ORIGINAL ARTICLE

Impact of Clinical Pharmacist Interventions on Medication Adherence, Lifestyle Modification, and Cardiometabolic Outcomes in Non-alcoholic Fatty Liver Disease

E. Pavan Kumar[1], Thirumaleswara Goud[2]

[1]Department of Research and Development, Jawaharlal Nehru Technological University, Anantapur, Andhra Pradesh, India, [2]Department of Pharmacy Practice, Creative Educational Society's College of Pharmacy, Kurnool, Andhra Pradesh, India

Abstract

Background: Non-alcoholic fatty liver disease (NAFLD) is closely associated with cardiometabolic disorders and is frequently complicated by suboptimal medication adherence, drug-related problems (DRPs), and inadequate lifestyle modification. Evidence describing the clinical impact of pharmacist-led interventions in NAFLD management remains limited. **Objectives:** The objective of the study was to evaluate the effect of structured clinical pharmacist interventions on medication adherence, lifestyle behaviors, DRPs, and cardiometabolic outcomes in adults with NAFLD. **Methods:** A prospective observational interventional study was conducted over a 12-month follow-up period at a government general hospital, Anantapur. Adult patients with NAFLD (n = 379) received clinical pharmacist-led interventions, including medication reconciliation using the best possible medication history approach, DRP identification based on the Pharmaceutical Care Network Europe classification, physician-directed recommendations, and individualized counseling on medication use and lifestyle modification. Clinical, biochemical, and patient-reported outcomes were evaluated at baseline and follow-up visits. **Results:** Pharmacist-led interventions were associated with significant improvements in adherence, knowledge, and lifestyle behaviors. A total of 48 clinically relevant DRPs were identified, with most pharmacist recommendations accepted by physicians. Significant improvements were observed in cardiometabolic parameters, including hemoglobin A1C (6.82 ± 1.12 vs. 6.34 ± 0.96, $P < 0.001$), low-density lipoprotein-cholesterol ($P < 0.001$), body mass index ($P < 0.001$), blood pressure, and Fatty Liver Index scores. Correlation analyses demonstrated significant associations between adherence, satisfaction, and clinical outcomes. **Conclusion:** Structured clinical pharmacist interventions improve medication safety, adherence, behavioral outcomes, and cardiometabolic risk indicators in NAFLD patients, supporting their integration into multidisciplinary care models.

Key words: Cardiometabolic outcomes, clinical pharmacist intervention, drug-related problems, medication adherence, non-alcoholic fatty liver disease, non-alcoholic steatohepatitis

INTRODUCTION

Non-alcoholic fatty liver disease (NAFLD) is currently the most prevalent chronic liver disorder worldwide, affecting nearly one-quarter of the global adult population and posing a major public health challenge due to its close association with metabolic syndrome and cardiovascular disease (CVD) risk.[1] NAFLD is now recognized not merely as a hepatic condition, but as a multisystem disease strongly linked to insulin resistance, type 2 diabetes mellitus, obesity, dyslipidemia, and hypertension.[2]

The clinical spectrum of NAFLD ranges from simple steatosis to non-alcoholic steatohepatitis (NASH), progressive fibrosis (FIB), cirrhosis, and hepatocellular carcinoma.[3] Importantly,

Address for correspondence:
E. Pavan Kumar, Department of Research and Development, Jawaharlal Nehru Technological University, Anantapur, Andhra Pradesh, India.
E-mail: dr.e.pavankumar@gmail.com

Received: 14-02-2026
Revised: 20-03-2026
Accepted: 29-03-2026

cardiovascular complications rather than liver-related events remain the leading cause of mortality among patients with NAFLD.[4] Evidence suggests that cardiometabolic risk factors, including poor glycemic control, atherogenic dyslipidemia, elevated blood pressure, and excess adiposity, are key determinants of both hepatic disease progression and adverse cardiovascular outcomes.[5]

Lifestyle modification and optimal management of metabolic comorbidities form the cornerstone of NAFLD treatment, as no pharmacotherapy has yet been universally approved specifically for NAFLD or NASH.[6] Sustained improvements in diet quality, physical activity, weight reduction, and cardiometabolic parameters such as hemoglobin A1C (HbA1c) and low-density lipoprotein-cholesterol (LDL-C) have been shown to reduce hepatic steatosis and improve long-term outcomes.[7] However, real-world implementation of these strategies is frequently hindered by suboptimal medication adherence, polypharmacy, and inadequate patient understanding of disease and treatment goals.[8]

Medication non-adherence remains a pervasive problem in chronic metabolic diseases, with rates approaching 40–50% in conditions such as diabetes, hypertension, and dyslipidemia.[9] In NAFLD populations, this issue is compounded by the frequent use of multiple medications, risk of drug–drug interactions, inappropriate continuation of potentially hepatotoxic agents, and insufficient therapeutic monitoring.[10] Drug-related problems (DRPs) are therefore common and clinically relevant in this population, yet often remain under-recognized in routine care.

Clinical pharmacists play a critical role in optimizing medication use through structured medication reconciliation, identification and resolution of DRPs, and patient-centered education. Pharmacist-led interventions have consistently demonstrated improvements in medication adherence, glycemic control, lipid profiles, blood pressure, and patient knowledge across diabetes and CVD settings.[11] Standardized approaches such as the best possible medication history (BPMH) and Pharmaceutical Care Network Europe (PCNE) classification systems enable systematic identification of discrepancies, inappropriate therapies, and safety concerns, thereby enhancing medication safety and clinical outcomes.[12]

Despite the metabolic complexity of NAFLD and its strong overlap with conditions that benefit from pharmacist involvement, evidence evaluating pharmacist-led interventions specifically in NAFLD care remains limited. Few studies have assessed the impact of clinical pharmacists on combined cardiometabolic outcomes, lifestyle behaviors, and patient-reported measures in NAFLD populations.[13] Addressing this gap is essential given the increasing emphasis on multidisciplinary models of care for chronic metabolic and liver diseases.

Therefore, the present study was designed to evaluate the impact of structured clinical pharmacist interventions, including medication reconciliation, DRP identification and resolution, and targeted lifestyle counseling on medication adherence, cardio metabolic outcomes, and patient-centered measures in adults with NAFLD over a 12-month follow-up period. This study aims to provide real-world evidence supporting the integration of clinical pharmacists into routine NAFLD management to improve care quality, safety, and long-term outcome.

MATERIALS AND METHODS

This 12-month prospective interventional study was conducted at Government General Hospital, Anantapur, India, to evaluate the impact of structured clinical pharmacist interventions on medication adherence, lifestyle modification, DRPs, and cardiometabolic outcomes in adults with confirmed NAFLD. Ethical approval was obtained, and written informed consent was secured. Adults (≥18 years) with NAFLD and at least one cardiometabolic comorbidity were enrolled ($n = 379$), while those with significant alcohol intake, other chronic liver diseases, advanced hepatic complications, or pregnancy were excluded. Pharmacist interventions at baseline and 3, 6, and 12 months included medication reconciliation using the BPMH approach, DRP identification per the PCNE classification, physician communication, and individualized lifestyle counseling. Primary outcomes included HbA1c, LDL-C, body mass index (BMI), blood pressure, and fatty liver index; secondary measures included triglycerides, high-density lipoprotein-cholesterol (HDL-c), liver enzymes, FIB-4 score, and waist circumference. Data were obtained from patient interviews, prescriptions, and medical records. Medication adherence was assessed using the Morisky Medication Adherence Scale (MMAS-8), physical activity using the International Physical Activity Questionnaire-Short-Form (IPAQ-SF), and dietary adherence using a MEDAS-adapted questionnaire. Continuous variables were expressed as mean ± SD and categorical variables as frequencies; pre–post comparisons were analyzed using paired statistical tests with $P < 0.05$ considered significant.

RESULTS

Table 1 summarizes the age- and gender-wise distribution of the study population ($n = 379$). The cohort included 190 females and 189 males, demonstrating an almost equal gender representation. Participants were distributed across all adult age categories, with the highest representation observed in the 31–40 and 71–80 year groups.

In the younger age intervals (18–20 and 21–30 years), gender distribution was relatively balanced. A higher proportion of males was observed in the 41–50 and 51–60 year groups, whereas females showed slightly greater representation in the 31–40 and 61–70 year categories. Equal representation

Table 1: Distribution of participants based on gender

Age interval	Female (n)	Male (n)
18–20	14	11
21–30	26	26
31–40	31	20
41–50	28	38
51–60	26	33
61–70	31	27
71–80	34	34
Total	190	189

Table 2: Distribution of educational status by age interval and gender

Age interval	Female		Male	
	Educated	Un educated	Educated	Un educated
18–20	14	0	11	0
21–30	23	3	24	2
31–40	26	5	17	3
41–50	22	6	34	4
51–60	0	26	20	10
61–70	0	31	17	10
71–80	0	34	12	22
Total	190		189	
	379			

Table 3: Gender-wise distribution of diabetes, hypertension, and dyslipidemia among study participants

Variable	Gender	Category	Frequency	Percentage
Diabetes	Female	Yes	78	41.05
		No	112	58.95
	Male	Yes	78	41.27
		No	111	58.73
Hypertension	Female	Yes	100	52.63
		No	90	47.37
	Male	Yes	79	41.80
		No	110	58.20
Dyslipidemia	Female	Yes	88	46.32
		No	102	53.68
	Male	Yes	90	47.62
		No	99	52.38

between males and females was noted in the 21–30 and 71–80 year groups. Overall, the findings indicate a well-distributed adult population across age intervals with near-equal gender representation.

The educational status analysis across age and gender revealed a distinct generational pattern. Participants aged 18–40 years demonstrated a higher level of education among both males and females, suggesting improved literacy and health awareness in younger cohorts. In contrast, the prevalence of uneducated individuals markedly increased in the older age groups (≥51 years), with females disproportionately affected, highlighting persistent gender disparities in access to education. Of the total 379 participants, 190 were educated, while 189 were uneducated, indicating an overall balanced distribution. This educational gradient underscores the critical role of socioeconomic and demographic factors in shaping health literacy and disease prevention practices. From a clinical and public health perspective, higher educational attainment in younger populations may translate into better comprehension of lifestyle modification strategies, adherence to medical advice, and responsiveness to clinical pharmacist-led interventions for NAFLD prevention and management.

The gender-wise analysis of comorbidities revealed comparable prevalence patterns between males and females. Diabetes was reported in approximately two-fifths of participants across both genders. Hypertension was more common among females, affecting over half of the group, whereas males exhibited a slightly lower prevalence. Dyslipidemia rates were nearly equal between genders, with marginally higher occurrence in males. These findings indicate that metabolic comorbidities are highly prevalent in both groups, underscoring their contribution to NAFLD progression and cardiovascular risk.

Both males and females exhibited comparable mean FLI and FIB-4 values, with males showing marginally higher FIB-4 scores, suggesting a slightly greater risk of FIB progression. A larger proportion of participants in both genders were categorized as low risk based on FLI, indicating moderate hepatic steatosis. However, the high prevalence of elevated FIB-4 scores among both males and females reflects a concerning trend toward liver FIB despite moderate fat accumulation. These observations emphasize the need for a comprehensive risk assessment that includes both steatosis and FIB indices to enable early detection, gender-sensitive evaluation, and timely intervention in NAFLD management.

Medication reconciliation among 379 patients with NAFLD identified a total of 48 clinically relevant drug-related problems, indicating that a subset of patients experienced medication-related challenges requiring targeted pharmacist intervention. Problems related to treatment effectiveness were most frequently observed, followed by treatment safety concerns and issues related to monitoring and documentation.

Evaluation of causative factors revealed that drug-use process errors and patient-related factors were the leading contributors to DRPs. These findings highlight the importance of patient education, adherence counseling, and regular follow-up in

Table 4: Gender-wise distribution of FLI and FIB-4 scores and associated risk categories among study participants

Variable	Gender	Mean	SD	Risk category	Frequency	Percentage
FLI score	Female	50.64	22.49	Low risk	116	61.05
				High risk	74	38.95
	Male	49.24	22.72	Low risk	115	60.85
				High risk	74	39.15
FIB4 score	Female	2.05	0.88	High risk	139	73.16
				Low risk	51	26.84
	Male	2.12	0.86	High risk	135	71.43
				Low risk	54	28.57

FLI: Fatty liver index, FIB-4: Fibrosis-4, SD: Standard deviation

Table 5: Distribution of drug-related problems identified during medication reconciliation

PCNE problem domain	Description	Number of DRPs
P1 – Treatment effectiveness	Non-adherence, untreated indication, suboptimal therapy	26
P2 – Treatment safety	Drug–drug interactions, hepatotoxic risk, excessive dosing	14
P3 – Other	Inadequate monitoring, unclear therapeutic goals	8
Total DRPs identified		48

PCNE: Pharmaceutical Care Network Europe, DRPs: Drug-related problems

Table 6: Causes of drug-related problems according to PCNE classification

PCNE cause domain	Description	Number of causes
C1 – Drug selection	Inappropriate or non-optimized therapy	9
C3 – Dose selection	Dose too high or too low	7
C6 – Drug use process	Incorrect administration, missed doses	16
C7 – Patient-related	Intentional or unintentional non-adherence	11
C9 – Monitoring	Inadequate laboratory or clinical monitoring	5
Total causes identified		48

PCNE: Pharmaceutical Care Network Europe

optimizing pharmacotherapy among NAFLD patients with multiple cardiometabolic comorbidities.

A total of 45 pharmacist-recommended interventions were proposed to address identified DRPs. Most recommendations were accepted and implemented, resulting in the resolution of the majority of problems within 1 month. Unresolved DRPs were primarily attributable to patient-related factors or clinical constraints, underscoring the need for sustained multidisciplinary follow-up Tables 2-9.

Table 7: Acceptance and resolution of pharmacist-recommended interventions

Outcome category	Number
Interventions proposed	45
Accepted and implemented	36
Accepted with modification	4
Not accepted	5
DRPs resolved within 3 months	38
DRPs partially resolved	6
DRPs unresolved	4

Medication adherence behavior demonstrated marked improvement over the 12-month follow-up period following clinical pharmacist intervention. At baseline, a substantial proportion of participants reported forgetting to take medications, missing doses within the previous 2 weeks, discontinuing therapy without medical advice, or omitting doses during travel. These non-adherent behaviors declined considerably at follow-up. Reports of forgetfulness reduced from 162 to 89 participants, missed doses decreased from 141 to 73 participants, and unsupervised discontinuation of medication declined from 96 to 41 participants. Similarly, stopping medication when symptoms improved decreased from 109 to 49 participants, and perceived difficulty remembering medications declined from 132 to 58 participants. Feelings of being burdened by long-term therapy also showed a notable reduction. Conversely, adherence to taking medication as prescribed improved, with participants confirming medication intake on the previous day increasing from 302 to 345. Overall, these findings reflect a significant reduction in both intentional and unintentional non-adherence behaviors, indicating enhanced treatment compliance and sustained

Table 8: Pre–post comparison of medication adherence responses (MMAS-8) following clinical pharmacist intervention

S. No.	Question	Yes		No		*P*-value
		Baseline	12 months	Baseline	12 months	
1	Do you sometimes forget to take your medications?	162	89	217	290	<0.001
2	In the past 2 weeks, were there days you did not take your medication?	141	73	238	306	
3	Have you stopped medication without informing doctor?	96	41	283	338	
4	When traveling, do you forget medications?	118	57	261	322	
5	Did you take medication yesterday?	302	345	77	34	
6	Do you stop medication when symptoms improve?	109	49	270	330	
7	Do you feel hassled sticking to treatment?	153	76	226	303	
8	Difficulty remembering medication	132	58	267	321	

Table 9: Pre–post comparison of physical activity parameters assessed using IPAQ-SF

S. No.	Question	Mean±SD		*P*-value
		Baseline	12 months	
1	In the last 7 days, how many days did you walk for at least 10 min at a time?	2.1±1.2 days	3.4±1.3 days	<0.001
2	How much time per day did you spend walking?	24.6±11.2 min	36.8±14.5 min	
3	In the last 7 days, how many days did you do moderate physical activities?	1.63±0.94 days	2.53±1.12 days	
4	How much time per day did you spend in moderate activities?	28.2±13.4 min	41.3±16.2 min	
5	In the last 7 days, how many days did you do vigorous physical activities?	0.84±0.72 days	1.41±0.91 days	
6	How much time per day did you spend doing vigorous activities?	18.5±10.1 min	29.6±12.8 min	
7	During the last 7 days, how much time did you spend sitting on a typical day?	7.6±1.8 h	6.1±1.5 h	

IPAQ-SF: International Physical Activity Questionnaire-Short-Form

patient engagement following structured pharmacist-led counseling.

Physical activity levels demonstrated statistically significant improvement across all IPAQ-SF domains over the 12-month follow-up period. The mean number of walking days per week increased from 2.1 ± 1.2 to 3.4 ± 1.3 days ($P < 0.001$), accompanied by a substantial rise in average walking duration from 24.6 ± 11.2 to 36.8 ± 14.5 min/day. Moderate-intensity activity frequency improved from 1.63 ± 0.94 to 2.53 ± 1.12 days/week, with corresponding increases in duration from 28.2 ± 13.4 to 41.3 ± 16.2 min/day. Vigorous activity participation also showed meaningful enhancement, with days per week increasing from 0.84 ± 0.72 to 1.41 ± 0.91 and duration rising from 18.5 ± 10.1 to 29.6 ± 12.8 min/day. Importantly, sedentary behavior decreased significantly, with average sitting time reducing from 7.6 ± 1.8 to 6.1 ± 1.5 h/day. Collectively, these findings indicate a clinically meaningful shift toward higher physical activity engagement and reduced sedentary time following pharmacist-led lifestyle intervention.

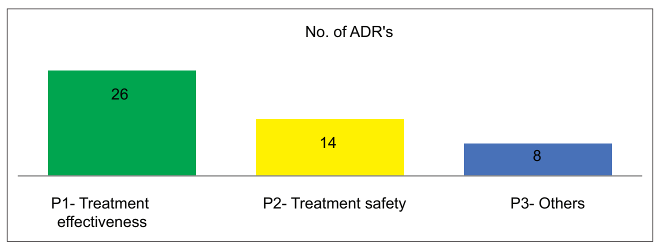

Figure 1: Distribution of adverse drug reactions

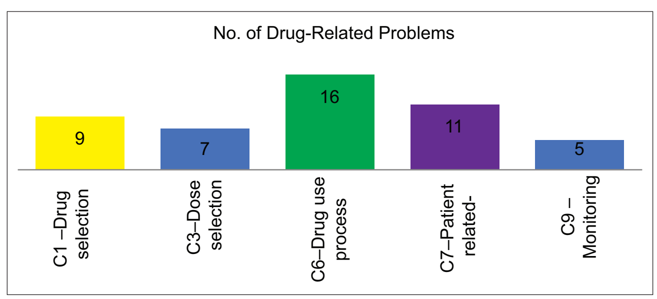

Figure 2: Causes for drug related problems

Table 10 presents the pre–post comparison of behavioral, medication adherence, cardiometabolic, and hepatic parameters over the 12-month follow-up period. Significant improvements were observed in lifestyle-related behaviors following clinical pharmacist intervention. Mean physical activity days per week increased significantly from 2.46 ± 1.11 at baseline to 3.50 ± 1.04 at 12 months ($P < 0.001$). Dietary adherence improved, with the proportion of participants categorized as having high adherence increasing significantly ($P < 0.01$). Concurrently, the prevalence of

Table 10: Pre–post comparison of behavioral, adherence, cardiometabolic, and hepatic outcomes

Outcome variable	Baseline	12 months	*P*-value
Behavioral outcomes			
Dietary adherence (%)	38.0	55.9	<0.01
Alcohol intake (%)	22.4	14.8	0.02
Tobacco consumption (%)	18.7	12.1	0.03
Medication adherence			
Medication adherence (%)	51.5	69.8	<0.001
Glycemic parameters			
HbA1c (%)	6.82±1.12	6.34±0.96	<0.001
Lipid profile			
LDL-C (mg/dL)	142.6±32.4	124.8±28.7	<0.001
HDL-C (mg/dL)	41.3±8.6	44.1±9.2	0.003
Triglycerides (mg/dL)	186.4±54.2	165.7±49.6	<0.001
Anthropometric measures			
BMI (kg/m²)	27.4±3.8	26.2±3.5	<0.001
Waist circumference (cm)	96.2±9.4	93.8±8.7	<0.001
Blood pressure			
Systolic BP (mmHg)	132.4±17.6	127.1±15.9	0.002
Diastolic BP (mmHg)	84.1±9.8	81.6±8.7	0.006
Hepatic indices			
Fatty liver index (FLI)	56.8±14.2	49.7±13.1	<0.001
FIB-4 score	2.31±0.71	2.18±0.69	0.089

BMI: Body mass index, LDL-C: Low-density lipoprotein-cholesterol, HDL-C: High-density lipoprotein-cholesterol, HbA1C: Hemoglobin A1C

regular alcohol consumption and active tobacco use declined significantly during follow-up (P = 0.02 and P = 0.03, respectively), indicating favorable behavioral modification.

Medication adherence demonstrated a marked improvement, with the proportion of patients classified as highly adherent increasing from 51.5% at baseline to 69.8% at 12 months (P < 0.001). These findings suggest improved compliance with prescribed pharmacotherapy following structured pharmacist-led counseling and follow-up.

Significant improvements were also observed across multiple cardiometabolic parameters. Mean HbA1c levels decreased significantly (P < 0.001), reflecting improved glycemic control. Lipid profile parameters demonstrated favorable changes, including significant reductions in LDL-cholesterol and triglycerides and a significant increase in HDL-C. Anthropometric indices, including BMI and waist circumference, showed statistically significant reductions (P < 0.001), indicating improvement in obesity-related risk factors. Both systolic and diastolic blood pressure values decreased significantly over the study period.

Table 11: Correlation analysis between adherence measures, satisfaction, and clinical outcomes

Variables correlated	Correlation coefficient (*r*)	*P*-value
Medication adherence versus HbA1c change	−0.42	<0.001
Medication adherence versus LDL change	−0.36	<0.001
Medication adherence versus BMI change	−0.31	<0.001
Diet adherence versus FLI change	−0.34	<0.001
Physical activity versus BMI change	−0.29	0.002

BMI: Body mass index, LDL: Low-density lipoprotein, FLI: Fatty liver index

With respect to hepatic indices, Fatty liver index scores declined significantly (P < 0.001), suggesting improvement in hepatic steatosis risk. In contrast, the reduction in FIB-4 score did not reach statistical significance (P = 0.089), indicating limited short-term change in FIB-related parameters.

Collectively, these findings demonstrate significant improvements in behavioral, pharmacological, metabolic, and steatosis-related outcomes over 12 months following structured clinical pharmacist intervention.

Correlation analysis identified statistically significant relationships between adherence measures, patient knowledge, satisfaction, and clinical outcomes (Table 11). Higher medication adherence levels were significantly associated with greater reductions in HbA1c, LDL-cholesterol, and BMI. Patient knowledge scores demonstrated positive correlations with both dietary adherence and physical activity levels, indicating that improved understanding was associated with healthier behavioral patterns.

Lifestyle adherence measures were similarly linked to clinical improvements. Greater dietary adherence correlated with reductions in fatty liver index scores, while higher physical activity levels were associated with decreases in BMI. Satisfaction scores exhibited strong positive correlations with both medication adherence and lifestyle adherence, suggesting that patient engagement and perceived value of pharmacist interventions were closely aligned with adherence behaviors Figures 1 and 2.

DISCUSSION

NAFLD is increasingly recognized as a multisystem metabolic disorder rather than an isolated hepatic condition, necessitating integrated strategies targeting cardiometabolic risk modification and long-term treatment adherence. The present study demonstrates that structured clinical pharmacist interventions were associated with improvements in medication adherence, lifestyle behaviors, and multiple cardiometabolic parameters among adults with NAFLD. These observations are consistent with and extend findings from prior high-quality studies evaluating pharmacist involvement in chronic metabolic disease management.

The observed improvement in medication adherence aligns with established evidence demonstrating the effectiveness of pharmacist-led interventions in chronic disease populations. A large meta-analysis by Santschi *et al.* reported that pharmacist care significantly improved adherence and cardiovascular risk factors across diverse healthcare settings, highlighting the pharmacist's role in optimizing pharmacotherapy and patient engagement.[14] Similarly, Stewart *et al.* demonstrated that pharmacist-delivered educational interventions improved adherence and self-management behaviors in chronic diseases, underscoring the importance of structured counseling and follow-up.[15] The present study reinforces these findings within a NAFLD cohort, a population frequently characterized by polypharmacy, metabolic comorbidities, and complex medication regimens. Given that medication adherence is a key determinant of therapeutic success in diabetes, hypertension, and dyslipidemia, enhanced adherence likely contributed to the improvements observed in glycemic and lipid parameters.

Significant improvements in cardiometabolic outcomes observed in this study are concordant with prior investigations demonstrating the clinical impact of pharmacist-integrated care. Pharmacist-led medication management has been shown to improve HbA1c, lipid profiles, and blood pressure control in patients with cardiometabolic disorders.[14,16] For example, a systematic review by Nkansah *et al.* found that pharmacist interventions resulted in clinically meaningful reductions in HbA1c among patients with type 2 diabetes, emphasizing the value of medication review and patient education.[16] The reductions in LDL-cholesterol and triglyceride levels observed in the present study similarly mirror findings from pharmacist-driven lipid management programs, where medication optimization and adherence reinforcement were central mechanisms.[14] These results are particularly relevant in NAFLD, where cardiometabolic dysfunction is a principal driver of disease progression and mortality.[17]

The decline in anthropometric measures, including BMI and waist circumference, further supports the role of pharmacist-mediated lifestyle counseling. Lifestyle modification remains the cornerstone of NAFLD management, with sustained dietary and physical activity changes demonstrating benefits for both hepatic steatosis and metabolic risk factors.[18] Romero-Gómez *et al.* emphasized that structured lifestyle interventions significantly improve metabolic and hepatic parameters, although adherence remains a major challenge in routine practice.[18] The improvements observed in the present study suggest that pharmacist-led counseling and repeated reinforcement may enhance behavioral adherence, thereby facilitating metabolic improvement. The correlation between knowledge scores and lifestyle adherence identified in this study is consistent with behavioral medicine literature, indicating that patient education is a critical determinant of sustained lifestyle change.[15,18]

Medication reconciliation and systematic identification of DRPs represent another clinically important dimension of pharmacist interventions. Previous studies have demonstrated that medication discrepancies and inappropriate prescribing are common in patients with chronic metabolic diseases, often resulting in preventable adverse outcomes.[19] Schindler *et al.* highlighted the utility of the PCNE classification system in enabling structured identification and resolution of DRPs across clinical settings.[20] The predominance of treatment-effectiveness and drug-use process issues observed in this study parallels findings from earlier investigations, where non-adherence, dosing errors, and suboptimal therapy were frequently encountered.[19,20] The high physician acceptance and resolution rates observed are consistent with collaborative care models, demonstrating that pharmacist recommendations are both clinically relevant and implementable.[14,19]

Improvements in Fatty Liver Index scores observed in this study provide indirect evidence of potential hepatic benefit associated with metabolic optimization. Prior epidemiological studies have established strong associations between metabolic risk reduction and improvements in hepatic steatosis markers.[17,18] Powell *et al.* emphasized that NAFLD progression is closely linked to modifiable cardiometabolic factors, including glycemic control, lipid abnormalities, and adiposity.[17] Therefore, the improvements in HbA1c, lipid parameters, and anthropometric measures observed may plausibly contribute to reduced hepatic risk. The absence of statistically significant changes in FIB-4 scores should be interpreted cautiously, as FIB indices typically evolve over longer durations and may not demonstrate substantial change within a 1-year follow-up.[21]

Correlation analyses in the present study offer mechanistic insights consistent with prior literature. Associations between adherence measures and metabolic improvements are well documented, with medication adherence strongly predicting glycemic and lipid control.[14,16] The positive relationship between satisfaction and adherence observed aligns with patient-centered care frameworks, suggesting that perceived quality of care influences treatment engagement and behavioral persistence.[15] These findings support the hypothesis that pharmacist-patient interactions may influence outcomes not only through pharmacological optimization but also through enhanced motivation, understanding, and self-management behaviors.

The findings of this study should be interpreted in light of certain limitations. The single-center design may limit generalizability, and reliance on self-reported adherence measures introduces potential reporting bias despite interviewer administration. The observational interventional design precludes definitive causal inference. Nonetheless, the study provides pragmatic evidence consistent with high-quality prior research supporting pharmacist integration in chronic metabolic disease management.[14-16,19]

The observed improvements in cardiometabolic parameters and lifestyle behaviors in the present study are consistent with evidence demonstrating that structured metabolic interventions can significantly influence NAFLD progression. Pharmacological and lifestyle-based trials, including the LEAN trial evaluating liraglutide in NASH, have demonstrated meaningful improvements in hepatic outcomes when metabolic risk factors are aggressively targeted.[22] Importantly, sustained weight reduction through structured lifestyle modification has been shown to reduce steatohepatitis and FIB progression in NAFLD populations.[23,24] The magnitude of improvement in glycemic control, lipid parameters, and anthropometric indices observed in our cohort aligns with this established metabolic framework.

Beyond pharmacological strategies, multidisciplinary and team-based care models have demonstrated superior control of cardiometabolic risk factors compared with standard physician-led care alone.[25] Current European cardiovascular prevention guidelines emphasize structured lifestyle counseling, behavioral reinforcement, and adherence optimization as essential components of long-term cardiometabolic risk reduction.[26] Moreover, the World Health Organization has consistently identified medication adherence as a major determinant of chronic disease outcomes, underscoring the importance of sustained behavioral engagement.[27] The present findings extend this evidence base by demonstrating that structured clinical pharmacist involvement can meaningfully improve adherence behaviors and lifestyle modification in NAFLD patients, thereby translating into measurable cardiometabolic benefits.

CONCLUSION

This study demonstrates that structured clinical pharmacist interventions are associated with significant improvements in medication adherence, lifestyle behaviors, and key cardiometabolic risk indicators among patients with NAFLD. Pharmacist-led medication reconciliation and systematic identification of DRPs contributed to enhanced treatment effectiveness and medication safety, while targeted patient counseling supported measurable gains in disease knowledge and health-related behaviors. Favorable changes observed across glycemic parameters, lipid profiles, anthropometric measures, blood pressure, and Fatty Liver Index scores suggest clinically relevant benefits of integrating clinical pharmacists into NAFLD management.

The findings further indicate that adherence, patient knowledge, and satisfaction are closely interrelated and may collectively influence therapeutic outcomes. The identification and resolution of DRPs underscore the importance of pharmacist involvement in optimizing complex pharmacotherapy, particularly in individuals with multiple cardiometabolic comorbidities. Overall, these results support the inclusion of structured clinical pharmacy services within multidisciplinary NAFLD care models, while highlighting the need for controlled longitudinal studies to confirm long-term clinical and economic impact.

ACKNOWLEDGMENT

The authors would like to thank Research and Development of the Jawaharlal Nehru Technological University and Government General Hospital for their support.

REFERENCES

1. Younossi ZM, Koenig AB, Abdelatif D, Fazel Y, Henry L, Wymer M. Global epidemiology of nonalcoholic fatty liver disease-meta-analytic assessment of prevalence, incidence, and outcomes. Hepatology 2016;64:73-84.
2. Chalasani N, Younossi Z, Lavine JE, Charlton M, Cusi K, Rinella M, *et al*. The diagnosis and management of nonalcoholic fatty liver disease: Practice guidance from the American Association for the Study of Liver Diseases. Hepatology 2018;67:328-57.
3. Friedman SL, Neuschwander-Tetri BA, Rinella M, Sanyal AJ. Mechanisms of NAFLD development and therapeutic strategies. Nat Med 2018;24:908-22.
4. Targher G, Byrne CD, Lonardo A, Zoppini G, Barbui C. Non-alcoholic fatty liver disease and risk of incident cardiovascular disease: A meta-analysis. J Hepatol 2016;65:589-600.
5. Mantovani A, Byrne CD, Benfari G, Bonapace S, Simon TG, Targher G. Risk of cardiovascular disease in patients with nonalcoholic fatty liver disease. Nat Rev Cardiol 2021;18:369-84.
6. Rinella ME, Sanyal AJ. Management of NAFLD: A stage-based approach. Nat Rev Gastroenterol Hepatol 2016;13:196-205.
7. Romero-Gómez M, Zelber-Sagi S, Trenell M. Treatment of NAFLD with diet, physical activity and exercise. J Hepatol 2017;67:829-46.
8. Polyzos SA, Kountouras J, Mantzoros CS. Obesity and nonalcoholic fatty liver disease: From pathophysiology to therapeutics. Metabolism 2019;92:82-97.
9. Brown MT, Bussell JK. Medication adherence: WHO cares? Mayo Clin Proc 2011;86:304-14.
10. Björnsson E. Hepatotoxicity of statins and other lipid-lowering agents. Liver Int 2017;37:173-8.
11. Chisholm-Burns MA, Kim Lee J, Spivey CA, Slack M, Herrier RN, Hall-Lipsy E, *et al*. US pharmacists' effect

as team members on patient care: Systematic review and meta-analyses. Med Care 2010;48:923-33.

12. Schindler E, Richling I, Rose O. Pharmaceutical care network Europe (PCNE) drug-related problem classification version 9.00: German translation and validation. Int J Clin Pharm 2021;43:726-30.
13. Chaves S, Pinho-Gomes AC, Azevedo LF. Role of multidisciplinary care in nonalcoholic fatty liver disease: A systematic review. Clin Gastroenterol Hepatol 2020;18:2493-505.
14. Santschi V, Chiolero A, Burnand B, Colosimo AL, Paradis G. Impact of pharmacist care in the management of cardiovascular disease risk factors: A systematic review and meta-analysis of randomized trials. Arch Intern Med 2011;171:1441-53.
15. Stewart D, MacLure K, George J, Pallivalapila A, McLay J, Bond C. A systematic review of pharmacist-led interventions to improve adherence and self-management in chronic diseases. Patient Educ Couns 2017;100:93-106.
16. Nkansah N, Mostovetsky O, Yu C, Chheng T, Beney J, Bond CM, *et al*. Effect of outpatient pharmacists' non-dispensing roles on patient outcomes and prescribing patterns. Cochrane Database Syst Rev 2010;2010:CD000336.
17. Powell EE, Wong VW, Rinella MR. Non-alcoholic fatty liver disease. Lancet 2021;397:2212-24.
18. Keating SE, Hackett DA, George J, Johnson NA. Exercise and non-alcoholic fatty liver disease: A systematic review and meta-analysis. J Hepatol 2012;57:157-66.
19. Mekonnen AB, McLachlan AJ, Brien JA. Effectiveness of pharmacist-led medication reconciliation programmes on clinical outcomes at hospital transitions: A systematic review and meta-analysis. BMJ Open 2016;6:e010003.
20. Strand LM, Morley PC, Cipolle RJ, Ramsey R, Lamsam GD. Drug-related problems: Their structure and function. DICP 1990;24:1093-7.
21. Angulo P, Hui JM, Marchesini G, Bugianesi E, George J, Farrell GC, *et al*. The NAFLD fibrosis score: A noninvasive system that identifies liver fibrosis in patients with NAFLD. Hepatology 2007;45:846-54.
22. Armstrong MJ, Gaunt P, Aithal GP, Barton D, Hull D, Parker R, *et al*. Liraglutide safety and efficacy in patients with non-alcoholic steatohepatitis (LEAN): A multicentre, double-blind, randomised, placebo-controlled phase 2 study. Lancet 2016;387:679-90.
23. Vilar-Gomez E, Martinez-Perez Y, Calzadilla-Bertot L, Torres-Gonzalez A, Gra-Oramas B, Gonzalez-Fabian L, *et al*. Weight loss through lifestyle modification significantly reduces features of nonalcoholic steatohepatitis. Gastroenterology 2015;149:367-78.e5; quiz e14-5.
24. Promrat K, Kleiner DE, Niemeier HM, Jackvony E, Kearns M, Wands JR, *et al*. Randomized controlled trial testing the effects of weight loss on nonalcoholic steatohepatitis. Hepatology 2010;51:121-9.
25. Carter BL, Rogers M, Daly J, Zheng S, James PA. The potency of team-based care interventions for hypertension: A meta-analysis. Arch Intern Med 2009;169:1748-55.
26. Piepoli MF, Hoes AW, Agewall S, Albus C, Brotons C, Catapano AL, *et al*. 2016 European Guidelines on cardiovascular disease prevention in clinical practice: The sixth joint task force of the European society of cardiology and other societies on cardiovascular disease prevention in clinical practice (constituted by representatives of 10 societies and by invited experts) developed with the special contribution of the European association for cardiovascular prevention & rehabilitation (EACPR). Eur Heart J 2016;37:2315-81.
27. Sabaté E. Adherence to Long-Term Therapies: Evidence for Action. Geneva: World Health Organization; 2003.

Source of Support: Nil. **Conflicts of Interest:** None declared.