Integrating NAFLD Screening into Primary Care in South Asia: Challenges in Lean, Pediatric, and Gender-Specific Populations — A Narrative Systematic Review

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Abstract

Background

Non-alcoholic fatty liver disease (NAFLD) is becoming an increasingly important public health concern worldwide and is now affecting a growing number of people across South Asia. The condition is characterized by excess fat accumulation in the liver in individuals who consume little or no alcohol. In South Asian populations, NAFLD often presents differently, particularly among lean individuals, children, and women, making early diagnosis and management more challenging.

Methods

A systematic narrative review was conducted using PubMed, Scopus, and Web of Science databases to identify relevant studies published between January 2010 and December 2025. The review was carried out in accordance with the PRISMA 2020 guidelines. A total of 1,281 records were identified through database and manual searches. After the removal of 194 duplicate records, 1,087 titles and abstracts were screened, 312 full-text articles were assessed for eligibility, and 87 studies were included in the final review. The quality of the included studies was evaluated using the Critical Appraisal Skills Program (CASP) checklists and the AMSTAR2 appraisal tools.

Results

The burden of NAFLD in South Asia was found to be substantial but varied widely across populations and diagnostic approaches, with reported prevalence ranging from 9% to 50%. Pediatric NAFLD rates were particularly concerning in some Indian studies, where prevalence ranged from 26% to 62%. Many cases of lean and pediatric NAFLD remain undetected because traditional BMI-based screening may overlook individuals with visceral fat accumulation and metabolic abnormalities despite having a normal body weight. Women also face additional barriers to timely diagnosis and treatment due to both biological factors and social or healthcare-related inequalities. Furthermore, NAFLD remains insufficiently integrated into national non-communicable disease (NCD) programs across much of South Asia, limiting opportunities for early screening and coordinated care.

Conclusions

Integrating NAFLD screening into existing national NCD programs could improve early detection and long-term disease management in South Asia. A practical "screen → score → escalate" approach may help strengthen primary care-based screening. In addition to BMI and liver enzyme testing, measures such as waist-to-height ratio and metabolic risk markers should be considered, especially for lean and pediatric populations. Greater emphasis should also be placed on sex-disaggregated reporting, frontline healthcare worker training, and district-level monitoring systems. Pilot implementation within existing healthcare frameworks may provide an effective first step toward broader regional scale-up over the next 3–5 years.

Keywords:

NAFLD, LMICs, metabolic syndrome, health equity, gender disparities, South Asia, public health policy, and NCD integration.

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1. Introduction

1.1 Background on NAFLD Globally and in South Asia

NAFLD refers to excess fat deposition in hepatic cells in individuals without significant alcohol intake. It is the most prevalent chronic hepatic condition, with more than 30% of adults in the world being affected [1, 2]. It increases with obesity and type 2 diabetes, which are metabolically closely connected. NAFLD is a liver dysfunction cause and predisposing factor to dyslipidemia (abnormal blood fats) and cardiovascular diseases [3, 4]. This transforms NAFLD into a household health issue and not only a clinical care issue, leading to a heavy burden in low- and middle-income nations like India. More common among South Asians is lean NAFLD, usually found in people with a normal body mass index, and it is defined by visceral adiposity (fat buildup around organs) and insulin resistance (the decreased efficiency of insulin) [5, 6]. The communicable diseases have been concentrated upon, leaving a gap in the understanding of the silent killer NAFLD. There is a need to highlight the necessity of focused interventions to fight NAFLD within different countries in South Asia, as most of the NCD programs do not include NAFLD [7]. This lack of awareness among care providers/policymakers itself reinforces uncontrolled disease progression, indicating that multi-layered policy focus is necessary [8]. Some historical analogy can be made—the early ignorance of hypertension can provide some insight, the historical lack of policy integration initially delayed hypertension treatment. Nevertheless, through concerted efforts, it has later become a success story of public health, proving that it is not impossible to overcome them.

This review will help summarize the existing evidence around epidemiology, pathophysiology, diagnostic issues, and management of NAFLD on a population basis. All stakeholders should be proactive and take measures without wasting more time in making NAFLD a top-priority, equity-driven health crisis and begin policy responses immediately [1, 9, 10].

1.2 Epidemiological Importance of Lean and Pediatric NAFLD.

The prevalence of NAFLD varies by region, with 30-32% found in the Middle East and South America, approximately 27-28% in Asia, and 23-24% in North America and Europe [1, 11, 12]. Ranging between 9-50% in South Asia, particularly India, the prevalence is with reference to the population and also due to the diagnostic criteria that are used [13, 14]. Increased prevalence in the region is influenced by urbanization, dietary changes, and the rise in diabetes and dyslipidemia. The diagnosis is complicated in this area because lean NAFLD is the metabolic dysfunction that appears in patients whose BMI is normal [14].

The prevalence of NAFLD is becoming a sharp increase among children. The prevalence of overweight children among Indian children ranges between 26-62% [15, 16]. Late hepatic dysfunction and high metabolic risk are probable. Screening fails frequently, and the diagnostic criteria vary by population group, affecting the reliability of the data and making country-to-country comparisons difficult. Variable and nonstandard diagnostic criteria do not provide the ability to adequately estimate prevalence rates. The regions use various techniques and criteria, meaning that there is scarcity of cross-study and cross-location comparability of data [17, 18].

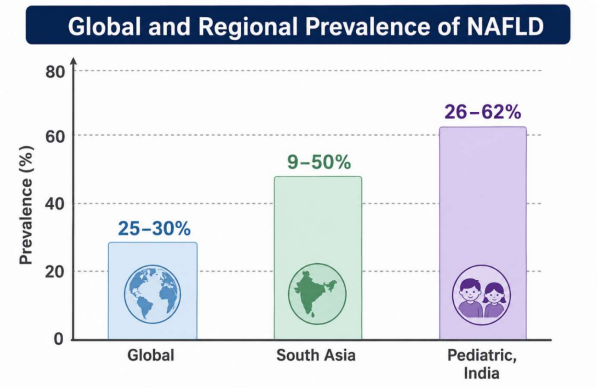

Figure 1: The bar chart titled *"Global and Regional Prevalence of NAFLD"* illustrates the variation in NAFLD prevalence across different populations. Globally, prevalence ranges between 25-30%, while in South Asia it spans a much wider range of 9% to 50%, reflecting regional heterogeneity, and 26% to 62% in pediatric populations in India.

Source: Adapted from global and regional epidemiological studies, including Zobair M. Younossi et al. (2016, 2023) and subsequent meta-analyses on NAFLD prevalence.

1.3.i Pathophysiology

The pathogenesis of NAFLD is complicated by a complex of metabolic, genetic, and environmental factors. Current evidence suggests that resistance to insulin is of particular significance because it facilitates the decomposition of fat in fat tissue, resulting in an increase in free fatty acids in the blood, which pass to the liver. These lipids are stored in the liver by the liver cells as triglycerides, which causes fat buildup in the liver, causing cellular stress responses [19, 20].

Too many lipids (fats) result in the formation of ceramides and diacylglycerols (fat types of molecules). The molecules destroy mitochondria (the energy producers of the cell), resulting in oxidative stress (imbalanced reactive oxygen molecules) and endoplasmic reticulum stress (impaired protein processing within the cells). Accordingly, the inflammatory pathways, including NF-κB (nuclear factor kappa-light-chain-enhancer of activated B cells) and JNK (Jun N-terminal kinase), are activated, which makes liver cells suffer damage, as reported. This pathway is accompanied by the activation of key hepatic immune cells, including Kupffer cells (specialized liver macrophages responsible for clearing cellular debris), hepatic stellate cells (which play a central role in fibrosis), and infiltrating macrophages involved in immune regulation. The coordinated activity of these cells promotes persistent inflammation and progressive fibrosis, leading to thickening and scarring of liver tissue. [21, 22].

Dysbiosis (an imbalance in the body's microbial communities, bacteria, fungi, and viruses, typically in the gut, caused by reduced beneficial microbes and increased pathogens) causes NAFLD by increasing intestinal permeability (the gut wall becomes leaky). This permits entry of bacterial endotoxins, particularly the lipopolysaccharides (LPS, toxins produced by bacteria), into the portal vein (blood vessel that transfers blood within the gut to the liver). These induce TLR4 (Toll-Like Receptor 4), which is an immune reaction protein, and exacerbate liver inflammation. It accelerates the transition of fatty liver (steatosis) to inflammation in the liver (steatohepatitis), scarring (fibrosis) of the liver, and liver cancer known as hepatocellular carcinoma (HCC) [23, 24].

Genetic variations (alterations in DNA sequence), especially in the PNPLA3 and TM6SF2 genes, raise the likelihood of fat in the liver and scarring tissue (fibrosis). These are independent of conventional metabolic markers. They are especially valuable in the cases of South Asian and pediatric (children) NAFLD, in which the disease cannot be related to BMI or insulin resistance [25, 26] underdiagnosis is probable in such cases.

The PNPLA3 gene helps regulate the way fats are processed and stored in liver cells. One of the most well-known genetic changes in this gene is the I148M variant (rs738409), where a small alteration in the protein structure affects its normal function, leading to increased fat accumulation within liver cells and a greater risk of developing steatosis and steatohepatitis.

TM6SF2 assists in the regulation of the transportation of fat and release of very low-density lipoprotein (VLDL) particles that carry fat in the bloodstream. Its E167K variant impairs VLDL secretion, causing the accumulation of fats in the liver and increasing the risk of NAFLD.

NAFLD takes a dynamic path along isolated steatosis, nonalcoholic steatohepatitis (NASH), fibrosis, cirrhosis, and, sometimes, hepatocellular carcinoma (HCC). It depends on genetics, age, sex, and the environment, such as diet, physical exercise, and microbiome makeup [27, 28].

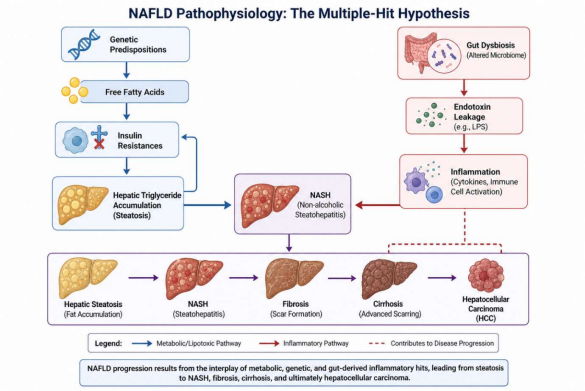

Figure 2: Pathophysiology of NAFLD according to the multiple-hit hypothesis. Genetic predispositions, metabolic disturbances (insulin resistance, free fatty acid overload, hepatic triglyceride accumulation), and gut dysbiosis with endotoxin leakage act synergistically to drive hepatic steatosis, inflammation, and progression to NASH, fibrosis, cirrhosis, and hepatocellular carcinoma.

Source: Adapted from Buzzetti et al. (2016) and Tilg et al. (2021), based on the multiple-hit hypothesis of NAFLD pathogenesis.

1.3.ii Diagnostic Landscape

The early and accurate diagnosis of NAFLD is complicated by its asymptomatic nature, as well as the absence of a unified system of screening. The gold standard method of evaluating steatosis and fibrosis is liver biopsy. Nevertheless, a biopsy is not only invasive but also expensive and dangerous hence, it cannot be applied in routine or mass screening [27]. A simple stepwise approach can help improve the diagnosis of NAFLD: screen, assess, and refer. The process should begin with non-invasive methods such as ultrasound or basic blood-based scores to identify individuals who may be at risk. These findings can then be used to estimate the likelihood and severity of the disease. Ultrasonography, being a noninvasive imaging, is cheap and is also readily accessible but has a low sensitivity, particularly in cases of mild steatosis or patients with increased BMI [28]. The transient elastography (Fibro-Scan) offers improved measures of steatosis and fibrosis but has fewer applications because of resource and cost factors, especially in LMICs [28].

Serum-based scoring systems, including the NAFLD Fibrosis Score (NFS), FIB-4 index, and AST-to-platelet ratio index (APRI), provide a feasible method of determining fibrosis risk based on a routine laboratory result. The reason is, however, that these tools are less precise among younger and leaner populations of less or no ethnic diversity, such as South Asians, meaning that population-specific changes are necessary [27, 28].

Pediatric and lean NAFLD instances do not show metabolic risk limits using traditional indicators, thus potentially underestimating the severity of the disease. There are limited validated noninvasive screening tools for these groups, resulting in underdiagnosis. It is advised to be done in several steps, namely, first, the factors at risk are to be identified; next, noninvasive screening is to be performed; third, the risk of fibrosis will be considered; and finally, a specialist will be required in case of need [27].

1.4 NAFLD and Gender Dimensions.

NAFLD has considerable gender disparities in prevalence, pathophysiology, clinical presentation, and access to care, but this has not been studied or addressed in research and policy. An Indian urban study points out that a decrease in socioeconomic status of women results in a delay in diagnosis of liver diseases among women in India because of limited access to healthcare services, which is a case of women-level interaction with caste and income. This gap highlights the fact that policy interventions are required to narrow these gaps.

1.4.i Biological and Hormonal Influences.

Estrogen provides protective properties against hepatic steatosis and inflammation, and this is part of the reason why there is a low prevalence of NAFLD in premenopausal women compared to men [29]. The women post-menopause have a higher risk of NAFLD, probably because of estrogen loss and metabolic alterations [30, 31]. Polycystic ovary syndrome (PCOS), which is marked by insulin resistance and hyperandrogenism, has a positive relationship with NAFLD in women of reproductive age even in the absence of obesity [32, 33].

1.4.ii Gendered Risk Profiles and Underdiagnosis.

Women usually have a normal BMI and more visceral fat, which are not easily detected in the clinical environment [30, 34]. The tools of diagnosis might not be effective in women, particularly South Asians, in whom lean NAFLD is prevalent. Women tend to seek care in a timely manner very often as well due to caregiving responsibilities, stigma, and poor access to healthcare. [30]

1.4.iii Intersectionality and Structural Barriers.

The inequity in NAFLD on gender lines overlaps with other social determinants such as caste, rural dwelling, education, and income. Women who are marginalized experience an added challenge to help them diagnose and receive treatment, such as lack of access to experts and health information that is culturally sensitive. Such intersectional inequalities are not sufficiently tackled in extant research and policy [34].

1.4.iv Inequality in Access and Awareness.

Women, especially in rural and low-income regions, are particularly vulnerable and simply lack access to quality and timely diagnosis or specialist treatment in many LMICs. The lack of sight of sex-specific risk factors or personalized messages is echoed in the public health campaigns and clinical guidelines, which predominantly do not include it [30]. There is a dire necessity of health policies to deal with these structural disparities, to take abstract imbalances and turn them into policy requirements.

1.4.v Research and Policy Weaknesses.

In national surveys, NAFLD data is rarely disaggregated based on sex, and this imposes restrictions on the possibility of following gender-specific trends [34]. Sex-stratified data, gender-sensitive screening measures, and involving women, especially PCOS or postmenopausal women, in clinical trials are urgently needed [29, 33]. The WHO Gender Mainstreaming Strategy offers a way in which gender can be incorporated in health policies, which need to be selected and applied to NAFLD.

1.5 Policy Oversights and Lost Integration.

The increased prevalence and asymptomatic development of NAFLD require immediate attention by the population. Although NAFLD shares the same risk factors as cardiovascular disease, type 2 diabetes, and other NCDs, it is still largely omitted in global and national prevention of NCDs. This results in discontinuous care, late diagnosis, and missing access to coordinated intervention. Implementing NAFLD screening in the traditional screening programs such as NPCDCS may have a considerable effect on coordinated care and generate very high economic benefits. Judging by the cost-saving potential of the NAFLD screening combined with diabetes screening, policymakers and finance ministries will be offered a good argument on how to allocate resources. The measurement of the possible savings may enhance the argument to change or alter the policies and make NAFLD a priority in the public health agenda.

The purpose and scope of the study will be as follows.

This is a systematic literature review on NAFLD in South Asia, focusing on lean and pediatric phenotypes, gender differences, and policy gaps. It unites clinical, epidemiological, and policy viewpoints to pinpoint obstacles to care and diagnosis and suggests a series of methods of including NAFLD into the current national health initiatives. The interdisciplinary and equity-oriented study will inform future studies, clinical practice, and health policy.

2. Methodology.

2.1 Study Design

This review approach was undertaken to identify clinical, epidemiological, and policy evidence on NAFLD in South Asia, and the process was guided by the PRISMA 2020 statement [35], ensuring transparency in search, selection, and reporting. In addition, a policy mapping approach was used to understand how NAFLD is currently addressed within national health programs.

2.2 Search Strategy

Relevant studies were identified through searches in PubMed, Scopus, and Web of Science published between January 1, 2010, and December 2025. Search terms were developed using a mix of MeSH terms and commonly used keywords, combined using Boolean operators [36, 37]. These included terms related to NASH or NAFLD, South Asia, lean or non-obese populations, gender differences, pediatric groups, and public health or policy frameworks. The search strategy was adjusted slightly for each database. In addition to database searches, reference lists of selected articles and key policy documents were also reviewed to identify any relevant studies that may have been missed.

2.3 Inclusion and Exclusion Criteria

Inclusion Criteria

- Studies conducted in South Asia or involving South Asian populations
- Studies focusing on lean NAFLD, pediatric NAFLD, gender differences, or policy-related aspects
- Systematic reviews, peer-reviewed research articles, and national health policy documents

Exclusion Criteria

- Animal or laboratory-based studies
- Commentaries and non-peer-reviewed sources
- Articles without full-text access

2.4 Screening and Selection

A total of 1,281 records were identified through manual searches (n = 38) and database searches (n = 1,243). After 194 duplicate records were removed, 1,087 titles and abstracts were screened for relevance. At the end of the screening process, 312 full-text articles were assessed in detail, of which 87 studies fulfilled the inclusion criteria and were ultimately included in the final review.

Identification of studies via databases and other methods

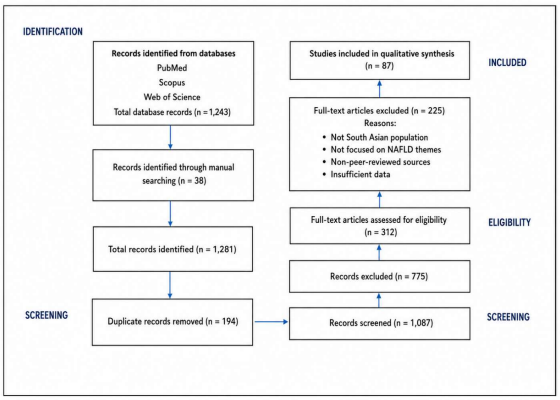

Figure 3. PRISMA 2020 Flow Diagram of Study Selection

The study selection process is illustrated in the PRISMA 2020 flow diagram (Figure 3).

2.5 Data Extraction

The following details were recorded for each study from the data collected using a structured format:

- Author, year, and country
- Study design and sample size
- Type of NAFLD studied (lean, pediatric, or gender-specific)
- Diagnostic methods used (such as liver enzymes, imaging, or biopsy)
- Main findings
- Relevance to policy or practice

2.6 Quality Appraisal

The quality of the included studies was assessed using CASP checklists and AMSTAR 2 for systematic reviews. Based on this assessment, 42 studies were rated as high quality, 31 as moderate, and 14 as low quality. Studies with lower quality were still considered where they added useful context.

2.7 Policy Mapping

Key national programs, including NPCDCS [40], RMNCH+A [41], and POSHAN Abhiyaan [42], were reviewed to understand how NAFLD could be integrated into existing health systems. Gaps related to service delivery, workforce training, and monitoring systems were identified to highlight areas for improvement.

2.8 Ethical Considerations

This systematic review was based on published studies and policy documents; therefore, formal ethical approval was not required.

2.9 Thematic Overview

The findings of the review were organized into three major themes:

1. Diagnostic challenges associated with lean and pediatric NAFLD
2. Gender-based differences in healthcare access and clinical outcomes
3. Limitations in policy development and program implementation

A total of 87 studies were included in the review, representing clinical, epidemiological, and public health perspectives. The literature consistently highlighted difficulties in early identification of NAFLD among lean individuals and pediatric populations, along with disparities related to gender and access to care. In addition, the review identified limited integration of NAFLD within existing healthcare policies and national health programs. Together, these findings emphasize the importance of developing more comprehensive and coordinated strategies for the prevention, diagnosis, and management of NAFLD.

3. Major Themes Identified in the Literature

3.1 Diagnostic Challenges in Lean and Pediatric NAFLD

3.1.i Lean NAFLD and Limitations of BMI-Based Screening

One of the main findings is the high prevalence rate of lean NAFLD in South Asia. People who are of normal body mass index (BMI) begin to develop a significant amount of hepatic steatosis and dysmetabolism. The traditional BMI criteria cannot detect such cases, with the South Asians having higher visceral fat and insulin resistance at a lower BMI level than the conventional BMI thresholds.

This diagnostic shortcoming leads to a number of missed or delayed diagnoses, with many or more being diagnosed as low-risk and not having metabolic abnormality underlying the BMI-based screening. The literature provides an emphasis on the role of supplementary methods, such as waist-to-height ratio and metabolic biomarkers, to improve the ability to detect NAFLD among South Asians in a younger age category [39, 40, 41].

3.1.ii NAFLD in Pediatrics: New Dilemma with Inadequately Incorporated Screening.

The literature also solidifies an emerging issue in relation to pediatric NAFLD in South Asia. Research has shown that fatty liver disease is present in 26-62 percent of children who are underweight and overweight in India, which implies an increase in childhood burden with lifelong consequences.

Liver health screening (alanine aminotransferase (ALT) and aspartate aminotransferase (AST)) is rarely a part of routine health programs and school-based interventions. A lack of awareness of the pediatric NAFLD among the pediatricians and health educators leads to underdiagnosis [27]. Common school physical examinations are generally focused on anthropometric and eye examination tests without examination of liver functionality. Early diagnosis and prevention of complications of NAFLD require the integration of liver function tests within the routine pediatric health examination [28].

Such diagnostic difficulties help to understand the importance of introducing simple liver function tests into the developed child health surveillance systems and enhancing the capacity of the healthcare professionals to detect NAFLD at the early phase.

3.1.iii Diagnostic Barriers and Proposed Solutions

Reviewed studies converge on key diagnostic obstacles and recommend actionable strategies summarized in Table 1:

Diagnostic Barrier	Description	Proposed Solution
Reliance on BMI screening	Misses high-risk lean NAFLD cases prevalent in South Asians	Utilize waist-to-height ratio and metabolic markers.
Limited imaging availability	Ultrasonography and advanced tools like FibroScan are scarce.	Expand portable diagnostics at the primary care level.
Lack of pediatric liver screening	Absence of liver enzyme testing in child health programs	Incorporate ALT/AST testing in school health checks.

3.2 Gendered Access and Outcomes

3.2.i Gender Disparities in Diagnosis and Disease Progression

One of the major discoveries is the high prevalence of lean NAFLD among South Asian groups. A normal body mass index (BMI) and normal person frequently experience excessive hepatic steatosis and malfunction of the metabolism. Normal BMI standards would fail to identify such cases, since South Asians tend to have more visceral fat and insulin resistance at lower BMIs.

This is a weakness of diagnosis that has resulted in a high number of cases being missed or diagnosed late, as the BMI-based screening usually objectifies such individuals as low-risk and fails to pinpoint the abnormalities made in the metabolism of that group. According to the literature, it is essential to introduce certain supplementary factors that include waist-to-height ratio and metabolic biomarkers in order to enhance early NAFLD diagnosis among South Asian patients [39].

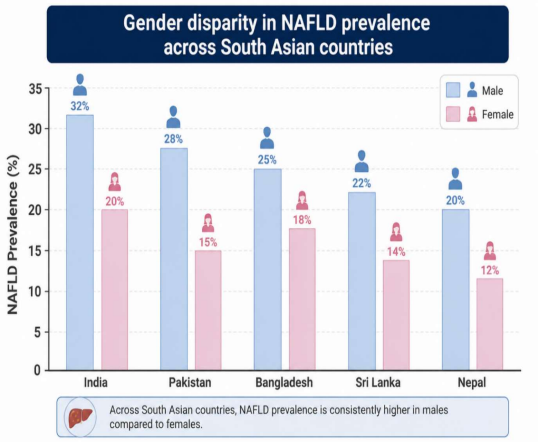

Figure 4: Gender differences in NAFLD prevalence across South Asia. In all five countries, males exhibit substantially higher prevalence rates than females, with the largest disparities observed in India and Pakistan. These findings suggest that gender-specific risk factors, including metabolic and lifestyle differences, may contribute to the observed variation and warrant targeted public health interventions.

Source: Author-generated figure based on synthesized data from published epidemiological studies on NAFLD in South Asia (e.g., Zobair M. Younossi et al., 2016; 2019; regional studies from India, Pakistan, and Bangladesh).

3.2.ii Intersectionality and Structural Barriers

Healthcare disparities are compounded by gender and socio-economic determinants (including caste, rural dwelling, education, and income level). Women in marginalized communities face complex barriers, such as lack of access to specialists and inappropriate health information based on cultural and digital exclusion.

The first gap is a critical one, that is, the lack of sex-disaggregated information within population-based

surveillance systems and clinical trials. In addition, the majority of the risk assessment tools and screening decision-making guidelines are not valid in women and fail to consider the hormonal state (menopause, PCOS, etc.). This demands higher gender sensitivity in the research design and policy models. [39, 40]

To fill this gap, it is necessary to bring extensive data-collection strategies. They should implement standardized reporting templates to guarantee effective systematization of sex-disaggregated data collection and reporting, thus enhancing inclusivity and allowing the investigation of gender-specific disease trends and dynamics.

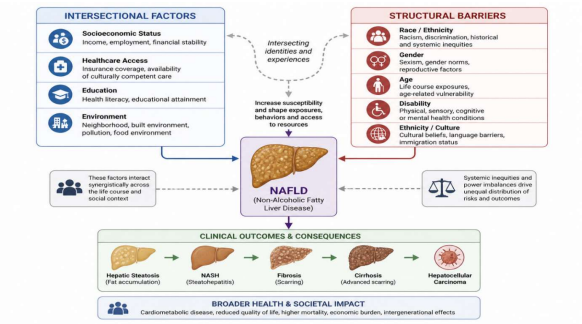

Figure 5. Structure Barriers and Intersectionality in NAFLD.

This conceptual framework represents the role of the intersecting social identities and structural determinants in the disparity in the outcomes of NAFLD. The interaction of structural barriers (socioeconomic status, access to healthcare, education, and environmental factors) with intersectional factors: race, ethnicity, gender, age, and disability. Such confounding factors increase vulnerability to risk, postpone diagnosis, and restrict access to quality care. The model indicates the importance of equity-based processes of public health policies to meet systemic and individual determinants of NAFLD.

Source: Author-developed framework based on intersectionality theory (Crenshaw, 1989) and World Health Organization framework (2008), with adaptation to NAFLD literature (e.g., Zobair M. Younossi et al.).

In Table 2, the major disparities and policy implications concerning gender are summarized:

Gender Disparity	Impact on NAFLD Outcomes	Policy Implication
Lower diagnostic rates in women	Delayed treatment and increased fibrosis risk	Promote sex-disaggregated screening.
Hormonal transitions overlooked	Under-recognition of at-risk postmenopausal women	Include menopausal status in risk assessments.
Limited female trial participation	Limited generalizability of clinical evidence	Mandate gender balance in research protocols.

3.3 Policy and Programmatic Gaps

3.3.i Absence of NAFLD in National Health Programs

Even though NAFLD is becoming an issue of growing concern and its associations with common NCDs, including diabetes and cardiovascular diseases, are becoming increasingly common, the review indicates that NAFLD is noticeably absent in the NCD programs of scale, e.g., NPCDCS or RMNCH+A. The exclusion has created disparate care trajectories, poor screening coverage, and insufficient resource allocation for NAFLD in the framework of the public health system.

3.3.ii Integration Strategic Recommendations.

Policy mapping reveals the prospects of incorporating liver examination (ALT, AST) and ultrasound (imaging) in the usual package of NCD screening and refers to the current structures of the programs. It would be a form of combining hepatic health surveillance with the rest of the risk factors in metabolic conditions [40, 41].

Multi segmental coordination, frontline worker capacity building, and community involvement are said to be major areas that can be enhanced in order to deal with NAFLD on a large scale.

4. Discussion

4.1 Diagnostic Blind Spots and Implications.

The review has also revealed the problems of the diagnosis of NAFLD in South Asia, particularly among lean and young individuals. The BMI is not a suitable measure among the South Asians who are prone to developing metabolic issues and other belly fat at lower BMIs in comparison with other ethnic groups. This results in the fact that a considerable portion of lean individuals with NAFLD are not

diagnosed and treated in time, and the disease develops to the later stages of its development [27].

Speaking of which, childhood NAFLD is also gaining prevalence as a social concern whose prevalence is catastrophic among obese children. However, currently child health programs hardly deal with liver-specific screening programs such as liver enzyme tests or liver scans, resulting in fewer instances of early detection. The consequence of such a lapse in diagnosis is the need to have proven, age-based, and culturally sensitive screening tools that are specific to groups of the pediatric population.

The common noninvasive methods of evaluation of fibrosis, such as the NAFLD Fibrosis Score and FIB-4 index, are less accurate in young and skinny patients [27, 28]. This also makes it difficult to detect cases in time. These gaps have to be closed to address the complications of the disease and aggravate the existing health conditions.

4.2 Gendered Invisibility and Intersectional Barriers.

Gender is an important factor of NAFLD epidemiology, pathophysiology, and health services use, yet the dimension appears to be underrepresented in clinical practice and policy. The protective effects of estrogen on NAFLD are postulated to reduce its prevalence and severity during the premenopausal state and increase the risk and severity of the condition during the postmenopausal stage. [44,45,47].

Regardless of high risk, women, especially minority ones, face more obstacles to diagnosis and treatment. Delay in seeking care and incomplete medical tests are explained by social-cultural norms, lack of access to medical care, and caregiving. These are particularly harmful to those female cases of lean NAFLD whose manifestations are very often ignored by conventional diagnostic devices [39, 43].

Intersectionality involving elements such as caste, rurality, education, and income interrelates with gender to exacerbate health inequity, particularly amongst women who have poor backgrounds. The current data systems in the majority of the cases fail to isolate information according to sex, and, therefore, such gender-specific patterns remain concealed, and it is impossible to develop solutions in terms of a specific design [43, 49].

It is imperative to apply the concepts of gender mainstreaming to solve the NAFLD research and policy issues in line with the WHO frameworks to achieve equal health outcomes. They include sex-disaggregated data collection, gender-sensitive screening tools, and representative clinical trials involving vulnerable groups of the female population.

4.3 Policy Gaps and Potential of Integration.

The epidemic of NAFLD is a phenomenon that propagates under extreme gaps in health system conditions in South Asia. Despite the recent surge in the prevalence and stated morbidity of NAFLD, major national health programs such as NPCDCS and RMNCH+A in India have failed to provide noteworthy coverage of the disease [41, 42]. This negligence acts as a hindrance to the attempt of having coordinated screening, diagnosis, and management and results in fragmented and sub-optimal care of patients.

Nevertheless, our corporate audit finds encouraging current platforms that may support the implementation of NAFLD. One of the opportunities of this nature is that nutritional and adolescent health schemes like the POSHAN Abhiyaan and the school health programs are unexploited entry points and can be used to create awareness, screening, and lifestyle change initiatives [42]. However, those platforms lack certain liver health functions and require the training of the frontline personnel, which reduces their possibility of overcoming NAFLD.

Expansion of these programs so that they can facilitate the identification of liver-specific signs (e.g., ALT and AST) and x-rays to become a routine element of NCD screening can potentially do a lot to improve the potential means of early diagnosis. In addition to that, strengthening referral systems and availability of specialist services are vital in effective management of the disease.

Similar views of NAFLD applied to high-income countries, such as the UK and Australia, helped to implement NAFLD into the framework of larger NCDs, which proves that universal strategies are not assumed when NAFLD is implemented in South Asian countries (Mazen et al., 2020).

Regarding the issue of public health, NAFLD should be reorganized into the national NCD agenda, and through existing platforms, it should be used to offer cost-effective screening, lifestyle guidance, and referral services. It is essential that to bridge the gap between the levels of diagnosis and treatment of NAFLD, the frontline employees are provided with special training regarding risk identification and disability sensitivity outreach to the male gender. Also, proper allocation of resources and optimization of the budget are also worth mentioning, and they will be the factors that determine the feasibility of such initiatives. The policymakers will have to consider reallocating the funds of less efficient programs or

seek other means of financing, such as the public-private partnership, such that NAFLD integration would not be a heavy burden on the budgets. Such an active intervention will contribute to the sustainability of NAFLD-related interventions in population health systems.

To be effective in the stratification of risk of NAFLD, the clinical practitioners in South Asia must consider extending their assessment models to include the waist-to-height ratio and metabolic biomarker assessment in addition to the traditional models that are tested based on BMI [46]. Pediatric practitioners should apply active preventive measures for fatty liver disease among overweight children, and such inadequacies should entail periodic assessment of liver functions.

Regarding their contribution to population health, it is necessary to rebrand NAFLD as a part of national NCD programs and use available structures to provide affordable screening, lifestyle change interventions, and referrals. It is vital to the closing of diagnostic and treatment disparities that the frontline workers receive designated training on the identification of NAFLD risk and that an outreach be gender-responsive.

Multidisciplinary cooperation, such as endocrinology, hepatology, nutrition, and community health, is the course of action that is needed to arrange a productive response to the NAFLD epidemic and decrease the systemic complications [44, 45, 50].

4.4. Limitation

Numerous contrasting studies were identified with significant heterogeneity. The absence of standard procedures in detecting NAFLD was a significant issue with these studies and, unfortunately, added to the divergence in NAFLD study feedback. The presence of NAFLD is frequently identified using various diagnostic tests such as computerized tomography, ultrasound, magnetic resonance imaging, and, more importantly, liver biopsies, which are typical of a confirmed diagnosis of NAFLD. Sex-disaggregated data has been noticeably absent, thus creating limitations, as pharmacological preferences depend on sex in males and females suffering from NAFLD. As noted in the review, there is a need for future studies to attempt to put together comparisons of NAFLD samples according to common markers in order to compare the cohort type, medication prescribed, and future feedback. While a thorough understanding of NAFLD risk includes knowledge of genetics and hormones, the well-developed body of global NAFLD studies does not include these influences in adequate fashion. For example, the interaction of NAFLD, microRNA, and hormonal balance, as well as possible polymorphisms or mutations in NAFLD risk genes, could present new avenues to future management methodologies.

5. Management Strategies

5.1 Overview

Since NAFLD is linked with metabolic syndrome, insulin resistance, genetics, and environmental factors, complex interventions, including medical, behavioral, and policy interventions, are required. This part is dedicated to the narration of the management approaches that are particularly South Asian and that focus on the problems of lean and pediatric cases and gender differences [44, 45, 46].

Considering the cultural context, it is productive to consider lifestyle instructions in the frames of the local culinary ways, such as the extensive use of refined rice, that can be rather useful to achieve adherence to dietary changes. More practical ways can involve dietary recommendations being more applicable in that they can be incorporated into the normal eating schedule since the dietary prescription is ideal and therefore successful in the long run.

5.2 Rationale for why NAFLD needs to be integrated into national programs.

It is approximated that NAFLD has a prevalence of about 9-32 percent, with most persons being individuals who are obese, diabetic, or have metabolic syndrome. Irrespective of this, NAFLD has never been included in single purposive, standalone programs with the single purpose of the public health programs. The policy change has been initiated by the acknowledgment of its role in severe complications, such as cardiovascular disease, cirrhosis, and hepatocellular carcinoma. Interestingly, in 2021, India became the first country to include NAFLD within its National Program on Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases, and Stroke (NPCDCS) and acknowledge its resemblance to other metabolic NCDs among risk factors.

This integration is an inestimable opportunity to exploit the available infrastructure, workforce mobilization, and multiply preventive and curative actions at the population level.

5.3. Proposed Model of Integration Across the Healthcare Continuum.

Management of NAFLD can be integrated by focusing on the primary, secondary, and tertiary healthcare levels:

Primary Level (Community and Health/Welfare Centers):

Risk stratification with adapted checklists, including the Community-Based Assessment Checklist (CBAC), should be used to determine people at high risk of NAFLD. The given tool can be viewed as a powerful instrument that allows supporting frontline health workers, like Accredited Social Health Activists (ASHAs), as it raises their position in the community and profession. By owning the use of the checklist, ASHAs will be able to serve as more trusted health advisors in the community, which will increase their level of acceptance and loyalty to the health programs they advocate.

Train frontline health workers, such as Accredited Social Health Activists (ASHAs) and Auxiliary Nurse Midwives (ANMs), to do lifestyle counseling about diet, physical activity, and behavioral change, but they should also be gender-aware and culturally sensitive.

Secondary Level (Community Health Centers and District Hospitals):

Make available the basic diagnostic services, such as liver function tests (ALT, AST) and ultrasonography.

Develop referral channels among patients who are diagnosed with having a high risk or at an early stage of disease occurrence to specialty care.

Continually renew the educational training of healthcare providers regarding the revised NAFLD management guidelines, with the focus on holistic metabolic care.

Tertiary Level (Specialist Centers and Medical Colleges):

Treat complex cases through diagnostics of high complexity, such as transient elastography (Fibro Scan), magnetic resonance elastography, and liver biopsy, as necessary.

Grant multidisciplinary services with hepatologists, endocrinologists, dietitians, and mental health representatives.

Conduct clinical trials and research to come up with region-specific therapeutics and management algorithms.

5.4 Lifestyle and Pharmacological Interventions

Lifestyle Modification:

The cornerstone of NAFLD management is lifestyle intervention targeting weight reduction, dietary optimization, and physical activity enhancement.

- Gradual and consistent weight loss of around 7–10% of body weight has been shown to reduce fat accumulation in the liver and improve insulin resistance.
- Dietary modifications should emphasize culturally appropriate and sustainable eating habits, including reduced intake of saturated fats and refined sugars, along with increased consumption of fiber-rich foods, whole grains, fruits, vegetables, and essential micronutrients.
- Regular physical activity should be encouraged based on an individual's fitness level and overall health status, incorporating both aerobic activities and resistance training to support better metabolic and liver health. Slow and progressive weight reduction (7-10% of body weight), which minimizes steatosis of the liver and alleviates insulin resistance.

Pharmacological Treatments:

There is no medically approved pharmacological treatment of NAFLD in the present scenario despite that, off-label application relies on comorbidities and fibrosis risk.

- Insulin-sensitizing drugs, including pioglitazone, have demonstrated efficacy in distinct patients with biopsy-confirmed NASH.
- Vitamin E has shown histologic response in non-diabetic NASH patients.
- There is an array of emerging therapies that are directed to metabolic, inflammatory, and fibrotic pathways, which should be considered pending other evidence.

The pharmacotherapy must be personal and hang on the wider metabolic risk management.

5.5 Gender-Specific and Equity-Oriented Approaches

To overcome the special obstacles experienced by women and marginalized groups, it is important to incorporate gender-transformational approaches into every aspect of NAFLD management.

- Provide screening and counseling services on meeting caregiving responsibilities and sociocultural limitations on female mobility and health-seeking.
- PCOS and menopause counseling practices.
- Community-based organizations work as active stakeholders in both the awareness and support programs.

5.6 Monitoring, Evaluation, and Data Integration

Systematic monitoring and evaluation are critical for assessing program impact and directing ongoing improvements:

- Include NAFLD data in the health management information system (HMIS) and computerized screens at Health and Wellness Centers (HWCs).
- Conduct periodical community and cohort surveys to assess disease prevalence, risk factor changes, and intervention effectiveness.
- Promote operational research to find out the cost-efficiency, acceptability, and scalability of integrated NAFLD management patterns.

5.7 Leveraging Technology and Innovation

The use of digital health can be used to improve the effectiveness and reach of NAFLD management.

- Install mobile health (mHealth) applications, which are expected to be used to screen risks, educate patients, and monitor their lifestyles.
- Use telemedicine to provide services of specialists in remote and underserved areas.
- Apply the application of artificial intelligence (AI)-based tools to optimize risk prediction and assist clinical decisions.
- The innovations are correlated with the goals of the digital health ecosystem in India and can be incorporated in solving the issues of the system's capacity present.
- Concisely, to control NAFLD in South Asia, gender-based approaches to managing NAFLD should be included within the context of the existing NCD interventions and skills training, quality monitoring, and use of emerging digital tools. In addition, the cross-sector collaboration systems are to be promoted. A relation to NAFLD based on the education sector can be made where NAFLD awareness should be incorporated into the education sector through the inclusion of physical activities that will aid in maintaining the liver. The health nutrition programs should be used to align the meeting of the nutrition aspects that lead to NAFLD to the aim of making the balanced meal more conveniently accessible to the population. This will be made possible by utilizing the collaboration with social welfare agencies to reach the marginalized populations where they will be given materials and education to overcome the social determinants of health. This is a multisectoral approach that can be used to decrease the burden of NAFLD and encourage health equity.

Conclusion

Non-Alcoholic Fatty Liver Disease (NAFLD) is an emerging and multifaceted health issue of intensive and growing significance, especially in South Asia, whereby different phenotypes of NAFLD include lean and pediatric NAFLD.

Although the prevalence of NAFLD is getting rapidly increasing, as it is now approximated to be about a quarter of the total global population, and the expenses that society might incur because of the disorder are substantial, NAFLD remains little known and is not adequately covered by the national health priorities and the policy frameworks. The findings of this review highlight several important gaps in the screening, diagnosis, and management of NAFLD, especially among women and vulnerable populations. Biological factors, social inequalities, differences in healthcare-seeking behavior, and limited access to early diagnostic services contribute to delays in recognition and treatment. In many settings, currently available screening approaches may not fully reflect the local epidemiological and socioeconomic realities, leading to underdiagnosis and missed opportunities for early intervention.

A broader and more inclusive approach is required to address the growing burden of NAFLD effectively. Community awareness, gender-sensitive healthcare strategies, improved training of healthcare professionals, and the use of digital health technologies such as telemedicine and mobile health services may help improve access to care and long-term disease monitoring. At the same time, collaboration across healthcare, nutrition, education, and social welfare sectors is essential for developing sustainable prevention and management strategies.

Strengthening research, improving public awareness, and implementing evidence-based policies can play an important role in reducing the long-term health and social impact of NAFLD and improving health outcomes for future generations.

Future Directions

Addressing the growing burden of NAFLD requires coordinated clinical, research, and policy-based efforts. Increasing rates of pediatric and adolescent

NAFLD highlight the need for age-specific diagnostic and treatment strategies, as early intervention may reduce long-term disease complications. Future longitudinal studies should examine factors such as age of onset, genetics, diet, and physical activity to better understand disease progression.

Large-scale international registries and cohort studies, including lean and pediatric NAFLD populations, are essential for identifying high-risk groups and evaluating treatment outcomes. Research should also consider socioeconomic status, healthcare access, and gender-related differences to support more inclusive care models.

Digital health approaches such as telemedicine, mHealth applications, and AI-based screening tools may improve early detection and lifestyle management, particularly in underserved areas. Their effectiveness, affordability, and patient acceptance should be further evaluated.

At the policy level, NAFLD should be integrated into national non-communicable disease (NCD) programs and international surveillance systems. Collaboration among researchers, healthcare professionals, and policymakers can help translate emerging evidence into effective public health strategies and healthcare policies**.**

Policy Advocacy and Governance: Elevating NAFLD within national NCD action plans and global monitoring frameworks is vital. Engagement with cross-sector stakeholders, including ministries of health, education, and finance, can support system-wide reforms and resource mobilization.

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