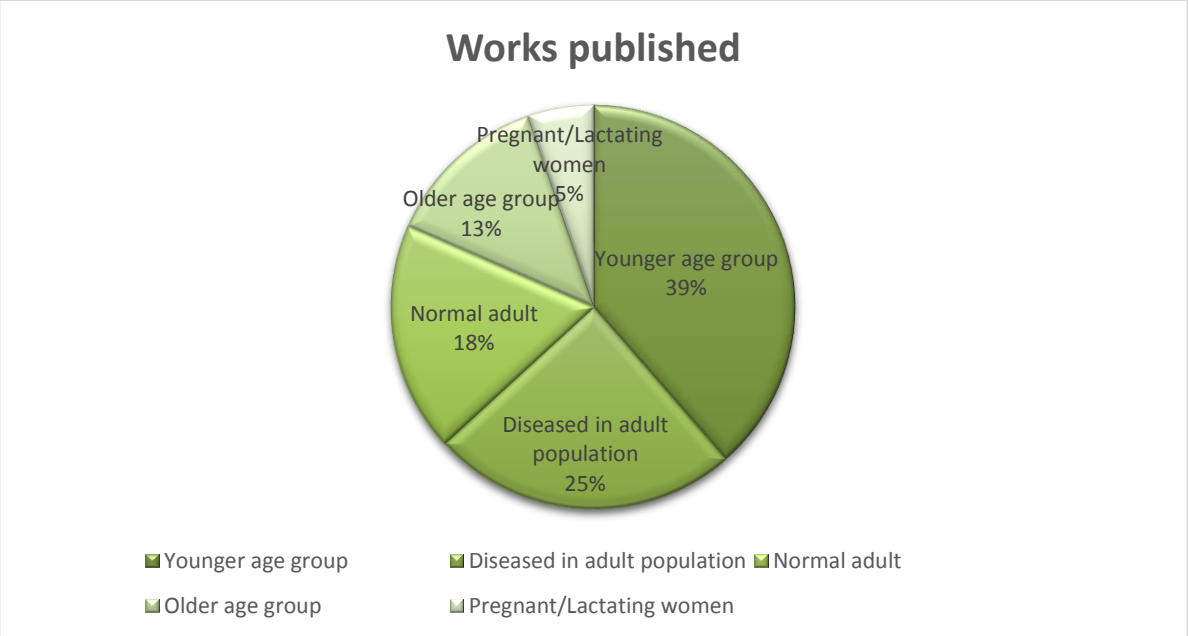

Figure 1. Classification of papers according to their target population

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First the collected works were manually sorted to remove all works which were not concerned with the assessment of nutritional status of humans. The remaining works were then sorted according to age, physiological conditions (i.e. pregnancy, lactation), disease, nationality and nutrients assessed. Works that dealt with Nutrition assessment (using at least any one of the ABCD Nutritional assessment tools) of seemingly-disease-free Indian Adults aged between 18-65 years of age were kept to be a part of this review.

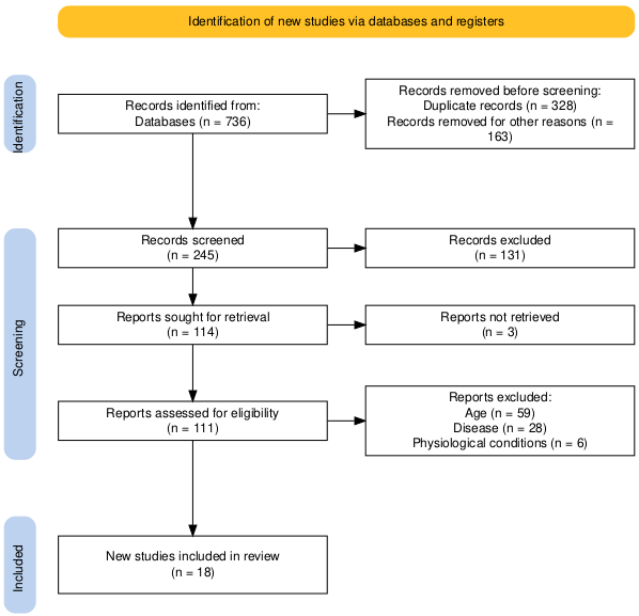

Figure 2. PRISMA flowchart [5]

2.5 Data Items: Data were sought for variables – Nutrition assessment; Dietary assessment; India; All genders; Adults (aged between 18-65 years); Non-diseased; Non-disabled; Non-pregnant; Non-lactating people; Assessment tools. The studies where the population sample included larger age group while including age we attempted to study were also included.

2.6 Analysis: Preferred Reporting Items for Systematic Reviews and Meta-Analyses **(**PRISMA) [5] was used to sort through the database for a systematic literature review. (Figure 2) Tools like Vos Viewer, RStudio, were used to analyze and show the observations in pictorial form.

2.7 Reporting Bias Assessment: Risk of Bias was assessed using the Mixed Methods Appraisal Tool (MMAT) tool [6]. Section 1, which is common for all types of research studies, as well as Section 4, which is concerned with Quantitative Descriptive Studies, were used to analyze methodological quality of the papers selected in the review.

3. Results

3.1 Methodology used: The collected papers used a variety of study designs including descriptive cross-sectional surveys, program evaluation, questionnaire validation study, study protocol, etc. The works were done from various regions of India and in diverse settings. The key research areas include malnutrition: both under and overweight; Validation and reproducibility of dietary assessment tools: specifically Food Frequency Questionnaires (FFQs); health behaviour among specific groups: like boxers, workers, students.

3.2 Aims and Purposes of the studies:

3.2.1. Assessment of Nutritional Status, Dietary Intake, and Associated Factors: A primary purpose across several studies was the assessment of the nutritional and health-status of specific groups in India:

A. Oral Health and Nutritional Status: One objective was to assess the oral health and nutritional status among school teachers in Dharamshala city, Himachal Pradesh. They aimed to establish baseline information in Dharamshala where healthcare facilities are less available. [7]

B. Farm Women's Nutritional Security: A study aimed to examine and analyze the dynamics of nutritional status based on dietary intake among farm women in Madhya Pradesh. The driving force was the ongoing concern about the nutritional security of women working in agriculture, especially since their average caloric intake is low and empirical data is needed for region-specific initiatives**.** [8]

C. Meitei Community Diet and Malnutrition: Research was conducted to determine the food consumption pattern and nutritional status of children, adolescents, and women of reproductive age (WRA) in the Meitei community of Manipur. The goal was to acquire data on food and nutrient intake to understand the dietary adequacy and prevalence of malnutrition, for forming future strategies for improvement.[9]

D. Older Adults and the Elderly: A study intended to estimate prevalence of malnutrition among older adults (45–59 years) and the elderly (60 years and above) based on socioeconomic and demographic characteristics, and to examine the risk factors, since malnutrition is a significant risk in the older population. [10]

E. Ultra-Processed Food and Micronutrient Inadequacy: One study sought to assess the contribution of ultra-processed foods (UPFs) to macronutrient intake and the risk of micronutrient inadequacy in the diet, while also assessing diet diversity, specifically among adults in upper-middle and high-income groups in Delhi. The study dealt with the 'triple burden of malnutrition' and the increased risk of non-communicable diseases (NCDs) resulting from UPF consumption. [11]

F. Athlete Energy Availability: Research was undertaken to assess the Energy Availability (EA) of Indian boxers (lightweight category) and to correlate it with factors that contribute to it such as body composition, anthropometric measurements , nutrient intake, dietary intake, and exercise energy expenditure (EEE). [12]

3.2.2. Validation and Development of Dietary Assessment Tools: A few studies focused on validating

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and developing dietary assessment instruments essential for long-term epidemiological research:

A. Global Diet Quality Score (GDQS) Validation: This study aimed to validate Global diet quality score (GDQS) for use in South India by examining its association with various NCDs and undernutrition indicators among non-pregnant women of reproductive age. The purpose was to develop a tool capable of monitoring population trends in diet quality relevant to the prevalent "double burden of malnutrition" in settings where resources are limited, like India. [13]

B. Cobalamin FFQ Development: The primary objective was to develop and validate a quick and easy-to-use Food Frequency Questionnaire for estimating dietary intake of Vitamin B12 (COIN-FFQ) in North Indians. [14]

C. MDRF-FFQ Validation: One objective was to assess reproducibility and construct validity of the Madras Diabetes Research Foundation FFQ (MDRF-FFQ) using serum lipids as biomarkers, and thereby creating a tool for large-scale epidemiological studies in India. [15]

D. South Kerala FFQ Validation: This research aimed to develop and validate a self-administered 360-item FFQ designed to assess dietary intake of the population in Trivandrum, Kerala, against a 7-day Food Diary. They aimed to establish a suitable, economical tool for epidemiological studies to explore relationships between dietary intake and health outcomes. [16]

3.2.3. Comprehensive Health and Socioeconomic Surveys: Several studies aimed to capture holistic health data:

A. Tribal Health Assessment (Odisha): The Odisha Tribal Family Health Survey (OTFHS) aims to describe and compare the health status of tribal communities in Odisha and to estimate the prevalence of key maternal-child health indicators and chronic diseases. [17]

B. Tea-Garden Workers Morbidity and Nutrition: The research purpose was to assess the morbidity pattern and nutritional status of tea-garden workers of West Bengal, India. [18]

C. Indigenous Food Environment and Biomarkers: A study intended to understand the links between indigenous food access, dietary intakes, and biomarkers (iron, vitamin A, and inflammation markers) among women of the Santhal Community in Jharkhand. This was motivated by the paradox of indigenous communities having access to biodiverse, nutrient-rich environments yet still suffering high rates of anemia and undernutrition, requiring objective biomarker measurement. [19]

D. Medical and Nursing Students' Lifestyle: The purpose was to identify and assess all six components of the Health-Promoting Lifestyle Profile-II (HPLP-II) among medical and nursing students in central India. The goal is to raise awareness and encourage these future health practitioners to evaluate and prioritize healthy behaviors like physical exercise and diet, especially given the rising risk of lifestyle-related chronic diseases. [20]

3.2.4. Food Insecurity and Socio-Behavioral Determinants: A key focus of several studies was understanding the complex factors driving food insecurity, especially concerning gender and unexpected societal shocks:

A. COVID-19 Lockdown Impact: The study aimed to assess the nutritional profile and associated anthropometric changes of women handloom workers before and during the COVID-19 pandemic lockdown, and to evaluate their occupational stress levels and psychological well-being. [21]

B. Gender Roles and Food Insecurity: Research proposed to investigate the experience of food insecurity among women in India, specifically aiming to determine their role in food production, examine gender roles and decision-making processes influencing food security, and investigate household nutritional status, to investigate the deeper social and cultural factors contributing to chronic food insecurity. [22]

C. Food Insecurity Experience Scale (FIES) and Socio-Demographic Determinants: A study aimed to measure food insecurity and explore its association with Body Mass Index (BMI) among Indian adults. This addressed the lack of standardised assessment tools being used in India for monitoring this critical public health problem. [23]

3.2.5. Evaluation of Nutrition-Sensitive Interventions: One study specifically evaluated the effects of a large-scale government program:

A. Agroecology Program Impact: The objective was to evaluate the potential impact of a nutrition-sensitive agroecology program (which included homestead food production, nutrition counseling, and cooking demonstrations) on adult and child dietary diversity, nutritional status, and child development. This program aimed to provide large-scale, evidence-based results, particularly concerning metrics often overlooked in similar studies, such as child development, maternal/child anemia, and men's dietary diversity. [24]

3.3 Tools used: A variety of tools were used to assess nutritional status of the respective sample population including anthropometric assessment, biochemical assessment, 24-hr dietary recall, multiple 24-hr dietary recall, food diary, FFQ, specific questionnaires and tools like HPLP-II, SGA, MNA. Some studies used 1 tool while some used a combination of tools. Also, certain studies were done to validate a prepared tool.

16.67% (n=3) of the works used only 1 tool to assess nutritional status. 72.22% (n=13) studies used anthropometry to gauge nutrition status. 0.06% (n=1) out of which used anthropometry alone while 88.9% used

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anthropometry along with other tools. 38.89% (n=7) studies used biochemical assessment to gauge nutrition status. Biochemical assessments were used along with other tools. 33.33% (n=6) studies used multiple 24-hr dietary recall, while 22.22% (n=4) used single 24-hr dietary recall.

3.3.1. Anthropometric Assessments: Anthropometry is a common, cost-effective method used across multiple studies to determine physical status, body composition, and malnutrition prevalence:

A. **Height and Weight:** Measured using standard equipment like **stadiometers** (for adults/older children), **infantometers** (for children below 2 years), and **weighing scales** (digital or electronic).

- **Body Mass Index (BMI)** (weight (kg) / height (m^2)) was calculated using these measurements. BMI was categorized according to established cutoffs to define nutritional grades such as underweight, normal, overweight, and obese.

B. **Circumferences:**

- **Mid-upper arm circumference (MUAC)** and **Waist circumference (WC)** were measured using non-stretchable metallic-tape.
- **Waist-to-hip ratio (WHR)** was measured by an ergonomic circumference-measuring tape and was analyzed to assess the risk of metabolic diseases.

3.3.2. Dietary Intake Assessment Tools: These tools collect data on specific food consumption patterns over varying time frames to determine nutrient adequacy and diet quality:

A. **24-Hour Dietary Recall / Multiple-Pass Method:** Used to collect detailed, day-specific information about the consumption of all foods and drinks.

B. **Food Diaries (FD):** Considered a robust reference method, the 7-day food record was used to validate a Food Frequency Questionnaire in Kerala.

C. **Food Frequency Questionnaires (FFQ):** These questionnaires estimate habitual or long-term dietary intake over a specific period.

- **Semi-quantitative FFQs:** Used widely as they are low cost and cause minimal burden to the participant. They list food items and require reporting frequency and portion size.
- **MDRF-FFQ:** The Madras Diabetes Research Foundation FFQ is a comprehensive, structured, quantitative national FFQ containing 236 food items developed for rural and urban Asian Indian adults. It was evaluated for reproducibility and construct validity. [15]
- **South Kerala FFQ:** A 360-item FFQ designed to assess intake in Trivandrum, Kerala, validated against 7-day Food Diary.[16]
- **COIN-FFQ:** A newly developed and validated 30-food items food frequency questionnaire for Cobalamin Intake in North Indians, specifically focused on estimating dietary intake of Vitamin B12. Its validation process included comparing results against 72-hour dietary recall and biochemical markers.

D. **Food Frequency Assessment (Checklist):** Used to observe how often or how frequently an individual eats a certain food group, alongside portion-size assessment, particularly relevant when studying changes related to socioeconomic factors or external shocks like the COVID-19 lockdown.

3.3.3. Diet Quality and Diversity Assessment: These tools specifically measure the variety and quality of the diet consumed:

A. Individual Dietary Diversity Score (IDDS) / FAO-DDS: Used to assess the quality of the diet based on the consumption of defined food groups over a reference period (usually 24 hours). The number of food groups consumed yields a score (e.g., maximum score of 7 or 9 food groups depending on the study). [11,23,24]

B. Women's Dietary Diversity Score (WDDS): Used to assess dietary diversity at the individual level among women handloom workers, categorized based on nine food groups proposed by the Food and Nutrition Technical Assistance (FANTA). This tool reveals the micronutrient adequacy of the diet. [21]

C. Global Diet Quality Score (GDQS): A novel food-based scoring system derived from 25 food groups (16 healthy, 9 unhealthy) designed to capture diet quality in relation to the **double burden of malnutrition**. It provides scores based on the frequency and quantity consumed. [13]

D. Minimum Dietary Diversity for Women (MDD-W): This is a binary indicator, used to measure nutrient adequacy among women. It is based on 10 food groups. [13,19,24]

E. Dietary Species Richness (DSR): Measures food biodiversity by counting the number of different species that are consumed by an individual in one day, which serves as a measure of micronutrient adequacy. [9]

F. Food Access Diversity Index (FADI): An index developed to measure access to diverse natural food sources available for indigenous communities, which is expressed as a ratio of number of foods accessed to the maximum possible number in the village. [19]

3.3.4. Biochemical and Clinical Measures: To obtain objective data on nutritional status and health outcomes, several clinical and laboratory tools were used including:

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A. Hemoglobin (Hb) Measurement: Used to assess anemia prevalence. Methods include:

- **Digital Hemoglobinometer:** Used in the OTFHS [25]. [17]
- **Mission1Hemoglobin system:** A point-of-care device using capillary blood. [24]
- **Filter paper cyanmethemoglobin method:** Used in the tea-garden workers study. [18]
- **Colorimetric method (cyanmethemoglobin):** Used to estimate Hb from dried blood spots method (DBS) in Santhal community study. [19]

B. Serum Lipids: triglycerides, high-density lipoprotein, low-density lipoprotein, and total cholesterol were measured from fasting venous blood samples using auto analyzers. These serve as biomarkers for validating fat and carbohydrate intake/diet quality related to chronic disease risk. [13,15]

C. Micronutrient and Inflammatory Biomarkers: Measured in venous or capillary blood samples, these were analyzed to objectively quantify nutritional status. Iron status [19], Vitamin A status [17,19], Inflammatory Markers [19], and Vitamin B12 Biomarkers [14] were assessed.

D. Assessment of Physical Activity and Energy Expenditure: Training records and MET (Metabolic Equivalent of Task) values were used to compute Exercise Energy Expenditure (EEE). [12] Energy Availability (EA) was computed using the formula: EA (kcal/kg FFM/day) = (EI - EEE) / FFM (where EI is energy intake and FFM is fat-free mass) to identify low energy availability (LEA) in athletes. [12] To assess Physical Activity Level (PAL) MDRF Physical Activity Questionnaire (MPAQ) was used. [15]

3.3.5. Other Tools

A. Household Food Security Scales: FIES [23], and United States Department of Agriculture Household Food Security Scale Measurement (USDA-HFSSM) [22] were used to gauge the perceived experience of food scarcity due to resource constraints.

B. Depression Anxiety Stress Scale (DASS) [21] **:** A tool used to assess psychological well-being (depression, anxiety, and stress) among women handloom workers, as these factors can affect nutritional intake and health status.

C. Health-Promoting Lifestyle Profile-II (HPLP-II) [20] **:** A questionnaire with 52 items across six subscales (where Nutrition and Physical Activity were also a part) used to assess health-promoting behaviours among medical and nursing students.

3.4 Analysis methods used: The analysis tools used in the research studies were robust and diverse, reflecting the complexity of assessing nutritional status, dietary patterns, health behaviors, and the impact of interventions within diverse Indian populations. These methods are as follows.

3.4.1. Epidemiological and Statistical Modeling: Statistical techniques were used to report descriptive data, to establish relationships, assess prediction accuracy, and handle complex data distributions.

- **For Association and Comparison:** Various statistical operations were used in the studies, like **T-tests and Mann–Whitney U tests** [7,11,12,14,16,19–21,23,24], **Chi-square test (χ^2):** [7,9,11,14,15,18,21], **One-Way ANOVA** [7–9,19,20], **Multivariate Linear Regression Analysis** [7,10,12,15,19,23,24], **Multiple Linear Regressions** [7,12,15,19,23,24], **Logistic Regression (Multivariate)** [9,10], **Linear Mixed Effects Regression (LMER)** [19], **Spearman Rank Correlation Coefficients (ρ)** [11,13,14,16], and **Rasch Model** [23]
- **For Advanced Modeling and Validation:** Studies used analysis methodologies that aligned to their aims and research, like **Mediation Analysis** [23], **Classification and Regression Tree (CRT) analysis** [8], **Cluster Analysis** [8], **Bland–Altman Analysis** [15,16], **Reproducibility Assessment** [14–16]

3.5 Nutritional status: Most studies concluded that the adult population of India sees a great deal prevalence of double burden of malnutrition. Among elderly population (aged above 60) 28% males and 25% females were underweight, and among older population (aged between 45-59 yrs of age) 37% females and 25% males were either overweight or obese. [10] Among working women, 28% were underweight and 19.6% were categorised either overweight or obese. [8] From the study done on Meitei community women, 6.9% women were underweight and 28.2% overweight/obese. [9] In South Kerala, 40.7% of the validated sample were overweight or obese. [16] Micronutrient deficiencies of almost all nutrients were seen in women from Santhal tribe, with iron deficiency upto 73%. [19] Calcium and iron intake deficit was seen in female boxers, while zinc and folate intake were lacking in both male and female boxers. [12] Vitamin B12 deficiency and Anemia was seen in Northern Indians. [14] In Delhi, Ultra-processed foods contributed 17% of total energy intake, 20% of total fat, and 33% of Na intake, among upper-middle and high-income adults in Delhi. [11] The risk of inadequacy for Iron, Vitamin B6, and Vitamin A was significantly higher among females, while the risk for Zinc, Folate, and Niacin inadequacy was significantly higher among males. [11]

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Table 1. Nutritional Assessment Tools used in the studies

Title	Anthropometric Assessment	24 hr dietary recall	Multiple 24 hr dietary recall	Questionnaire	FFQ	Food diary	DDS	Biochemical	No. of tools used
Assessment of Nutritional Status and Energy Availability of Indian Boxers [12]	✓		✓		✓				**3**
Assessment of nutritional status and habitual dietary intake of Indian farm women: Evidence from a case study in central India [8]	✓	✓		✓					**3**
Assessment of nutritional status using anthropometric index among older adult and elderly population in India [10]	✓								**1**
Assessment of Oral Health and Nutritional Status of School Teachers in Dharamshala City, Himachal Pradesh [7]			✓						**1**
Cobalamin Intake in North Indians by Food Frequency Questionnaire (COIN-FFQ) - A Development and Validation Study [14]	✓		✓		✓			✓	**4**
Contribution of natural food environments to nutritional intake and biomarker status: insights from the women of indigenous santhal communities of Jharkhand, India [19]			✓				✓	✓	**3**
Dietary adequacy and nutritional status of Meitei community of Manipur, Northeast India [9]	✓	✓					✓		**3**
Documenting the Food Insecurity Experiences and Nutritional Status of Women in India: Study Protocol [22]	✓		✓						**2**
Effect of Covid 19 lockdown on the lifestyle and dietary diversity of women handloom workers [21]	✓	✓			✓		✓		**4**
Evidence of potential impacts of a nutrition-sensitive agroecology program in Andhra Pradesh, India, on dietary diversity, nutritional status, and child development [24]	✓	✓					✓	✓	**4**
Food insecurity and its determinants among adults in North and South India [23]	✓			✓	✓		✓		**4**
Health Promoting Lifestyle Profile Assessment among Medical and Nursing Students of Central India [20]				✓					**1**
Intake of ultra-processed food, dietary diversity and the risk of nutritional inadequacy among adults in India [11]			✓				✓		**2**
Odisha tribal family health survey: methods, tools, and protocols for a comprehensive health assessment survey [17]	✓			✓				✓	**3**
Poverty, undernutrition and morbidity: The untold story of tea-garden workers of Alipurduar district, West Bengal [18]	✓							✓	**2**
Reproducibility and construct validity of a food frequency questionnaire for assessing dietary intake in rural and urban Asian Indian adults [15]	✓				✓			✓	**3**
The Evaluation and Use of a Food Frequency Questionnaire Among the Population in Trivandrum, South Kerala, India [16]					✓	✓			**2**
Validation of Global Diet Quality Score Among Nonpregnant Women of Reproductive Age in India: Findings from the Andhra Pradesh Children and Parents Study (APCAPS) and the Indian Migration Study (IMS) [13]	✓				✓		✓	✓	**4**
	13	4	6	4	7	1	7	7	

3.6 Subgroup Analysis : A subgroup analysis was done for subgroups namely residence (rural/urban), geographical region, gender, age, wealth/income, educational level, and underlying health/dietary habits (e.g., vegetarianism, physical activity level, intervention exposure) for the collected papers and it gave a gist of how certain variables/factors influence diet quality and nutritional status of the population.

3.6.1. Demographic Subgroups

A. Gender: Gender was a crucial factor influencing diet quality, nutritional status, and health-promoting behaviors in several studies. Micronutrient deficiencies

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were prevalent for both the genders. Food intake is more in males than in females, which could be due to various factors included in which is the patriarchal structure of society.

B. Age Group: Several nutritional inadequacy findings were stratified by age, particularly among younger and older populations. Since the target population for this study was 18-65 yrs of age, we would report findings of that specific age group even when a few of the studies included a aleger bracket of age groups in their studies. The study that divided the age group further noted better GDQS score in younger people than older people.

A. Residence (Urban vs. Rural) and State: Differences were observed between rural and urban populations, as well as between distinct geographical states (Sonipat/Vizag, regions in the MDRF-FFQ study). Availability and accessibility might lead to better dietary diversity among people in urban localities than in rural localities.

A. Dietary Habits and Diversity: Theoretically, non-vegetarians should have better dietary diversity than vegetarians, this was proved in the studies to be true.

Table 2. Subgroup Analysis - Gender

Study	Subgroup Variable	Primary Findings
Ganpule et al. (Food Insecurity)	Food Insecurity (FIES)	Food insecurity was reported to be more common among women than men. [23]
Khan et al. (Older Adults)	Underweight/Overweight	Underweight was higher among elderly males (28%) than elderly females (25%). Overweight/obesity prevalence was higher among older adult females (37%) compared to males (25%). [10]
Mediratta et al. (UPF Intake)	UPF Intake and Micronutrient Risk	Ultra-processed foods led to a higher intake of energy, protein, fat percentage, carbohydrate, and free sugar in males. Risk of micronutrient inadequacy, specifically of Zinc, Folate, and Niacin was seen higher in males, while risk for Iron, Vitamin B6, and Vitamin A was significantly higher among females. Males also had significantly higher Dietary Diversity Scores (DDS). [11]
Rathod & Chandorkar (Boxers)	Macronutrient Intake	Higher intake of energy, carbohydrates, protein, and dietary fiber was seen in males compared to females. Female boxers could not fulfill the Estimated Average Requirement (EAR) for calcium and iron, whereas both genders failed to meet zinc and folate recommendations. [12]
Chouhan S et al. (Students)	Health Promoting Lifestyle	Male MBBS students had significantly higher scores than female MBBS students in Health-Promoting Lifestyle, Nutrition, Physical Activity and Health Responsibility. No significant gender differences were found among MD/MS students. [20]
Vijay et al. (FFQ Validation)	Reporting Bias	Women tended to over-report nutrient intakes when the Food Frequency Questionnaire results were compared with against the Food Diary (FD) reference method. [16]

Table 2. Subgroup Analysis – Age group

Study	Subgroup Variable	Primary Findings
Loukrakpam et al. (Meitei Community)	Micronutrient Inadequacy	The prevalence of micronutrient inadequacy was highest in children aged 1–7 years (45%) compared to other age groups (e.g., WRA 35%). [9]
Matsuzaki et al. (GDQS Validation)	Diet Quality Score	The mean GDQS score was significantly higher in the younger age subgroup (15–29 years, mean 23.2) compared to the older subgroup (30–49 years, mean 22.8) [13]

C. Socioeconomic Status (Wealth, Education, Income)

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Table 3. Subgroup Analysis - Socioeconomic Status

Study	Subgroup Variable	Primary Findings
Ganpule et al. (Food Insecurity)	Wealth Index	Those with the lowest wealth were more likely to experience food insecurity than those with higher income. The relationship between FIES and wealth index was consistently significant across all quintiles, with increasing wealth associated with lower FIES scores. [23]
Singh et al. (Santhal WRA)	Education	Women with above primary education had significantly lower mean Retinol Binding Protein (RBP) levels compared to those with primary and below. [19]
Singh et al. (Santhal WRA)	Wealth Index	No statistically significant difference in biomarker levels (RBP, ferritin, sTfR) were found across the five household wealth quintiles. [19]
Vijay et al. (FFQ Validation)	Income	Mean intake of energy, calcium, and phosphorous was significantly lower in the low-income group compared to middle and high-income groups. [16]
Mediratta et al. (UPF Intake)	Income Group	No significant difference in dietary diversity score (DDS) was observed based on income group (upper-middle vs. high-income). Nevertheless, more than half of the individuals with higher incomes consumed milk and milk products, as well as vegetables and fruits, in compliance with recommended intake,s compared to the upper-middle income group. [11]
Yasmin et al. (Tea-Garden Workers)	Social Class	Maximum tea-garden workers were female (76%) and belonged to a backward social class (81.2%) and the lower income quartile (67.2%). For Scheduled Tribe caste, undernutrition, and anaemia were independent determinants of morbidity. [18]

Table 4. Subgroup Analysis - Residence area

Study	Subgroup Variable	Primary Findings
Ganpule et al. (Food Insecurity)	State and Residence	Participants from South India reported higher food insecurity compared to those in North India. Dietary diversity was lower in rural areas compared to urban areas.
Khan et al. (Older Adults)	Residence	Underweight was seen more in rural older adults/elderly, while overweight/obesity was drastically higher in urban areas across all age and sex subgroups.
Sudha et al. (MDRF-FFQ Validation)	Region and Residence	Significant regional differences existed across all assessed regions (North, South, East, West, Northeast) in body weight, BMI, blood pressure, and serum cholesterol. The Northeast region had the highest consumption of refined cereals and animal foods. A higher percentage of rural adults (11.5%) were found to be under-reporters of energy intake compared to urban adults (9.2%).
Vijay et al. (FFQ Validation)	Domicile (Urban/Rural)	Significant differences in nutrient intakes were observed between participants residing in urban and rural areas.
Ch et al. (Agroecology Program)	Village Type (Tribal/Non-Tribal)	43% of intervention villages were classified under 'tribal villages' with 23% of control villages. In child development outcomes, differences between intervention and control villages for the 18–23 months age group were no longer significant after adjusting for tribal status.

Table 5. Subgroup Analysis - Dietary habits and Diversity

Study	Subgroup Variable	Primary Findings
Mediratta et al. (UPF Intake)	Eating Habit (Vegetarian/Non-vegetarian)	Non-vegetarians had significantly higher DDS (5.4) than vegetarians (4.5).
Rawat et al. (COIN-FFQ Validation)	Food Habits (Vegetarian/Non-vegetarian)	The FFQ established discriminant validity by confirming that dietary B12 intake and serum B12 levels were considerably lower in vegetarians than in non-vegetarians.
Loukrakpam et al. (Meitei Community)	Dietary Intake Tertiles	Low intake of food groups such as pulses and legumes and cereals and millets significantly increased risk of micronutrient inadequacy.
Gurung D et al. (School Teachers)	Dietary Compliance	The mean Decay Promoting Potential Score (DPPS) for the "watch out" zone (15 or more) was reported to be higher among private elementary teachers than teachers in other groups across all 5 days of dietary recording.
Gurung D et al. (School Teachers)	BMI and Diet	There was a strong correlation between the Food Group Score (FGS) variation for the Meat Group and BMI category.

B. Physical Activity and Morbidity Status

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Table 6. Subgroup Analysis - Physical activity

Study	Subgroup Variable	Primary Findings
Khadatkar et al. (Farm Women)	Physical Activity Work Group	The farm women were divided into sedentary (4%), moderate (65.8%), and heavy work groups (30.2%). The average age was highest in the sedentary group (43.3 years) and lowest in the heavy work group (33.5 years). [8]
Yasmin et al. (Tea-Garden Workers)	Morbidity Determinants	Among the tea garden workers, anemia and undernutrition were independent predictors of any morbidity. [18]
Chouhan S et al. (Students)	Course (Profession/Training)	Nursing students had significantly higher mean scores than medical students (MBBS/MD/MS) in five out of six Health-Promoting Lifestyle Profile-II (HPLP-II) subscales. [20]

3.7 Sensitivity Analysis: Several, but not all, studies conducted Sensitivity analysis to ensure that the core findings remained consistent when adjusting for key confounding variables, or when altering measurement methods.

3.7.1. Adjustment for Confounding Variables - The agroecology program evaluation and the food insecurity study explicitly used adjusted models as a form of sensitivity analysis.

A. Agroecology Program Evaluation [24]

- **Method:** Adjusted linear regression models were run to account for whether the village was tribal or not. Adjusted models for women and children controlled for their respective ages.
- **Results Consistency:**
  - There were significant differences in women's underweight in the unadjusted model (12% intervention vs 8% control), while they were no longer significant after adjusting for age, village type, and type of scale used.

B. Food Insecurity Study [23]

- **Method:** To study the association between IDDS, BMI, and FIES, adjusted for state, residence (urban/rural), age, sex, and wealth index multivariate linear regression was used.
- **Results Consistency:** The inverse relation between the FIES and IDDS/BMI remained statistically significant in the fully adjusted multivariate model, while the determinants of FIES (state of residence, sex, and wealth index) also remained significant.

C. GDQS Validation [13]

- **Method:** Models examining the association between GDQS quintiles and clinical outcomes were first adjusted for age, and then tested for robustness by running the same models while adjusting for occupation types, education levels and standard of living index scores.
- **Results Consistency:** No differences were found in the study in substantive findings across these more heavily adjusted models, except for the relationship between the GDQS− submetric and waist-circumference, where the value of P changed to 0.077 from 0.033.

3.7.2. Measurement-Related Sensitivity - Two studies specifically addressed the influence of measurement tools or proxies as a form of sensitivity analysis:

A. Agroecology Program Evaluation [24]**:** The study acknowledged that the use of different anthropometry measurement scales influenced results. When measured with analogue scale children were found to be twice as likely to be wasted (23%) as those measured with a digital scale (11%). This highlights a sensitivity to the measurement instrument itself.

B. B12 Validation [14]**:** To establish validity, the COIN-FFQ results were cross-compared against two distinct biomarkers of B12 status: serum B12 and total homocysteine (tHcy). The FFQ intake estimation showed a positive correlation with serum B12 and with tHcy showed a negative correlation. Furthermore, the clinical utility tested by calculating the FFQ intake cut-off for deficiency using both B12 levels and tHcy levels sequentially as the gold standard, demonstrating consistency in the utility of the tool across different biochemical markers.

C. Meitei Community Study [9]**:** The multivariate logistic regression used the Adjusted Odds Ratio (AOR) adjusted for age and gender to confirm that several low food group intakes were significantly associated with micronutrient inadequacy, verifying the robustness of the crude findings.

3.8 Citations: All the studies had 0 citations.

3.9 Thematic analysis: In the initial phase of the collection of works done, the majority of the works revolved around "female" keyword and the majority of the space was cluttered with diseases, which can be seen in the Fig. 3. The Thematic map of selected papers for review was centralized around humans. Fig. 4 shows the occurrences of keywords

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in the collection of papers selected for our review. The most frequent being “humans” followed by “female”.

The Core Focus of the collected research papers is primarily concerned with studies on women ("female" and "humans" are the strongest cluster). The Methodological Priority or the most common and established method used in the collected research papers is is the cross-sectional study design. Topics related to eating, adolescents, and the middle-aged are well-explored and have a strong, clear body of evidence (high development). Research focusing on the aged and on using surveys and questionnaires is currently fragmented, less important, or in decline. These areas are not the focus of current, established efforts. Concepts like diet and energy intake act as central bridges connecting the various themes which can be seen in the thematic map. (Figure 5)

From the frequency of keyword occurrences, it can be perceived that finding nutritional status were not the focal area of the researches, but a part of aims of the researches (Figure 6).

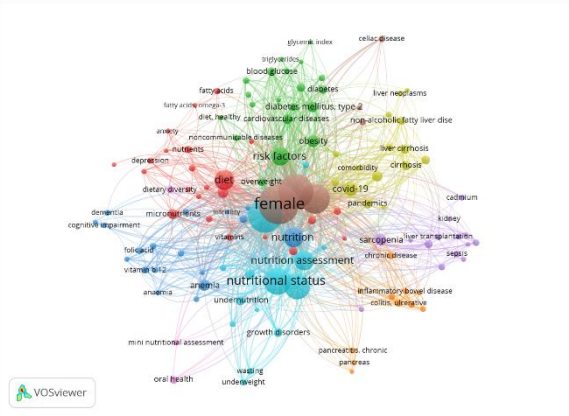

Figure 3. Thematic representation of all the full database

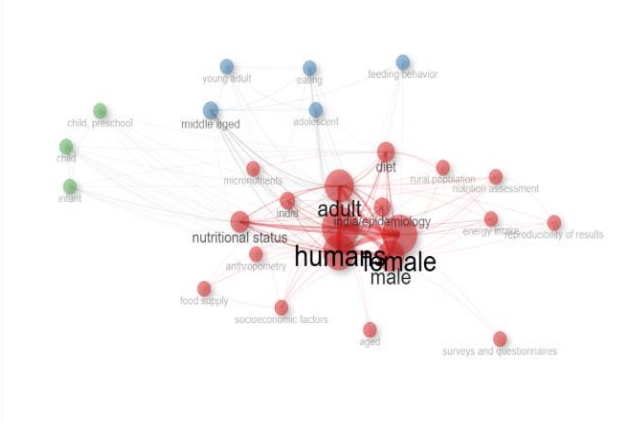

Figure 4. Thematic representation of the works selected for review

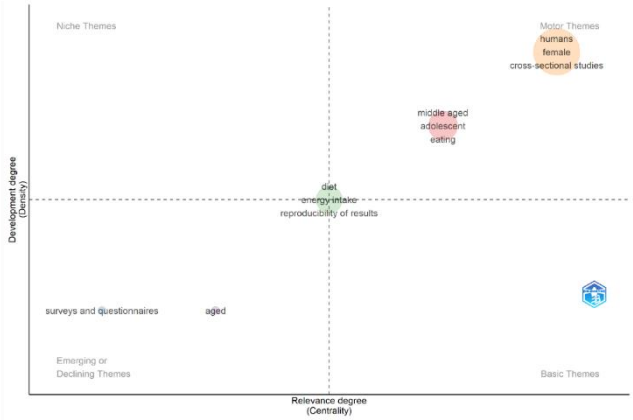

Figure 5. Thematic plotting of topics

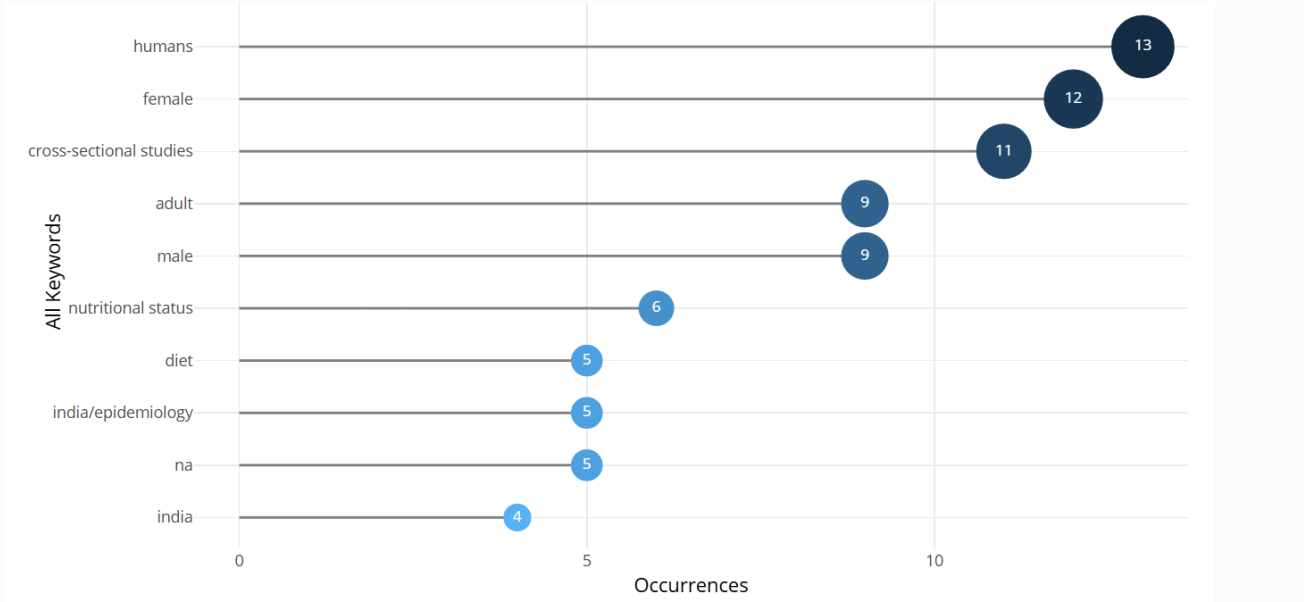

Figure 6. Keyword occurrences in the papers

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Table 7. Summary of the papers included in the review

S. No	Author	Date	Place	Target population	Aim	Sample size	Tools used	Analysis methods	Results
1	**Rathod N, Chandorkar S**	July 3, 2024	Mumbai, Maharashtra, India.	Boxers; Both genders; 18 yrs and above	To assess energy availability of Indian boxers and correlate it with factors like anthropometry, body composition, food intake, and exercise energy expenditure. [12,26]	30 (21 male, 9 female)	Semi-structured questionnaire, anthropometric measurements, body composition, 3-days dietary recall, and exercise energy expenditure calculation.	Descriptive statistics, t-test or Mann-Whitney U test, Pearson's correlation, multiple linear-regression, and moderation analysis.	Diets were deficient in a number of nutrients and food groups. High EA was associated with high energy and nutrient intake, but high fat-free mass was inversely related to EA. The energy intake of male and female boxers differed significantly, with a substantial effect size. Among boxers, underweight -36.67%, normal BMI - 46.67%, and overweight - 16.67%. Majority of the boxers had normal BMI. Participants did not have adequate intake of various food groups both before and after adjustment of the calorie intake. Packaged and/or processed foods intake was common among the participants. The subjects' intake of micronutrients was insufficient. Most of the boxers were unable to meet the daily requirements for energy, carbohydrates, protein, and fat. Among female participants, Iron and calcium intake was inadequate.
2	**Khadatkar A, et al.**	January 21, 2023	Bhopal, Madhya Pradesh (Villages – Dhamarra, Kachhi-barkheda)	Farm workers; Women; 18-60 yrs of age	To understand nutritional status of Farm women of Central India through the dietary intake.	225	Interview schedule and 24-hr dietary recall, Anthropometric measurements	Tabular and visualization analyses, Gini coefficient, Classification and Regression Tree (CRT) analysis, cluster and discriminant analysis.	BMI results indicated 28% of women were underweight, 52.4% normal, 17.8% overweight, and 1.8% obese. The actual intake of nutrients varied significantly across physical status, physical activities, and income level. There was poor intake of micronutrients in their diet.
3	**Khan J, et al.**	2023	All India	Older adults; age - 45-59;60 >; Both genders	To estimate malnutrition rates based on socioeconomic and demographic characteristics and to look at risk factors.	59073	Anthropometric measurements (Data from the Longitudinal Aging Study in India (LASI), Wave 1 survey)	Descriptive statistics, box plots, multiple bar diagrams, bivariate cross-tabulation, and step-wise logistic regression models.	Among those 60+, 28% of males and 25% of females were underweight. The urban population was less likely to be underweight and more likely to be overweight. Low economic status, endemic diseases, and edentulism were risk factors for being underweight. Females aged 45–59 years had a higher burden of overweight (26%) and obesity (11%) compared to males of the same age.
4	**Gurung D, et al.**	2024	Dharamshala city, Himachal Pradesh, India	School teachers;	To appraise the dental and dietary health of school teachers.	800	Modified WHO oral assessment form, 5-day dietary recall, and Dental Health Diet Score (FGS, NES, DPPS).	Descriptive statistics and inferential statistics (like chi^2, Mann-Whitney test, Kruskal-Wallis, ANOVA), and multiple linear regression.	The mean DMFT was 3.79±2.52. Carbohydrates were the primary component of the diet, while proteins were frequently missing. Approximately one-third of teachers had a Decay Promoting Potential Score (DPPS) in the "watch out" zone.
5	**Rawat S, et al.**	2024	North India (South Delhi).	Healthy adults aged 18–60 years, Both genders	To create and then validate a Food Frequency Questionnaire - COIN-FFQ, for estimating vitamin B12 intake.	115	COIN-FFQ (30 food items), 72-hour dietary recall, and biochemical assessments (serum B12, homocysteine, hemoglobin).	Descriptive statistics, t-test, chi^2, Mann–Whitney, Spearman rank correlation, and Cronbach's alpha.	The newly developed COIN-FFQ was found to be a valid and reliable tool for estimating dietary B12 intake. It showed significant correlation with serum B12 levels and 72-hour dietary recall, and demonstrated good test-retest reliability.
6	**Singh A, et al.**	2023	17 villages, Godda, Jharkhand	Women of the Santhal Indigenous Community.	To understand the relation between access to indigenous food, dietary intake, and nutritional status biomarkers.	211	Household surveys, 2-day 24-h dietary recall, Biochemical assessments.	Descriptive statistics, Linear Mixed Effects Regression, DietCal; Bivariate analysis – Karl Pearson correlation coeficient; t-tets; 1-way anova; post hoc test.	Poor dietary diversity resulted from limited access to a variety of natural food sources. The mean consumption of all nutrients was less than the projected average requirement. Iron deficiency (70%) and vitamin A insufficiency (33.6%) were found to be quite prevalent. Vitamin A level was favorably correlated with having access to kitchen gardens. Nutrient intakes were higher among women with higher dietary diversity scores. Compared to non-consumers, women who consumed indigenous foods had considerably greater intakes of calcium and thiamine. Approximately 70% of people had iron insufficiency. About 33.6% of women had vitamin A insufficiency, while 28.4% had a deficiency.

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S. No	Author	Date	Place	Target population	Aim	Sample size	Tools used	Analysis methods	Results
7	**Loukrakpam B, et al.**	2020	Thoubal and Bishnupur districts, Manipur.	Children, adolescents, and women of reproductive age (WRA) from the Meitei community in 12 villages.	To determine the food intake pattern and nutritional status of the Meitei community.	1,961 - anthropometry; 259-dietary survey	Anthropometric measurements, 1-day 24-h recall using a validated questionnaire and standardized cups/spoons.	Descriptive statistics (median, IQR), Kruskal–Wallis, ANOVA, chi^2, logistic regression.	The prevalence of stunting in children under 5 was 45%. 28% of WRA were overweight or obese. Low dietary diversity and low intake of specific food groups were associated with micronutrient inadequacy.
8	**McKay FH, et al.**	May 26, 2020	Thuha, Punjab.	Women (>18 years) from households in a rural village.	To study food insecurity faced by women in India, including their involvement in food production, gender roles, and the nutritional status of households.	100 households	Structured interviews, USDA Household Food Security Survey Module, Anthropometric measurements, and 2-days 24-h diet recall	Descriptive statistics, standard food insecurity calculations, nutritional analysis via Foodworks 10, and thematic analysis of qualitative data.	This source was a study protocol and did not contain results from the data collection.
9	**Aiswarya A, Bhagya D**	2021	Kanhirode Weaver's Co-operative Society, Kannur, Kerala	Women handloom workers (30–60 years).	To assess nutritional profile and changes in anthropometric measurements of women working in handloom before and during the COVID-19 pandemic lockdown.	100	Interview schedule (occupational health profile, physical activity), Anthropometry, Women's Dietary Diversity Score (WDDS), 24-h recall, FFQ, and Depression Anxiety Stress Scale (DASS).	Descriptive statistics (mean, std. deviation, percentage) and inferential statistics (chi^2, paired sample t-test).	The majority of workers' lifestyles were adversely affected by the COVID-19 lockdown (90.7%). Following lockdown, a notable rise in body weight and BMI was noted. Diets were found to be inadequate in calories, fat, Vitamin A, Ascorbic acid, and calcium. The majority of the subsamples did not fulfill the criteria for calories, fat, and micronutrients like calcium, vitamin A and C.
10	Ch LD, et al	May 13 2024	Andhra Pradesh, India.	Village Households with a nutrition-sensitive agroecology program (intervention) and villages with only an agroecology program (control). Both genders and children.	To assess the potential effects of a government-funded nutrition-sensitive Agroecology program on adult and child dietary diversity, nutritional status, and development.	3,511 households (1,121 intervention and 2,390 control).	Questionnaire (socio-economic and demographic characteristics), FAO guidelines for dietary diversity, WHO IYCF indicators, anthropometric measurements, 24 hr dietary recall; biochemical assessment (hemoglobin)	Descriptive statistics (mean, SD, proportions), t-tests, and adjusted linear regression models.	Intervention villages showed notably higher dietary diversity scores for women, men, and children. Children under 2 years in intervention villages had a lower likelihood of being anemic. Development scores for children aged 18–35 months were elevated in the villages that received the intervention. In intervention villages, 87% of women and 83% of men had a varied diet (DDS 5), while in control villages, this was true for 79% of women and 73% of men. Women were less prone to overweight (16% compared to 23%, respectively) in intervention villages and when compared to women in control villages they more prone to underweight.
11	**Ganpule A, et al.**	2023	Sonipat (North India) and Vizag (South India).	Both genders; 30 years and above	To measure food insecurity using Food Insecurity Experience Scale and study its determinants and association with Body Mass Index.	9005	Questionnaires (socio-demographics) FAO's Food Insecurity Experience Scale (FIES), FFQ for Individual Dietary Diversity Score (IDDS), and anthropometric measurements	Descriptive statistics, 2-sample t-test or Mann Whitney U tests, multivariate linear regression analysis, and mediation analysis.	Food insecurity was experienced by about 10% of participants. Dietary diversity was low. Compared to urban areas, in rural areas the dietary diversity was lower. Lower IDDS and BMI, both were linked with higher food insecurity. Women and people in the lowest wealth index reported higher food insecurity.
12	Chouhan S, et al.	2022	AIIMS and Gandhi Medical College, Bhopal	Medical and nursing students	To recognize and assess the 6-components of the Health-Promoting Lifestyle Profile among medical and nursing students.	619	The Health Promoting Lifestyle Profile-II (HPLP-II) questionnaire.	Descriptive statistics, independent samples t-test, ANOVA, Chi-squared test, and Kruskal-Wallis Test.	Male MBBS students had significantly higher scores than females in Health-Promoting Lifestyle, Nutrition, and Physical Activity. Nursing students had higher scores on five of six scales compared to medical students.
13	**Mediratta S, et al.**	2023	Delhi, India	Adults; 20-40 yrs of age; middle and upper income groups	To study dietary diversity, and intake of excessively-processed foods and to study its effect on macro-and micronutrient intake.	589	2-days 24-h dietary recall method and FAO-diet diversity score (DDS).	Descriptive statistics, Mann–Whitney U, and Spearman's rank correlation and DietCal software.	17% of total energy, 29% - added sugar, and 33% - sodium intake was contributed by Ultra-processed foods. Diets showed a high risk of micronutrient inadequacy specially for zinc, folate, iron, and vitamin A, with significant gender differences. Risk of nutrient deficiencies was seen more in females.

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S. No	Author	Date	Place	Target population	Aim	Sample size	Tools used	Analysis methods	Results
14	Kshatri JS, et al.	July 10, 2023	Odisha	Tribals from 13 districts; all age groups	To study and compare the health status of tribal communities in Odisha and estimate prevalence of key health indicators.	40,921 individuals from 10,230 households.	3 level Questionnaires, anthropometric measurements, and Biochemical assessment (iron profile, seroprevalence tests).	Descriptive analysis using R software, with survey weights applied. Standard errors estimated using Taylor linearization method and Jackknife repeated replication approach.	This source describes the methodology, protocols, and tools for an ongoing survey. Results are not yet available as it is a protocol paper.
15	**Yasmin S, et al.**	June 30, 2022	Alipurduar, West Bengal	Age more than 18; Tea-garden workers; Both genders	To assess morbidity pattern and nutritional status	463	Questionnaire, anthropometric assessment, BP, Biochemical assessment (Hemoglobin)	Simple proportion and Chi-square test. Multiple logistic regression	A high prevalence of morbidity (69.8%), anemia (87.9%), and undernutrition (36.1%) was found. Common morbidities included NCDs, musculoskeletal disorders, and respiratory issues.
16	Sudha V, et al.	2020	Chandigarh, Punjab, Bihar, Jharkhand, Arunachal pradesh, Tripura, Gujarat, Maharashtra, Karnataka, Tamilnadu	Adults (≥20 years); Both genders	To evaluate reproducibility and construct validity of MDRF-FFQ.	500	MDRF-FFQ (236 items), administered twice at a 12-month interval; anthropometric assessments; and biochemical assessments (serum lipids).	Kruskal Wallis test, Chi-square test, intra-cluster correlation coefficients (ICC), Bland Altman analysis, and multivariate regression analysis.	The MDRF-FFQ was found to be a reliable tool, with reproducibility ICCs ranging from 0.50-0.89 for various nutrients and food groups. Carbohydrate consumption was positively linked with triglycerides, while dietary fat was positively linked with HDL, LDL, and total cholesterol.
17	**Vijay A, et al.**	January 31, 2020	Trivendrum, Kerela	Age >18	To validate a 360-item FFQ against a 7-day food diary (FD) and explore dietary intake differences.	460	FFQ (360-item), 7-day food diary, and a socio-economic status questionnaire.	Spearman rank correlations, ANOVA, paired t-tests, cross-classification, Bland–Altman plots, and multivariable regression	The FFQ showed acceptable reproducibility but tended to overestimate nutrient intake when compared to the food diary. Spearman correlations for macronutrients ranged from 0.61 to 0.72. Significant differences were seen between nutrient intake in urban and rural domiciles.
18	Matsuzaki M, et al.	2021	Hyderabad, Telangana	Nonpregnant women (15–49 years) from Andhra Pradesh Children And Parents Study (APCAPS) and Indian Migration Study (IMS).	To validate a novel GDQS	3041	Semi-quantitative FFQ, anthropometric measurements, Biochemical assessment (blood pressure, fasting blood samples for lipids and glucose).	Descriptive statistics, Spearman correlations, and age-adjusted least square means across quintiles of the GDQS.	The average GDQS was 23 points. Maximum score was 46.5. GDQS was useful for reflecting overall nutrient adequacy. It was also associated with higher total cholesterol, lower HDL, and higher BMI.

3.10 Risk of Bias (RoB): The Risk of Bias assessment done through MMAT tool [6] confirmed that all studies successfully met the fundamental screening criteria (S1 and S2) by defining clear research questions and employing appropriate data collection tools to address them. However, the overall methodological quality, particularly concerning representativeness and bias control, varied considerably.

High Quality Studies (100% Criteria Met): A significant number of high-quality descriptive studies rely on robust sampling methodologies (C2) characteristic of large, multi-stage surveys. Studies analyzing data from the LASI survey [10] or the UDAY cohort [23] scored perfectly due to their large, representative samples and meticulous handling of variables, including using Rasch models to refine tools like FIES. Furthermore, high quality was consistently achieved by validation studies [13,15,16] that utilized highly controlled designs, often involving biomarkers (C3), high response rates (e.g., 92.6% for MDRF-FFQ), and explicit statistical methods to mitigate selection and reporting biases (C4) such as adjusting for under-reporters using the EI/BMR ratio or inflammation markers.

Weaknesses in Sampling and Bias Control (C2 & C4): The primary methodological weakness among the lower-rated studies stems from inadequate sampling strategies (C2) and insufficient documentation of bias management (C4).

- Non-Probability Sampling**:** Studies using purposive sampling [8,12] or convenience/snowball sampling [20,21] were rated Low/Moderate because their samples were narrowly specific (e.g., lightweight boxers, high-income Delhi residents, or specific university students),

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limiting the generalizability of their descriptive findings.

- Bias Management**:** Several descriptive reports, such as the study on Tea-garden Workers [18], used multi-stage sampling but lacked critical information regarding non-response rates or methods to address potential attrition, thus earning a lower score on C4. Similarly, the protocol study by McKay [22] was rated Moderate on C4 because details regarding sampling and non-response were not provided in the excerpts.

Strengths in Measurement (C3): A universal strength observed across all studies is the appropriate selection of measurement tools (C3). These ranged from specific, validated instruments like the HPLP-II, the WHO oral assessment form 2013, and the FAO FIES/IDDS, to objective anthropometric measures and the robust application of FFQs validated against 7-day food records or 72-hour recalls.

Table 8. Risk of Bias Assessment

Study	Design	S1	S2	C1	C2	C3	C4	C5	% Criteria Met	Quality Rating
1. Rathod & Chandorkar (Boxers/EA) [12]	Descriptive Cross-sectional Study				●				70%	Moderate
2. Khadatkar et al. (Farm Women/Nutrition Status) [8]	Descriptive Survey				●		●		60%	Low
3. Khan et al. (Nutrition Status/Older Adults - LASI) [10]	Cross-sectional Secondary Analysis								100%	High
4. Gurung et al. (Oral Health/Teachers) [7]	Descriptive Cross-Sectional								90%	High
5. Rawat et al. (COIN-FFQ Validation) [14]	Development and Validation Study								90%	High
6. Singh et al. (Santhal WRA/Biomarkers) [19]	Exploratory Cross-sectional Study								100%	High
7. Loukrakpam et al. (Meitei Community) [9]	Cross-sectional Study								90%	High
8. McKay et al. (Food Insecurity/WRA Protocol) [22]	Cross-sectional Design (Protocol)				*		●		70%	Moderate
9. Aiswarya & Bhagya (Covid/Lifestyle) [21]	Cross-sectional Assessment				●		●		60%	Low
10. Ch et al. (Agroecology Program) [24]	Cross-sectional Program Evaluation								90%	High
11. Ganpule et al. (Food Insecurity/UDAY) [23]	Cross-sectional Cohort Baseline Data								100%	High
12. Chouhan et al. (HPLP/Students) [20]	Cross-sectional Descriptive Study				●		●		60%	Low
13. Mediratta et al. (UPF/Diet Diversity) [11]	Cross-sectional Survey				●				70%	Moderate
14. Kshatri et al. (OTFHS Survey Protocol) [17]	Population-based Cross-sectional Survey (Protocol)								100%	High
15. Yasmin et al. (Tea-garden Workers) [18]	Cross-sectional Study						●		80%	Moderate
16. Sudha et al. (MDRF-FFQ Validation) [15]	Validation Study								100%	High
17. Vijay et al. (Kerala FFQ Validation) [16]	Cross-sectional Validation Study								100%	High
18. Matsuzaki et al. (GDQS Validation) [13]	Validation Study (Secondary Cohort Analysis)								100%	High

*(Note: =Yes, ●=No, =Partial, *= Couldnot Determine)*
(Note: S1: Clear Research Questions?; S2: Data Allow to Address Questions?; C1: Clear Objective & Design; C2: Adequate/Representative Sampling; C3: Appropriate/Validated Measurement Tools; C4: Risk of Non-Response/Bias Addressed; C5: Appropriate Descriptive Statistical Analysis)
(Note: % Criteria Met of C1-C5)

4. Discussion

There was homogeneity in the age groups, however, the aims of the works, tools used and categories of results obtained varied according to aims of the works. And, since the researchers wanted to assess only the variety, frequency and combinations of the tools used to assess nutrition status in the adult population of India, the results of the various studies could/would not be justifiably compared.

Longitudinal researches were not seen which means the actual long-term impact of food interventions could not be studied either.

The traditional methodology for Nutrition evaluation has been ABCD methods. It is now ABCDEF with Energy assessment (E) and Functional assessment (F) being added. The papers studied in this review show more frequent use of anthropometry and only 1 used clinical assessment and 1 included handgrip strength as functional assessment. The most used tool to assess nutritional status/dietary intake was

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anthropometric assessment; however, it was seen to be used along with other tools more than as a sole tool to gauge nutritional status. While procedures of A, B and C assessment remain constant, Dietary assessment varies according to age group, region, and objective of the research.. Also, other varying tools were used, accompanying the nutritional assessment according to the research aim. Ultimately, all the tools used in the study for nutrition assessment align with the ABCDEF frame, however, nutrient and disease specific variation were observed. While Energy assessment and Functional assessment have been recently classified as separate categories in nutrition assessment module, they both have existed as core principles in nutrition assessment long before.

Lack of citations seen in the studies reveals slow progress in this field of research. It might be perceived from the lack of citations that these works have either not reached public and/or no further researches from their respective work has been done.

The studies and the process of sifting through the database show significant evidence that there is a lack of standardized tools to assess nutritional status in healthy adult populations in India, and to a lesser extent, that there is a lack of studies specifically focused on the normal healthy adult population relative to vulnerable groups.

1. Lack of Standardized and Validated Tools for Adults - Multiple studies emphasize the critical need for validated, context-specific tools, particularly for assessing specific nutrients or for use across diverse regions, indicating a gap in current standardized assessment methods for the general adult population. In India, due to the diversity of cuisines and a wide variety of regional and cultural food habits and practices, dietary intake assessments are by default difficult. This diversity necessitates the development and validation of suitable dietary tools. Existing FFQs were restricted to selected industrial/rural migrant populations or developed separately for urban and rural populations, highlighting the challenge of a **standardized tool generalizable across the entire adult population**.

2. Comparative Lack of Studies on the Normal Healthy Adult Population - While several studies analyze adult populations, the context often restricts the sample, suggesting that resources and effort are heavily dedicated to vulnerable or specific non-generalizable groups like older adults, working women, high-income adults, health professionals etc. This suggests a focus on the vulnerable, not the general, healthy population. While studies on specific target populations are very important and necessary, there is also a need to assess the seemingly healthy adult population from time to time.

5. Conclusion

The nutritional assessment scenario in India resembles patches of tailored maps designed for particular areas; while these maps serve well for local navigation, there exists a critical need for a simple, unified, standardized GPS system that could accurately monitor the basic nutritional health of the entire adult population nationwide easily. Developing a standardized assessment format is crucial for effectively forecasting and preventing the triple burden of malnutrition across India.

6. Limitation

The research took up works from 2020-2024, thus works after November 2024 could not be included in the review. The review only included works published in PubMed, since it is considered top on the list of free, open-source database.

7. Strength

The review focuses on the neglected but majority of the population - “the seemingly healthy adult” population. The study reviews the tools used to assess nutritional status of this population, the purpose of these works, and the quality of works published concerning the target population.

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Statement of Ethics

As this study is a systematic review and meta-analysis of previously published literature, it did not require ethical approval or informed consent from participants. All data analysed were sourced from publicly available literature, adhering to copyright and publication ethics guidelines.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Shreya Rathi: Collected the data, sorted the papers. Manual screening of the papers. Review of papers. Analysis of the data collected. Structuring of the paper.

Dr. Abhaya R. Joglekar: Review of paper. Analysis of the data collected.

Dr. Dipti Chandrakar: Structuring of paper.

Data Availability Statement

The data is sourced and assessed from open-source previously published articles.

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