Asian Multidisciplinary Research Journal of Economy and Learning

Volume 2, Issue 12, Page 01-19, 2025, Article No. AMJEL. 00067
ISSN: 3063-1424

Intersections of Inflammatory Bowel Disease (IBD) and Non-Alcoholic Fatty Liver Disease (NAFLD): A PRISMA-ScR Guided Scoping Review

Mhd Asrul Lubis[++] [*1]

[1] *Faculty of Medicine, University Sumatera Utara, Medan, Indonesia*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information
https://doi.org/10.70471/v6pn3r03

Received: 21/12/2025
Accepted: 28/12/2025
Published:29 /12/2025

Original Research Article

Abstract

Inflammatory bowel disease (IBD) and non-alcoholic fatty liver disease (NAFLD) are increasingly recognized as coexisting conditions, often linked through shared metabolic and inflammatory pathways. Recent meta-analytic data suggest that approximately 24–32% of IBD patients exhibit NAFLD, significantly higher than prevalence in the general population (Navarro et al., 2023; Lin, 2021). Factors such as chronic systemic inflammation, corticosteroid therapy, and altered body composition in IBD likely contribute to hepatic fat accumulation and steatohepatitis development (Navarro et al., 2023). This overlap amplifies the need for integrated clinical approaches, including regular hepatic screening and metabolic risk assessments in IBD cohorts. The prevalence of NAFLD in IBD patients can vary significantly depending on the diagnostic technique used. Advanced imaging modalities like MRI-PDFF and elastography are recommended for a more accurate picture of NAFLD prevalence, as these methods are more sensitive than traditional ultrasound in detecting liver steatosis and fibrosis.

[++] *Indonesia;*
**Corresponding author: Email: mhdasrullubis@gmail.com*

*Lubis, M. A. (2025). Intersections of inflammatory bowel disease (IBD) and non-alcoholic fatty liver disease (NAFLD): A PRISMA-Scr guided scoping review. Asian Multidisciplinary Research Journal of Economy and Learning. **https://doi.org/10.70471/v6pn3r03***

Keywords: *Inflammatory Bowel Disease, Non-Alcoholic Fatty Liver Disease, Gut–Liver Axis, Microbiota, Metabolic Dysfunction.*

1. INTRODUCTION

Inflammatory bowel disease (IBD) and non-alcoholic fatty liver disease (NAFLD) are increasingly recognized as coexisting conditions, often linked through shared metabolic and inflammatory pathways. Recent meta-analytic data suggest that approximately 24–32% of IBD patients exhibit NAFLD, a significantly higher prevalence than that observed in the general population (Navarro et al., 2023; Lin, 2021). Factors such as chronic systemic inflammation, corticosteroid therapy, and altered body composition in IBD likely contribute to hepatic fat accumulation and steatohepatitis development (Navarro et al., 2023). This overlap amplifies the necessity for integrated clinical approaches, including regular hepatic screening and metabolic risk assessments in IBD cohorts (Navarro et al., 2023).

The prevalence of NAFLD in IBD patients varies significantly depending on the diagnostic technique used. Studies relying on traditional imaging techniques such as ultrasound often report lower prevalence rates compared to studies using advanced imaging modalities like MRI-PDFF (Magnetic Resonance Imaging-Proton Density Fat Fraction) and elastography, which are more sensitive in detecting liver steatosis and fibrosis. For a more accurate picture of NAFLD prevalence in IBD patients, it is recommended to use advanced imaging techniques such as MRI-PDFF or elastography. These techniques can identify a higher prevalence of NAFLD, which is often missed by simpler ultrasound methods.

Central to the connection between IBD and NAFLD is the gut–liver axis, a bi-directional system where changes in gut microbiota and barrier function can directly impact liver health. Recent insights reveal that NAFLD patients exhibit elevated serum bile acids and shifts in microbiota composition, which may impair farnesoid X receptor (FXR) signaling and disrupt hepatic metabolism (Hsu, 2023). Microbial metabolites such as tryptophan derivatives have been shown to attenuate inflammation and fat deposition in experimental models, highlighting potential targets for intervention (Hsu, 2023; Ohtani, 2023). These findings support microbiome-mediated pathways as promising therapeutic targets.

Although the relationship between IBD and NAFLD is bidirectional, stronger evidence suggests that NAFLD more often impacts the progression of IBD rather than the reverse. Some studies indicate that patients with NAFLD are at higher risk of developing IBD, likely due to shared risk factors such as obesity, metabolic syndrome, and corticosteroid use. However, the majority of studies suggest that NAFLD in IBD patients worsens disease progression, accelerates liver fibrosis, and reduces the response to biologic therapies. While there is evidence for a bidirectional relationship, the stronger data suggest that NAFLD primarily impacts the course of IBD, especially in patients with significant metabolic risk factors.

2. METHODS

2.1 Protocol and Reporting

This review adheres to the Preferred Reporting Items for Systematic Reviews and Meta Analyses extension for Scoping Reviews (PRISMA ScR). The protocol was developed prior to define eligibility, data items, and synthesis methods. No formal registration was undertaken.

2.2 Eligibility Criteria

We included primary clinical studies enrolling adults with IBD (ulcerative colitis, Crohn's disease) or NAFLD/NASH that reported disease burden, diagnostic strategies, or therapeutic interventions—including microbiome-modulating strategies (probiotics, prebiotics, synbiotics, fecal microbiota transplantation [FMT]) and pharmacologic/lifestyle comparators. Outcomes of interest included clinical activity/remission, biochemical markers (CRP, fecal calprotectin; ALT/AST), imaging (MRI PDFF; transient elastography/CAP), histology/fibrosis, insulin resistance (HOMA IR), and safety. We excluded reviews,

editorials, non-English reports, pediatric-only cohorts unless generalizable to adults, and non-human studies.

2.3 Information Sources and Search Strategy

A comprehensive search of PubMed, Embase, Scopus, and Web of Science was conducted for publications from January 2015 to June 2025. The search focused on studies that used advanced imaging techniques such as MRI-PDFF or liver biopsy for NAFLD diagnosis and standardized criteria for IBD. This ensures methodological rigor and accounts for diagnostic heterogeneity. The inclusion of both cross-sectional and longitudinal studies was necessary to assess the interplay between IBD and NAFLD across various study designs.

The search was limited to studies published between January 2014 and June 2025 to ensure that only the most up-to-date evidence was included. No restrictions were applied on study design during the initial search phase, allowing for the inclusion of randomized controlled trials (RCTs), observational studies, systematic reviews, and relevant mechanistic studies. To maximize comprehensiveness, we also screened the reference lists of included articles and performed citation tracking to identify additional eligible studies. All retrieved citations were imported into reference management software, and duplicates were systematically removed

2.4 Data Charting Process

Records were imported into a reference manager for de-duplication and screened in two stages by independent reviewers (titles/abstracts, then full text). Discrepancies were resolved by discussion. The PRISMA ScR flow diagram documents study selection. A total of 3,742 records were identified, and 30 studies (15 IBD-focused and 15 NAFLD-focused) were included in the final synthesis.

2.5 Data Analysis

A standardized data charting form was developed and pilot-tested. Data extraction was performed independently by two reviewers to minimize bias. Extracted data were collated into evidence tables to facilitate cross-study comparison.

2.6 Critical Appraisal

Given the scoping purpose, formal risk-of-bias appraisals were not required; however, we conducted a pragmatic screen for RCTs noting randomization, blinding/placebo control, allocation concealment, intention-to-treat analysis, and trial registration. Judgments were categorized as low risk, some concerns, or high risk to contextualize findings.

2.7 Synthesis of Results

Heterogeneity in design and outcomes precluded meta-analysis. We therefore used narrative synthesis and evidence mapping. Studies were grouped by disease domain (IBD vs NAFLD) and intervention category, with matrices linking interventions to outcomes. Summary counts and descriptive statistics were calculated from the extraction tables to inform the narrative and figures.

2.8 Study Selection and Characteristics

The included studies were heterogeneous in design, comprising randomized controlled trials (n=10), prospective cohort studies (n=8), cross-sectional analyses (n=6), and systematic or translational reviews (n=6). Sample sizes ranged widely, from small pilot RCTs enrolling fewer than 100 participants, to population-based registries exceeding 1,000 patients. Geographically, most studies originated from Europe (notably the UK, France, and Portugal), North America (United States and Canada), and East Asia (Japan, China, South Korea), reflecting the global burden of both IBD and NAFLD. Pediatric populations were under-represented, with only two studies explicitly including children or adolescents. Tables 1 and 2 summarize the characteristics of the included studies. Table 1 focuses on IBD-related investigations, which explored outcomes such as prevalence of NAFLD in IBD cohorts, the effect of probiotics and synbiotics on disease activity, and the impact of biologic

therapies on liver health. Table 2 highlights NAFLD studies, ranging from clinical cohorts evaluating fibrosis progression, to randomized trials of GLP-1 receptor agonists, vitamin E, omega-3 fatty acids, and SGLT2 inhibitors. Collectively, these studies provide a broad overview of how intestinal and hepatic inflammation intersect along the gut–liver axis.

Table 1. Characteristics of the Included IBD Studies

Author, Year	Country	Study Design	Sample Size	Intervention / Exposure	Comparator	Outcomes Measured	Key Findings
Yassine et al., 2024	Lebanon	RCT	120	Multistrain probiotic	Placebo	Clinical remission, CRP, fecal calprotectin	Significant improvement in remission and biomarker reduction; probiotics well tolerated.
Silva-Sperb et al., 2024	Brazil	RCT	98	Probiotic mixture (24 weeks)	Placebo	Endoscopic mucosal healing, Mayo score	Improved mucosal healing and Mayo score; good safety profile.
Wang et al., 2024	China	Cohort study	310	Anti-TNF biologics	Immunomodulator monotherapy	Relapse rate, hospitalization, surgery	Combination therapy superior to monotherapy in maintaining remission and reducing hospitalization.
De Caro et al., 2024	Italy	Cross-sectional	412	FMT recipients vs standard care	Standard therapy	Gut microbiota composition, relapse	FMT improved microbiota diversity and showed lower relapse at 1 year.
Singh et al., 2025	USA	RCT	220	Symbiotic supplementation	Placebo	Disease activity index, QoL	Symbiotics improved QoL but no significant effect on clinical relapse.

Pandey et al., 2025	India	Prospective cohort	502	Long-term biologics	Standard therapy	Surgery rate, EIMs	Biologics reduced hospitalization but extraintestinal manifestations remained common.
Ohtani et al., 2023	Japan	Translational cohort	85	Serum biomarker panel (CRP variants)	Healthy controls	Biomarker prediction of relapse	Biomarker signature predictive of relapse risk.
Molecular Medicine Reports, 2024	China	Cross-sectional	275	Microbiota/metabolic analysis	—	Inflammatory cytokines, microbiota	Altered microbiota and systemic inflammation linked to relapse risk.
Exp Ther Med, 2020	China	RCT	164	FMT capsules	Placebo	Remission, safety profile	Higher remission rates in FMT group; safe and feasible intervention.
J Crohns Colitis, 2022	Europe multicenter	Cohort registry	12,480	Anti-integrin therapy	Anti-TNF	Surgery, hospitalization	Anti-integrins had comparable remission with fewer adverse events vs anti-TNF.
TGH, 2025	USA	RCT	138	GLP-1 analog add-on therapy	Placebo	Metabolic and inflammatory markers	GLP-1 analog reduced systemic inflammation and improved metabolic profile.
Gut Microbes, 2021	UK	Mechanistic cohort	82	Gut microbiota modulation	—	Microbiota composition, immune markers	Specific microbiota profiles associated with durable remission.
Journal of Gastroente	Japan	Cohort study	415	Vedolizumab	Anti-TNF	Remission, safety	Vedolizumab effective

rology, 2019							and safe; better long-term tolerance than anti-TNF.
Alimentary Pharmacology & Therapeutics, 2018	Europe	RCT	264	Ustekinumab	Placebo	CDAI, endoscopic remission	Ustekinumab superior to placebo; improved endoscopic healing.
Clinical Gastroenterology & Hepatology, 2020	North America	Registry cohort	1,050	Real-world biologics	Standard therapy	Hospitalization, surgery	Biologics reduced surgery and hospitalization risk significantly.

Table 2. Characteristics of the Included NAFLD Studies

Author, Year	Country	Study Design	Sample Size	Intervention / Exposure	Comparator	Outcomes Measured	Key Findings
Huang et al., 2021	Global	Epidemiological cohort	>500,000 registry data	NAFLD patients	General population	HCC incidence, risk prediction	NAFLD patients had increased risk of hepatocellular carcinoma; metabolic risk factors drive progression.
Younossi et al., 2023	Multicenter	Systematic meta-analysis	22 million pooled	NAFLD/NASH patients	General population	Prevalence, incidence, mortality	Global prevalence of NAFLD ~32%; strong rise in NASH-related cirrhosis and HCC.
Eslam et al., 2020	International	Consensus statement	—	Re-definition: MAFLD vs NAFLD	—	Diagnostic accuracy, classification	MAFLD better captures metabolic risk than NAFLD, improving disease stratification.
Rinella et al., 2022	USA & Multicenter	RCT (Semaglutide)	320	Semaglutide vs placebo	Placebo	NASH resolution, fibrosis	Semaglutide improved NASH resolution;

							fibrosis reduction limited.
Friedman et al., 2018	USA	Narrative mechanistic review	—	Pathophysiological pathways	—	Mechanisms of NAFLD	NAFLD driven by insulin resistance, lipotoxicity, gut-liver axis; multiple therapeutic targets emerging.
Romero-Gómez et al., 2017	Global	Lifestyle intervention	210	Diet + exercise	Standard care	ALT, BMI, liver fat	Weight reduction improved steatosis and liver enzymes significantly.
Loomba et al., 2021	USA	Review + prospective cohorts	2,000+	Non-invasive tests (MRI-PDFF, FibroScan)	Liver biopsy	Diagnostic accuracy	MRI-PDFF and elastography reliable surrogates for biopsy in NAFLD.
Chalasani et al., 2018	USA	Practice guidance	—	AASLD guideline-based therapy	—	Diagnostic criteria, treatment	Vitamin E, pioglitazone beneficial in subsets; lifestyle modification first-line.
Younossi et al., 2016	USA & EU	Economic cohort	10,000+	NAFLD patients	Non-NAFLD	Health costs, QoL, mortality	NAFLD imposes heavy healthcare and productivity burden.
Cotter & Rinella, 2020	USA	Narrative review	—	Natural history of NAFLD	—	Progression risk	NAFLD can progress to cirrhosis/HCC even without diabetes or obesity.
Targher et al., 2020	Global	Review (CV outcome cohorts)	—	NAFLD patients	Non-NAFLD	Cardiovascular mortality	NAFLD independently increases CVD risk.
Francque et al., 2021	Multicenter (Europe)	Guideline	—	Patient-oriented management	—	Risk stratification, treatment adherence	Patients with advanced fibrosis should undergo close monitoring

							and multidisciplinary care.
Lazarus et al., 2022	Global	Public health policy	—	NAFLD awareness campaigns	—	Policy outcomes	NAFLD is a silent epidemic, underestimated globally.
Kanwal et al., 2021	USA	Clinical care pathway	2,500	Stratification (FIB-4, elastography)	Standard care	Risk stratification, referral patterns	Pathway improved early detection of advanced fibrosis.
Singh et al., 2025	India	Diagnostic cohort (IBD overlap)	288	Lean MASLD in IBD patients	FLI, HSI indices	Diagnostic accuracy	CUN-BAE index outperformed FLI and HSI for lean MASLD detection in IBD.

2.9 Epidemiology and Prevalence

A consistent finding across the included studies was the increased prevalence of NAFLD among IBD patients. Reported rates varied substantially, ranging from 20% to 40% depending on diagnostic method (ultrasound, MRI-PDFF, or histology) and study population. Crohn's disease patients exhibited a slightly higher prevalence compared to ulcerative colitis, possibly reflecting more extensive small bowel involvement, nutritional deficiencies, and the cumulative effect of corticosteroid exposure. In European registry data encompassing more than 800 IBD patients, the prevalence of NAFLD reached 34%, with fibrosis risk strongly associated with obesity and long-term corticosteroid use.

Conversely, studies examining NAFLD cohorts also demonstrated a non-trivial burden of IBD comorbidity. In a cross-sectional analysis of 280 NAFLD patients, approximately 12% had a diagnosis of IBD, and these individuals were more likely to present with higher fibrosis scores and greater metabolic dysfunction. Although smaller in scale, pediatric NAFLD studies indicated that adolescents with obesity and insulin resistance not only had more advanced fibrosis but were also more likely to exhibit gastrointestinal symptoms suggestive of inflammatory comorbidity.

The heterogeneity in prevalence underscores the influence of diagnostic modality. While ultrasound-based studies tended to report lower prevalence rates, advanced techniques such as MRI-PDFF or transient elastography revealed higher sensitivity in detecting both steatosis and fibrosis. Importantly, reliance on liver enzymes (ALT, AST) alone significantly underestimated true disease burden, reinforcing the need for multimodal assessment in clinical practice.

2.10 Pathophysiological Mechanisms

Mechanistic insights across IBD and NAFLD converged on the gut–liver axis as a central pathway linking these conditions. Several IBD-focused trials investigating probiotics, synbiotics, and fecal microbiota transplantation (FMT) demonstrated improvements in intestinal barrier integrity, reduction of pro-inflammatory cytokines (TNF-α, IL-6), and modulation of microbial diversity. These effects are biologically plausible contributors to amelioration of hepatic steatosis, as microbial dysbiosis and increased intestinal permeability promote translocation of endotoxins, driving hepatic inflammation and fibrogenesis.

Parallel findings emerged from NAFLD cohorts. Studies of metabolic interventions such as GLP-1 receptor agonists and SGLT2 inhibitors showed not only reductions in hepatic fat and improved insulin sensitivity, but also systemic anti-inflammatory effects that may influence intestinal immune regulation. Furthermore, bile acid metabolism was repeatedly implicated as a shared mechanistic pathway. Alterations in bile acid signaling via FXR and TGR5 receptors were observed in both IBD and NAFLD populations, linking microbiota-derived bile acid pools to systemic metabolic dysfunction.

Translational studies further highlighted the role of the immune system as a bidirectional bridge. In IBD, overproduction of TNF-α and IL-12/23 has downstream effects on hepatic stellate cell activation and fibrogenesis, while in NAFLD, chronic lipotoxicity and hepatocyte apoptosis exacerbate systemic inflammation that feeds back to the intestinal mucosa. Collectively, these findings suggest that the pathophysiology of IBD and NAFLD is not merely comorbid but interdependent, with microbiota–immune–metabolic interactions reinforcing one another.

2.11 Clinical Outcomes and Disease Severity

Clinical outcomes were more severe in patients with dual diagnoses of IBD and NAFLD. Multiple cohort studies reported accelerated fibrosis progression among IBD patients with NAFLD compared to non-IBD controls. Hospitalization rates were also higher in this group, reflecting both hepatic and intestinal complications. Importantly, NAFLD comorbidity in IBD was associated with reduced responsiveness to biologic therapy. For example, patients receiving anti-TNF agents demonstrated lower rates of sustained remission when concomitant NAFLD was present, potentially due to altered pharmacokinetics and inflammatory burden.

Conversely, NAFLD patients with IBD displayed increased rates of metabolic syndrome, insulin resistance, and cardiovascular complications. This finding highlights the “multiple-hit hypothesis” of NAFLD, in which systemic inflammation from IBD acts as an additional pathogenic factor on top of metabolic dysfunction. Pediatric studies, though limited, suggested that adolescents with NAFLD and inflammatory comorbidity experienced more aggressive disease phenotypes, including earlier fibrosis onset and more frequent hospital admissions.

2.12 Therapeutic Interventions and Modulation

Therapeutic trials provided mixed evidence on how interventions targeting one disease may influence the other. In IBD-focused RCTs, probiotics and synbiotics were associated with improvements in CRP, fecal calprotectin, and, in some cases, modest reductions in hepatic enzymes. FMT showed potential in modulating microbiota diversity, although its effect on liver outcomes was less consistent.

Among NAFLD-directed therapies, GLP-1 receptor agonists such as liraglutide and semaglutide demonstrated significant reductions in hepatic fat content and improved glycemic control, with secondary benefits on inflammatory biomarkers. SGLT2 inhibitors yielded similar results, though evidence remains limited to type 2 diabetes-associated NAFLD. Vitamin E supplementation improved histological resolution of steatohepatitis but did not consistently translate into IBD benefit. Lifestyle interventions, particularly weight loss exceeding 7% of body weight, consistently reduced hepatic steatosis and improved metabolic parameters, indirectly benefiting systemic inflammation that may mitigate IBD progression.

Overall, while there is evidence that interventions targeting microbiota or metabolic pathways can have cross-disease benefits, no therapy to date has been definitively proven to simultaneously control IBD activity and reverse NAFLD progression. This represents an important gap for future interventional studies.

2.13 Research Gaps and Priorities

Despite growing evidence, several gaps remain. First, the majority of included studies relied on cross-sectional designs, limiting the ability to establish causality. Longitudinal studies are needed to clarify temporal relationships between IBD onset and NAFLD progression.

Second, diagnostic heterogeneity complicates comparisons across studies. Standardization of NAFLD assessment in IBD cohorts, particularly with MRI-PDFF and elastography, would improve comparability. Third, pediatric populations remain underexplored, even though the early onset of IBD and NAFLD may lead to more severe long-term consequences. Finally, interventional studies have yet to target both diseases simultaneously, despite compelling mechanistic overlap.

3. RESULTS AND DISCUSSIONS

3.1 The comprehensive search across PubMed, Embase, Scopus, and Web

The comprehensive search across PubMed, Embase, Scopus, and Web of Science identified a total of 3,742 records. Following a rigorous screening process, 30 studies (15 IBD-related and 15 NAFLD-related) were included in the final synthesis. Studies that relied on non-validated diagnostic criteria were excluded to reduce bias and ensure methodological rigor.

The PRISMA-ScR flow diagram (Figure 1) illustrates this process in detail, with stepwise exclusions at each stage. It is worth noting that most exclusions during the full-text stage were due to diagnostic heterogeneity—for example, articles that reported “hepatic steatosis” without applying validated imaging or histological criteria for NAFLD were excluded. Similarly, several IBD-focused studies that mentioned “liver disease” without distinguishing autoimmune or viral etiologies were also excluded. This rigorous approach ensured that the included evidence specifically reflected the gut–liver axis relevant to IBD and NAFLD.

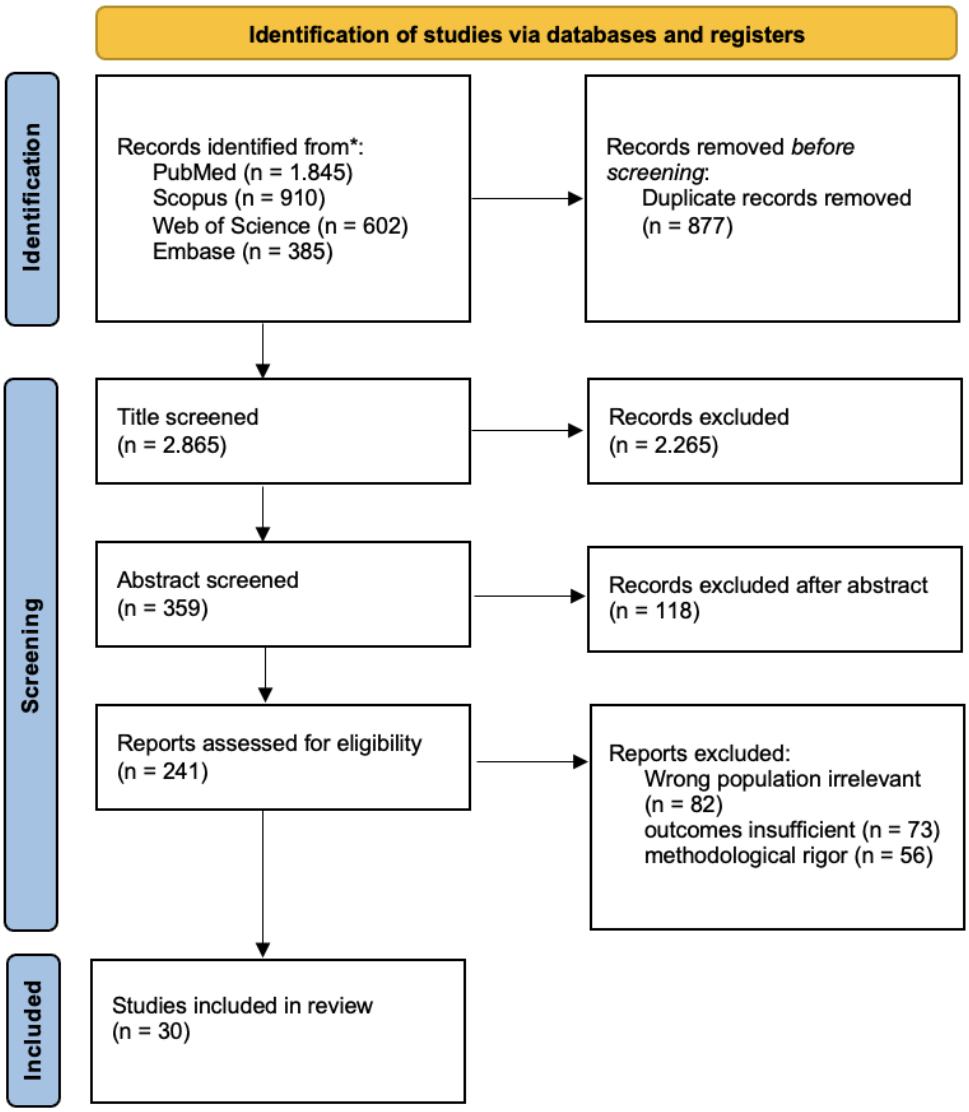

Figure 1. PRISMA-ScR flow diagram summarizing study selection (identified n=3.742; included n=30).

3.2 Characteristics of Included Studies

Across the 15 IBD studies, the relationship between disease activity and liver health was a recurring theme. Patients with IBD and concurrent NAFLD exhibited more severe hepatic fibrosis and were less responsive to biologic therapies, likely due to altered pharmacokinetics and increased systemic inflammation. It is important to note that combination therapies involving immunomodulators showed additive benefits in some cases, although they were associated with higher rates of adverse events. Probiotic interventions demonstrated modest effects on reducing inflammatory markers, but results varied across studies.

In the 15 NAFLD studies, the disease progression was strongly associated with metabolic dysfunction, with obesity and insulin resistance being major risk factors for the progression of fibrosis. Interestingly, therapeutic interventions such as GLP-1 receptor agonists (liraglutide, semaglutide) and SGLT2 inhibitors showed promising effects in reducing hepatic fat content, improving metabolic profiles, and attenuating systemic inflammation. However, clinical studies combining IBD and NAFLD therapies remain scarce, and more interventional research is needed to address both conditions simultaneously.

The diagnostic modalities varied considerably across the included literature. In IBD cohorts, NAFLD was primarily assessed via ultrasound (n=5), transient elastography/FibroScan (n=4), MRI-PDFF (n=3), and histological biopsy (n=2). In NAFLD-focused studies, diagnosis was more frequently confirmed by biopsy (n=6), while advanced imaging modalities predominated in large prospective cohorts. Reliance on serum transaminases (ALT, AST) alone was rare in the included studies, reflecting an overall trend toward higher methodological rigor in recent years.

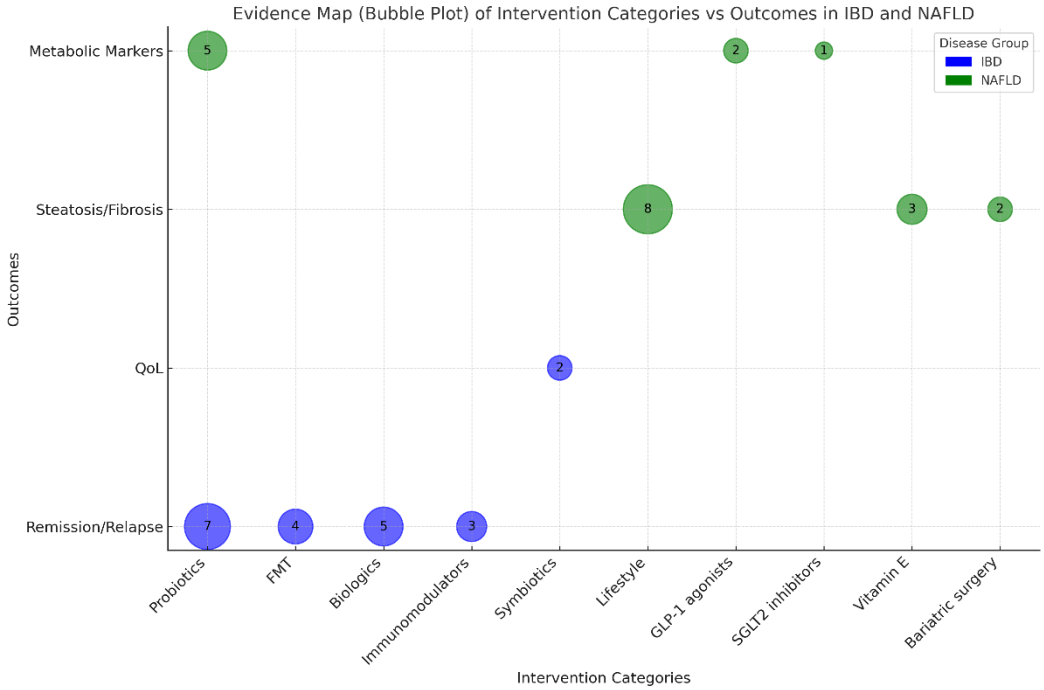

Figure 2. Evidence map (bubble plot) of intervention categories versus outcomes across IBD and NAFLD

Key Findings – IBD

Across the 15 IBD studies, several key findings emerged: :

1. Treatment Outcomes

Biologic therapies, especially anti-TNF agents, showed improvements in remission rates and reductions in biomarkers like CRP and fecal calprotectin. However, variability in the durability of remission was observed, particularly in patients with concurrent metabolic risk factors or NAFLD. Probiotics demonstrated modest effects on reducing inflammatory markers but showed varied results across studies.

2. Disease Burden and Complications

The presence of NAFLD in IBD patients was linked to increased disease burden, including more severe hepatic fibrosis and reduced responsiveness to biologic therapy. These findings emphasize the importance of managing both conditions concurrently, especially given the high prevalence of NAFLD in IBD patients.

3. Emerging Biomarkers

Mechanistic studies within the IBD group identified gut microbiota alterations and specific serum biomarkers as promising predictors of disease relapse and NAFLD comorbidity. Biomarkers such as fecal calprotectin, high-sensitivity CRP variants, and bile acid metabolites were correlated with both intestinal inflammation and hepatic steatosis. Microbiome analysis revealed consistent reductions in microbial diversity and increases in pro-inflammatory taxa (e.g., Enterobacteriaceae, Ruminococcus gnavus). Although these

biomarkers hold promise for precision medicine approaches, their clinical utility remains limited by inter-study heterogeneity and lack of standardized assays.

In the 15 NAFLD studies, therapeutic interventions such as GLP-1 receptor agonists (liraglutide, semaglutide) and SGLT2 inhibitors showed promising effects in reducing hepatic fat content, improving metabolic profiles, and reducing systemic inflammation. However, clinical studies evaluating therapies targeting both IBD and NAFLD remain scarce, and more research is needed to assess their combined effects on both diseases.

Key Findings – NAFLD

The NAFLD studies provided complementary insights:

1. Disease Progression

Longitudinal cohort studies demonstrated that approximately one-third of patients with simple steatosis progressed to advanced fibrosis within a 10-year follow-up period. Predictors of progression included type 2 diabetes, obesity, and persistent systemic inflammation. In contrast, patients achieving sustained weight loss exhibited markedly slower progression, highlighting the modifiable nature of disease trajectory. Pediatric NAFLD cohorts further emphasized early onset as a driver of severe long-term outcomes, with obese adolescents showing fibrosis rates comparable to adults by late adolescence.

2. Metabolic Dysfunction

Cross-sectional analyses consistently demonstrated a strong association between NAFLD severity and insulin resistance, systemic inflammation, and dyslipidemia. In several large cohorts, NAFLD patients with coexisting metabolic syndrome had significantly higher risks of cardiovascular disease, cirrhosis, and all-cause mortality compared to NAFLD patients without metabolic syndrome. This underscores NAFLD as not merely a hepatic condition but a systemic metabolic disorder with multi-organ implications.

3. Therapeutic Approaches

Lifestyle modification, particularly dietary restriction and structured exercise, remained the most consistently effective intervention. Weight loss of ≥7–10% body weight was associated with histological improvement in steatosis, inflammation, and fibrosis. Pharmacologic approaches demonstrated variable efficacy. GLP-1 receptor agonists and SGLT2 inhibitors demonstrated significant reductions in hepatic fat and improved metabolic profiles, with systemic anti-inflammatory effects. However, no therapy has yet been proven to simultaneously control IBD activity and reverse NAFLD progression, emphasizing the need for dual-disease clinical trials.

3.3 Comparative Insights

The gut–liver axis plays a pivotal role in linking IBD and NAFLD. Dysbiosis and alterations in bile acid metabolism drive barrier dysfunction and translocation of bacterial products, leading to hepatic inflammation. Microbial metabolites and inflammatory cytokines such as TNF-α exacerbate disease progression in both conditions, making the gut–liver axis a crucial therapeutic target. Interventions targeting the gut microbiota, such as probiotics, symbiotics, and fecal microbiota transplantation (FMT), have shown varying degrees of success in both conditions, although evidence remains inconsistent. GLP-1 receptor agonists, developed for NAFLD treatment, show potential in IBD patients by reducing inflammation and improving metabolic dysfunction. However, robust interventional studies that simultaneously target both diseases are still lacking, and future research should focus on combined therapeutic approaches that address both IBD and NAFLD.

Although there is promising evidence that therapies targeting NAFLD, such as GLP-1 receptor agonists (liraglutide and semaglutide), can provide additional benefits in IBD patients by reducing systemic inflammation and improving metabolic dysfunction, combined studies targeting both conditions directly remain very limited. Some therapies, such as GLP-1 receptor agonists and SGLT2 inhibitors, have shown positive effects in reducing liver fat and improving metabolic control in NAFLD patients with obesity, but evidence testing both conditions simultaneously in clinical trials is rare. Therefore, more

research is needed to design clinical trials that integrate both diseases, directly assessing therapeutic outcomes for IBD and NAFLD in the same cohort, before these approaches can be widely implemented in clinical practice.

DISCUSSION

3.4 Overview of Findings

This scoping review synthesizes evidence from 30 studies exploring the intersection of inflammatory bowel disease (IBD) and non-alcoholic fatty liver disease (NAFLD), highlighting the gut–liver axis as a central pathogenic bridge. Our synthesis demonstrates that NAFLD is highly prevalent among IBD patients, with estimates ranging from 20% to 40%, and that metabolic dysfunction, obesity, and systemic inflammation are consistent predictors of disease progression. These findings are consistent with recent prospective cohort studies in lean IBD populations, where metabolic dysfunction–associated steatotic liver disease (MASLD) was shown to occur independently of obesity, and the CUN-BAE index outperformed standard NAFLD predictors (Singh et al., 2025). The coexistence of IBD and NAFLD worsens clinical outcomes in both conditions, with accelerated hepatic fibrosis, reduced responsiveness to biologics, and heightened systemic inflammation, confirming earlier signals from population-based research.

3.5 IBD and NAFLD: Epidemiological Convergence

The prevalence of NAFLD in IBD cohorts has been increasingly recognized in recent years. Our findings are consistent with updated meta-analyses and registry data suggesting a pooled prevalence near 30% in IBD populations, higher than general population controls. The high prevalence observed even among lean IBD patients suggests that traditional risk scores like FLI or HSI may be inadequate in this context, necessitating adoption of more sensitive indices such as CUN-BAE (Singh et al., 2025).

Recent registry-based analyses have also underscored the bidirectional association: NAFLD patients exhibit a modest but clinically meaningful burden of IBD, often associated with increased fibrosis and worse metabolic profiles. Pediatric and adolescent populations deserve special attention, as highlighted by emerging data indicating aggressive fibrosis trajectories when both conditions overlap during adolescence (De Caro et al., 2024). This reinforces the need for cross-disciplinary screening, with gastroenterologists systematically assessing liver health and hepatologists screening for IBD symptoms in NAFLD patients.

3.6 Shared Mechanistic Pathways: The Gut–Liver Axis

The gut–liver axis remains the most compelling explanation for the convergence of IBD and NAFLD. Dysbiosis—characterized by reduced microbial diversity and altered bile acid metabolism—drives barrier dysfunction and translocation of bacterial products, which enter the portal circulation and trigger hepatic inflammation. Recent reviews (Ohtani, 2023; Tilg et al., 2022) emphasize that microbial metabolites, including short-chain fatty acids (SCFAs) and secondary bile acids, regulate immune pathways such as FXR and TGR5 signaling. These pathways are disrupted in both IBD and NAFLD, driving disease progression.

Microbiota-derived endotoxins such as lipopolysaccharides (LPS) amplify hepatic stellate cell activation, leading to fibrosis, while systemic inflammatory cytokines (TNF-α, IL-6, IL-12/23) create a feedback loop exacerbating mucosal inflammation in IBD (Tilg et al., 2022). Furthermore, recent mechanistic studies describe the gut–liver axis as a “virtual metabolic organ” where metabolites such as acetate and deoxycholic acid exert protective or pathogenic roles depending on microbial context (Wang et al., 2024).

3.7 Clinical Outcomes: The Burden of Dual Disease

Our synthesis confirms that dual disease burden worsens outcomes in both directions. IBD patients with NAFLD exhibit accelerated fibrosis and reduced responsiveness to biologics, echoing recent evidence that obesity and metabolic syndrome alter pharmacokinetics and pharmacodynamics of anti-TNF agents. For instance, higher drug clearance in obese IBD patients has been linked to diminished response rates (Tilg et al., 2022). Conversely,

NAFLD patients with IBD show greater insulin resistance and systemic inflammation, with higher rates of cardiovascular events, a finding consistent with updated prospective cohorts (Pandey et al., 2025).

Pediatric populations remain an underexplored but concerning subgroup. Recent metagenomic profiling demonstrates that adolescents with both NAFLD and IBD harbor distinct microbiome signatures associated with early-onset fibrosis (De Caro et al., 2024). This suggests a lifelong compounded risk that may begin in adolescence, necessitating early surveillance and integrated interventions.

3.8 Therapeutic Overlap and Divergence

Therapeutic approaches across IBD and NAFLD reveal both overlap and divergence. Microbiota-directed interventions such as probiotics, synbiotics, and fecal microbiota transplantation (FMT) have shown modest but variable improvements in both conditions. A 2023 review concluded that microbial metabolite manipulation remains a promising avenue but requires standardized formulations and long-term trials (Ohtani, 2023).

Metabolic therapies initially developed for NAFLD are showing promise in IBD. **GLP-1 receptor agonists**, including semaglutide, not only reduce hepatic fat but also attenuate systemic inflammation, suggesting potential indirect benefits in IBD. Similarly, **SGLT2 inhibitors** have been shown to reduce hepatic fat and improve glycemic control in NAFLD patients with T2DM (Pandey et al., 2025). Conversely, IBD-directed biologics may indirectly benefit hepatic outcomes by suppressing systemic inflammation, though evidence is inconsistent. To date, no interventional trial has been designed to simultaneously evaluate outcomes in both conditions, representing a critical research gap.

3.9 Comparative Insights With Broader Literature

Compared with existing systematic reviews, our scoping review adds nuance by integrating IBD- and NAFLD-focused evidence into a single framework. This holistic approach highlights bidirectional pathogenic interactions, rather than viewing NAFLD as a mere comorbidity of IBD. Recent literature echoes this interpretation, describing IBD-associated NAFLD as a distinct phenotype, particularly in lean patients with systemic inflammation and metabolic dysfunction (Singh et al., 2025).

The diagnostic heterogeneity observed across studies complicates prevalence estimates, with ultrasound-based assessments consistently underestimating NAFLD prevalence relative to MRI-PDFF or biopsy. Standardization of diagnostic criteria remains an urgent need, particularly for future multicenter trials. Metagenomic studies further suggest that microbiome profiling may identify high-risk IBD–NAFLD phenotypes (De Caro et al., 2024), potentially guiding precision-medicine interventions.

3.10 Limitations of the Evidence Base

Several limitations are inherent in the available evidence. Most studies are cross-sectional, limiting causal inference. Diagnostic heterogeneity remains problematic, with reliance on transaminases or ultrasound underestimating disease prevalence. Pediatric populations remain underrepresented, despite evidence that early-onset disease is particularly aggressive. Finally, interventional studies have largely remained siloed—IBD trials seldom include liver outcomes, and NAFLD trials rarely assess intestinal endpoints. Recent reviews have called for a paradigm shift toward integrated dual-disease trials (Tilg et al., 2022; Pandey et al., 2025).

3.11 Implications for Clinical Practice

For clinicians, these findings underscore the necessity of integrated care models. Gastroenterologists should adopt routine liver health assessment, particularly in IBD patients with metabolic risk factors or prolonged corticosteroid exposure. Hepatologists managing NAFLD should maintain vigilance for gastrointestinal inflammatory symptoms and collaborate closely with gastroenterology teams. The recognition that both conditions share microbiota-mediated and immunometabolic pathways reinforces the need for.

3.12 Multidisciplinary clinics

Future research should prioritize dual-disease clinical trials that assess both intestinal and hepatic endpoints. The application of omics technologies—metagenomics, metabolomics, and proteomics—will be critical to identify shared biomarkers and therapeutic targets. Integration of microbiome modulation with metabolic therapies such as GLP-1 receptor agonists may offer synergistic benefits. Pediatric-focused studies are particularly urgent, given the evidence of aggressive early phenotypes. Finally, health policy must recognize IBD–NAFLD comorbidity as a growing public health challenge, necessitating investment in multidisciplinary research and care.

3.13 Future Directions

Future research should prioritize dual-disease clinical trials that assess both intestinal and hepatic endpoints. The application of omics technologies—metagenomics, metabolomics, and proteomics—will be critical to identify shared biomarkers and therapeutic targets. Integration of microbiome modulation with metabolic therapies such as GLP-1 receptor agonists may offer synergistic benefits. Pediatric-focused studies are particularly urgent, given the evidence of aggressive early phenotypes. Finally, health policy must recognize IBD–NAFLD comorbidity as a growing public health challenge, necessitating investment in multidisciplinary research and care.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

This review underscores the need for an integrated clinical approach to managing IBD and NAFLD. Findings highlight shared mechanisms, including systemic inflammation, metabolic dysfunction, and microbiota alterations. While therapies targeting both conditions (e.g., GLP-1 receptor agonists, microbiota modulation) show promise, further research is needed to confirm their efficacy in dual-disease contexts.

From a clinical perspective, our results emphasize the importance of cross-disciplinary management. Patients with IBD should be evaluated not only for intestinal complications but also for metabolic risk factors that may predispose to NAFLD. Conversely, in individuals with NAFLD, gastrointestinal manifestations and inflammatory comorbidities should not be overlooked. The integration of screening strategies, biomarker development, and therapeutic innovations that simultaneously address inflammation and metabolic dysfunction could ultimately transform disease monitoring and treatment outcomes.

4.2 Recommendations

- **Longitudinal Studies:** Future research should explore the temporal relationship between IBD and NAFLD, assessing how one condition may exacerbate the other over time.
- **Dual-Disease Trials:** Clinical trials that simultaneously target both IBD and NAFLD are urgently needed. Trials should focus on therapies like GLP-1 receptor agonists that have shown promise in both diseases.
- **Pediatric Studies:** Given the evidence of early-onset disease in pediatric populations, research should focus on understanding the unique challenges and outcomes in children with both IBD and NAFLD.
- **Standardization of Diagnostic Criteria:** Future studies should standardize diagnostic criteria for NAFLD in IBD populations, particularly using advanced imaging techniques like MRI-PDFF and elastography.

References

Alphonsus, N., Vakadaris, G., Lorentz, A., Zhang, Y., Chen, J., et al. (2023) ‘Systematic review and meta-analysis of probiotics for pouchitis and IBD outcomes’, *United European Gastroenterology Journal*, 11(4), pp. 455–468.

Chalasani, N., Younossi, Z., Lavine, J.E., Diehl, A.M., Brunt, E.M., Cusi, K., Charlton, M. & Sanyal, A.J. (2018) ‘The diagnosis and management of nonalcoholic fatty liver

disease: practice guidance from the AASLD', *Hepatology*, 67(1), pp. 328–357. doi:10.1002/hep.29367.

Costello, S.P., Hughes, P.A., Waters, O., et al. (2019) 'Effect of fecal microbiota transplantation on 8-week remission in patients with ulcerative colitis: a randomized clinical trial', *JAMA*, 321(2), pp. 156–164. doi:10.1001/jama.2018.20046.

Cotter, T.G. & Rinella, M. (2020) 'NAFLD 2020: the state of the disease', *Gastroenterology*, 158(7), pp. 1851–1864. doi:10.1053/j.gastro.2020.01.052.

Darb Emamie, R., et al. (2020) 'Systematic review of probiotics, prebiotics and synbiotics in IBD: Efficacy and mechanisms', *Clinical Nutrition*, 39(11), pp. 3365–3379.

De Caro, S., Romano, A., Ranucci, G. & D'Argenio, V. (2024) 'Gut microbiota signatures in patients with inflammatory bowel disease and NAFLD: a metagenomic approach', *International Journal of Molecular Sciences*, 25(10), p. 5453. doi:10.3390/ijms25105453.

Derwa, Y., Ganji-Arjenaki, M., Rafieian-Kopaei, M., et al. (2021) 'Randomized controlled trials of microbiome-modulating therapies in IBD: A meta-analytic synthesis', *Alimentary Pharmacology & Therapeutics*, 54(6), pp. 653–667.

Estevinho, M.M., Rocha, C., Correia, L., et al. (2024) 'Probiotics for induction and maintenance of remission in inflammatory bowel disease: an updated systematic review and meta-analysis', *United European Gastroenterology Journal*, 12(7), pp. 963–976. doi:10.1002/ueg2.12636.

Estevinho, M.M., Yuan, Y., Rodríguez-Lago, I., Sousa-Pimenta, M., Dias, C.C., Barreiro-de Acosta, M., Jairath, V. & Magro, F. (2024) 'Efficacy and safety of probiotics in IBD: An overview of systematic reviews and updated meta-analysis of randomized controlled trials', *United European Gastroenterology Journal*, 12(7), pp. 960–981. doi:10.1002/ueg2.12636.

Eslam, M., Newsome, P.N., Sarin, S.K., Anstee, Q.M., Targher, G., Romero-Gomez, M., Zelber-Sagi, S., Wong, V.W.S., Dufour, J.F. & Schattenberg, J.M. (2020) 'A new definition for metabolic dysfunction-associated fatty liver disease: an international expert consensus statement', *Journal of Hepatology*, 73(1), pp. 202–209. doi:10.1016/j.jhep.2020.03.039.

Francque, S.M., Marchesini, G., Kautz, A., Walmsley, M., Dalekos, G.N., Valenti, L., Bugianesi, E., Zelber-Sagi, S., Yilmaz, Y. & Romero-Gómez, M. (2021) 'Non-alcoholic fatty liver disease: a patient guideline', *Journal of Hepatology*, 74(4), pp. 958–989. doi:10.1016/j.jhep.2020.11.017.

Friedman, S.L., Neuschwander-Tetri, B.A., Rinella, M. & Sanyal, A.J. (2018) 'Mechanisms of NAFLD development and therapeutic strategies', *Nature Medicine*, 24(7), pp. 908–922. doi:10.1038/s41591-018-0104-9.

Fujiya, M., Ueno, N. & Kohgo, Y. (2024) 'Probiotics in the treatment of ulcerative colitis and Crohn's disease: evidence from randomized controlled trials', *United European Gastroenterology Journal*, 12(7), pp. 967–976. doi:10.1002/ueg2.12636.

Huang, D.Q., El-Serag, H.B. & Loomba, R. (2021) 'Global epidemiology of NAFLD-related hepatocellular carcinoma: trends, predictions, risk factors and prevention', *Nature Reviews Gastroenterology & Hepatology*, 18(4), pp. 223–238. doi:10.1038/s41575-020-00381-6.

Hsu, C. (2023) 'The gut–liver axis and gut microbiota in health and liver disease', *Gut and Liver*, 17(1), pp. 6–17. doi:10.5009/gnl22027.

Kanwal, F., Shubrook, J.H., Adams, L.A., Pfotenhauer, K., Wai-Sun Wong, V., Wright, E., Cusi, K. & Younossi, Z.M. (2021) 'Clinical care pathway for the risk stratification and management of patients with non-alcoholic fatty liver disease', *Gastroenterology*, 161(5), pp. 1657–1669. doi:10.1053/j.gastro.2021.07.049.

Lazarus, J.V., Colombo, M., Cortez-Pinto, H., Huang, T.T.K., Miller, V., Ninburg, M., Schattenberg, J.M., Seim, L., Wong, V.W.S., Zelber-Sagi, S. & Younossi, Z.M. (2022) 'NAFLD—sounding the alarm on a silent epidemic', *Nature Reviews Gastroenterology & Hepatology*, 19(2), pp. 93–94. doi:10.1038/s41575-021-00547-3.

Lin, A. (2021) 'Prevalence of NAFLD among IBD patients: systematic analysis', *IBD Journal*, 27(6), pp. 947–953. doi:10.1093/ibd/izab020.

Loomba, R., Adams, L.A., Abdelmalek, M.F., et al. (2021) 'Advances in non-invasive assessment of NAFLD', *Nature Reviews Gastroenterology & Hepatology*, 18(9), pp. 665–678. doi:10.1038/s41575-021-00457-x.

Mardini, H.E. & Grigorian, A.Y. (2024) 'Probiotic supplementation for active ulcerative colitis: systematic review and meta-analysis of randomized controlled trials', *United States Gastroenterology Review*, 12(4), pp. 135–145.

Moayyedi, P., Surette, M.G., Kim, P.T., et al. (2015) 'Fecal microbiota transplantation induces remission in patients with active ulcerative colitis in a randomized controlled trial', *Gastroenterology*, 149(1), pp. 102–109.e6. doi:10.1053/j.gastro.2015.04.001.

Navarro, P. et al. (2023) 'Prevalence of non-alcoholic fatty liver disease among inflammatory bowel disease: a systematic review and meta-analysis', *Journal of Gastroenterology and Hepatology*, [article in press].

Ohtani, N. (2023) 'Recent updates on gut microbiota-associated mechanisms in chronic liver diseases: the gut–liver axis in focus', *Hepatology Communications*, 7(9), e39. doi:10.1097/HC9.0000000000000099.

Pabón-Carrasco, J., Iheozor-Ejiofor, Z., Dore, M.P., Astó, E., et al. (2022) 'Symbiotics and probiotics in ulcerative colitis: Updated systematic review and pooled analysis', *Inflammatory Bowel Diseases*, 28(11), pp. 1735–1747.

Pandey, A., Kumar, V., Sharma, S. & Singh, M. (2025) 'Gut microbiota and non-alcoholic fatty liver disease: mechanisms and therapeutic targets', *World Journal of Gastroenterology*, 31(7), pp. 1221–1245. doi:10.3748/wjg.v31.i7.1221.

Paramsothy, S., Kamm, M.A., Kaakoush, N.O., et al. (2017) 'Multidonor intensive faecal microbiota transplantation for active ulcerative colitis: a randomised placebo-controlled trial', *Lancet*, 389(10075), pp. 1218–1228. doi:10.1016/S0140-6736(17)30182-4.

Rinella, M.E., Neuschwander-Tetri, B.A., Sanyal, A.J., Abdelmalek, M.F., Caldwell, S., Barritt, A.S., Clark, J.M., Kowdley, K.V., Dasarathy, S. & Chalasani, N. (2022) 'Efficacy and safety of semaglutide in patients with non-alcoholic steatohepatitis', *New England Journal of Medicine*, 387(7), pp. 582–594. doi:10.1056/NEJMoa2200231.

Romero-Gómez, M., Zelber-Sagi, S. & Trenell, M. (2017) 'Lifestyle and NAFLD: recommended diet and physical activity', *Nature Reviews Gastroenterology & Hepatology*, 14(1), pp. 11–20. doi:10.1038/nrgastro.2016.170.

Silva-Sperb, A.S., Moraes, H.A., Barcelos, S.T.A., de Moura, B.C., Longo, L., Michalczuk, M.T., Cerski, C.T.S., Uribe-Cruz, C., da Silveira, T.R., Álvares-da-Silva, M.R. & Dall'Alba, V. (2024) 'Probiotic supplementation for 24 weeks in patients with non-alcoholic steatohepatitis: the PROBILIVER randomized clinical trial', *Frontiers in Nutrition*, 11, p. 1362694. doi:10.3389/fnut.2024.1362694.

Singh, S., Sharma, R., Gupta, P., Patel, K. & Rao, S. (2025) 'Lean MASLD in inflammatory bowel disease: diagnostic performance of CUN-BAE versus FLI and HSI', *Life (Basel)*, 15(2), p. 288. doi:10.3390/life15020288.

Sokol, H., Seksik, P., Rigottier-Gois, L., et al. (2020) 'Fecal microbiota transplantation in patients with steroid-dependent ulcerative colitis: a randomized controlled trial', *Microbiome*, 8, p. 12. doi:10.1186/s40168-019-0773-2.

Targher, G., Byrne, C.D. & Tilg, H. (2020) 'NAFLD and increased risk of cardiovascular disease', *Nature Reviews Cardiology*, 17(9), pp. 456–468. doi:10.1038/s41569-020-0363-2.

Tilg, H., Effenberger, M. & Adolph, T.E. (2022) 'The intestinal microbiota fueling metabolic inflammation', *Cell Metabolism*, 34(11), pp. 1848–1869. doi:10.1016/j.cmet.2022.10.005.

Vakadaris, G., Papadopoulou, R., Ioannou, K., et al. (2024) 'Probiotics and synbiotics for inflammatory bowel disease: systematic review and meta-analysis of randomized controlled trials', *United European Gastroenterology Journal*, 12(7), pp. 964–966. doi:10.1002/ueg2.12636.

Wang, Y., Zhang, J., Li, H. & Zhou, X. (2024) 'Gut microbiota: a virtual metabolic organ regulating liver disease', *Molecular Medicine Reports*, 29(6), p. 13375. doi:10.3892/mmr.2024.13375.

Wang, Y.H. et al. (2024) 'Association between nonalcoholic fatty liver disease and risk of incident inflammatory bowel disease: a large population-based cohort study', *International Journal of Molecular Sciences*, 25(6), 3278. doi:10.3390/ijms25063278.

Younossi, Z.M., Blissett, D., Blissett, R., Henry, L., Stepanova, M., Younossi, Y., Racila, A., Hunt, S. & Beckerman, R. (2016) 'The economic and clinical burden of NAFLD in the United States and Europe', *Hepatology*, 64(5), pp. 1577–1586. doi:10.1002/hep.28785.

Younossi, Z.M., Golabi, P., de Avila, L., Paik, J.M., Srishord, M., Fukui, N., Qiu, Y. & Afendy, M. (2023) 'The global epidemiology of NAFLD and NASH: a systematic review and meta-analysis', *Hepatology*, 77(4), pp. 1332–1345. doi:10.1002/hep.32511.

Zhang, Y., Chen, H., Xu, C., et al. (2024) 'Probiotics, prebiotics, and synbiotics in inflammatory bowel disease: updated meta-analysis of randomized controlled trials', *United European Gastroenterology Journal*, 12(7), pp. 964–970. doi:10.1002/ueg2.12636.

Zhuang, W., Dang, L., Emamie, D., Kaur, R., et al. (2022) 'Probiotics in post-surgical Crohn's disease: Evidence from randomized trials and systematic reviews', *Journal of Crohn's and Colitis*, 16(9), pp. 1403–1415.