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# Study Of Metabolic dysfunction associated steatotic liver disease in T2DM Subjects and its association with microalbuminuria

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## Abstract

***Background:*** Type 2 Diabetes Mellitus is a multisystem disorder frequently associated with metabolic complications such as MASLD and Microalbuminuria. Both conditions are linked to insulin resistance and may reflect early hepatic and renal involvement. ***Objectives:*** To determine the prevalence of MASLD in T2DM patients and to assess its association with microalbuminuria. Method***s:*** A prospective observational study was conducted among 73 T2DM patients at a tertiary care hospital from April 2024 to September 2025. MASLD was diagnosed using ultrasonography, and microalbuminuria was assessed using urine albumin –creatinine ratio (UACR). Statistical significance was considered at $p < 0.05$. ***Results:*** The prevalence of MASLD was 67.12%, while microalbuminuria was present in 68.49% of participants. A statistically significant association was observed between MASLD and microalbuminuria ($p = 0.0173$). MASLD was more prevalent in patients with microalbuminuria (76.00%) compared to those without (47.83%), indicating a 1.59-fold increased likelihood. The coexistence of MASLD and microalbuminuria was noted in 52.05% of cases, indicating a high-risk metabolic phenotype. ***Conclusion***: MASLD is highly prevalent in T2DM patients and shows a significant association with microalbuminuria, suggesting early renal involvement. These findings highlight MASLD as a marker of systemic metabolic dysfunction.

**Keywords:** Type 2 Diabetes Mellitus, MASLD, Microalbuminuria, insulin resistance, hepatic steatosis, diabetic nephropathy.



## INTRODUCTION

MASLD has emerged over the past two decades as one of the most prevalent chronic liver disorders worldwide, paralleling the global rise in obesity, insulin resistance, and type 2 diabetes mellitus. Once considered a relatively benign accumulation of fat within hepatocytes, it is now recognized as a dynamic spectrum of disease ranging from simple steatosis to metabolic dysfunction associated steatohepatitis, progressive fibrosis, cirrhosis, and even hepatocellular carcinoma. [1] In individuals with type 2 diabetes mellitus, the burden of MASLD is disproportionately high, reflecting the shared mechanisms of both conditions. Diabetes not only increases the prevalence of fatty liver but also accelerates its progression and worsens hepatic and extrahepatic outcomes, making this association clinically significant rather than incidental.[1,2]

In subjects with type 2 diabetes mellitus, the coexistence of MASLD and microalbuminuria appears to be more than a simple coincidence. Epidemiological studies have consistently shown a higher prevalence of microalbuminuria in diabetic patients with fatty liver compared to those without hepatic steatosis, even after adjusting for traditional risk factors such as glycemic control, blood pressure, and duration of diabetes. This association suggests the presence of shared pathophysiological pathways linking hepatic fat accumulation to early renal damage.[3]

From a clinical perspective, the coexistence of MASLD and microalbuminuria in type 2 diabetes carries important implications. Both conditions are markers of heightened cardiometabolic risk and predict adverse outcomes independently. Their concurrence may identify a subgroup of patients with more severe insulin resistance, greater inflammatory burden, and a higher likelihood of progression to advanced liver disease and overt diabetic nephropathy. Microalbuminuria, in this context, can be viewed not only as an early sign of renal involvement but also as a window into systemic vascular and metabolic dysfunction driven in part by hepatic pathology.[4]

Early recognition of metabolic dysfunction associated steatotic liver disease in diabetic patients with microalbuminuria offers an opportunity for timely intervention. Lifestyle modification aimed at weight reduction, improved insulin sensitivity, and metabolic control remains the cornerstone of management and has beneficial effects on both hepatic steatosis and albuminuria. Pharmacological agents commonly used in type 2 diabetes, such as insulin sensitizers and newer antidiabetic drugs, have shown promise in improving liver fat content and reducing renal risk, underscoring the interconnected nature of these organ systems.[5]

The aim of this study was to evaluate the study of MASLD in T2DM subjects and its association with microalbuminuria.

## MATERIALS AND METHODS

A prospective observational study was carried out at the Department of General Medicine, Mysore Medical College & Research Institute (MMCRI), Mysore, with patient recruitment from both the Outpatient Department (OPD) and Inpatient Department (IPD) of K.R Hospital, MMCRI. The study duration was 18 months, spanning from April 2024 to September 2025.

**Inclusion Criteria:**

- Patients aged above 18 years.
- Diagnosed with Type 2 Diabetes Mellitus, including both recently diagnosed and long- standing cases.
- Willing to provide written informed consent.

**Exclusion Criteria:**

- History of significant alcohol intake (>20g/day in women, 30g/day in men).
- Known history of viral hepatitis.
- History of intake of hepatotoxic medications (e.g., methotrexate, amiodarone, synthetic estrogens, HAART, ATT, steroids, NSAIDs, valproate) for more than one month.
- Pre-existing renal dysfunction diagnosed prior to the onset of diabetes.
- Known inborn errors of metabolism affecting lipid metabolism.
- Diagnosis of inflammatory bowel disease.
- Patients on Total Parenteral Nutrition (TPN), with a history of bariatric surgery, or with known thyroid disorders.

**Study Sampling**

Simple random sampling was employed to select participants from the eligible pool of T2DM patients attending the OPD or admitted to the IPD.

**Study Sample Size**

The sample size was calculated as 73 participants. The calculation was based on the following formula for estimating a population proportion:

$S = Z^2PQ / D^2$ Where:

- Z = 1.96 (standard value at 95% confidence level)
- P = Estimated prevalence of MASLD in T2DM subjects (5% or 0.05)

Q = 1 - P = 0.95

- D = Margin of error (5% or 0.05)

The calculated sample size was 73, which was rounded to 75 to account for potential dropouts or incomplete data.

**Study Groups**

This was an observational, single-group study. All enrolled participants belonged to the same cohort of T2DM patients. Within this group, comparisons and correlations were made based on the presence or absence of MASLD (as diagnosed by ultrasound) and the presence or absence of microalbuminuria (as determined by urine albumin-creatinine ratio). Therefore, subgroups were formed based on investigational outcomes rather than pre-defined allocation.

**Study Parameters**

The following parameters were systematically collected and analyzed:

- Demographic and Clinical Data: Age, sex, duration of diabetes, treatment history, personal and family history, and findings from general physical and systemic examination.
- Laboratory Investigations:

o Glycemic Control: Fasting Blood Sugar (FBS), Post-Prandial Blood Sugar (PPBS), Glycated Hemoglobin (HbA1c).

o Liver Assessment: Liver Function Tests (LFTs - Serum bilirubin, ALT, AST, ALP, proteins).

o Renal Assessment: Renal Function Tests (RFTs - Blood urea, serum creatinine), Urine Routine Examination, Urine Albumin-Creatinine Ratio (UACR) for detecting microalbuminuria.

• Radiological Investigation: Ultrasonography (USG) of the abdomen and pelvis was the primary tool for diagnosing and grading MASLD (based on echogenicity features like hepatorenal echo contrast, liver brightness, and vascular blurring).

**Study Procedure**

The procedure was standardized as follows:

1. Ethical Approval & Consent: After obtaining Institutional Ethical Committee clearance, potential participants were approached.
2. Investigations: Participants underwent the prescribed set of investigations (FBS, PPBS, HbA1c, LFT, RFT, Urine Routine, UACR and USG abdomen).
3. Data Recording: All clinical and investigational data were meticulously recorded in the individual case record form for each participant.

**Study Data Collection**

Data collection was prospective and primary. A structured and pre-tested proforma (case record form) was used to ensure uniformity and completeness of data collection. The form captured:

• Section I: Demographic and clinical history.
• Section II: Findings of clinical examination.
• Section III: Results of all laboratory and radiological investigations.

Data were collected directly from the patient interviews, clinical examinations, and hospital investigation reports.

**Data Analysis**

Collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) software, version 28.

• Descriptive Statistics: Categorical variables were expressed as frequency and percentage. Continuous variables were expressed as mean ± standard deviation (SD).
• Inferential Statistics:
o Chi-square test was used to find the association between categorical variables (e.g., presence of MASLD and presence of microalbuminuria).
o Independent samples t-test was used to compare means of continuous variables (e.g., HbA1c, liver enzymes) between groups (e.g., those with vs. without microalbuminuria).
o Pearson's correlation coefficient was used to assess the strength and direction of linear relationships between continuous variables.
o If data were found to be non-normally distributed, equivalent non-parametric tests (e.g., Mann-Whitney U test, Spearman's correlation) were employed.
• A p-value of less than 0.05 was considered statistically significant for all tests.

## RESULTS

• The study included a total of 73 participants with a mean age of 48.71 ± 14.77 years, indicating a predominantly middle-aged population. The age range extended from 26 to 74 years, demonstrating a wide distribution across adult age groups. The sex distribution of the study population showed a slight male predominance. Out of the total participants, 41 individuals (56.16%) were males, whereas 32 participants (43.84%) were females. This indicates that more than half of the study subjects were male.

The distribution of treatment modalities among study participants demonstrated that oral hypoglycemic agents (OHA) alone were the most commonly used treatment. A total of 32 participants (43.84%) were receiving only OHA therapy. Insulin-only therapy was used in 21 participants (28.77%), while 17 individuals (23.29%) were receiving a combination of OHA and insulin. A very small proportion of participants (4.11%) were managed with diet control alone. This pattern suggests that the majority of patients required pharmacological intervention for glycemic management.

**Table 1: Distribution of Participants According to Treatment Modality**

| Treatment | Frequency | Percent |
|---|---|---|
| Diet control | 3 | 4.11 |
| Insulin only | 21 | 28.77 |
| OHA + Insulin | 17 | 23.29 |
| OHA only | 32 | 43.84 |
| **Total** | **73** | **100.00** |

Family history of diabetes was present in more than half of the participants. A total of 39 individuals (53.42%) reported a positive family history of diabetes, whereas 34 participants (46.58%) did not report any family history.
Hypertension was highly prevalent among the study participants. Out of the total individuals included in the study, 50 participants (68.49%) were diagnosed with hypertension, whereas 23 participants (31.51%) did not have hypertension. The prevalence of dyslipidemia among the study participants was relatively high. Out of the total 73 individuals included in the study, 45 participants (61.64%) were found to have dyslipidemia, whereas 28 participants (38.36%) did not have dyslipidemia.

Microalbuminuria was observed in a substantial proportion of the study population. Among the 73 participants, 50 individuals (68.49%) were found to have microalbuminuria, whereas 23 participants (31.51%) did not exhibit microalbuminuria. The findings suggest that nearly two- thirds of the study population demonstrated evidence of early renal involvement. The high prevalence of microalbuminuria highlights the importance of early screening for renal dysfunction, particularly in individuals with metabolic disorders, as microalbuminuria is recognized as an early marker of diabetic nephropathy and vascular damage.

**Table 2: Prevalence of Microalbuminuria Among Study Participants**

| Microalbuminuria | Frequency | Percent |
|---|---|---|
| No | 23 | 31.51 |
| Yes | 50 | 68.49 |
| **Total** | **73** | **100.00** |

**Distribution of MASLD Severity Based on Ultrasonography**
The ultrasonographic grading of MASLD revealed varying degrees of hepatic steatosis among the participants. Grade 0 (normal liver) was observed in 24 individuals (32.88%). Among those with fatty liver changes, Grade 1 (mild steatosis) was the most common, seen in 20 participants (27.40%). Grade 2 (moderate steatosis) was present in 18 individuals (24.66%), while Grade 3 (severe steatosis) was identified in 11 participants (15.07%). These findings indicate that a considerable proportion of the study population demonstrated mild to moderate fatty liver changes, with fewer patients showing severe hepatic steatosis.

**Table 3: Distribution of MASLD Severity Based on Ultrasonographic Grading**

| **USG** MASLD **Grade** | **Frequency** | **Percent** |
|---|---|---|
| Grade 0 (Normal) | 24 | 32.88 |
| Grade 1 (Mild) | 20 | 27.40 |
| Grade 2 (Moderate) | 18 | 24.66 |
| Grade 3 (Severe) | 11 | 15.07 |
| **Total** | **73** | **100.00** |

The analysis of MASLD status demonstrated that the majority of participants had evidence of fatty liver on ultrasonography. Out of the total 73 individuals included in the study, MASLD was present in 49 participants (67.12%), while 24 participants (32.88%) had normal liver findings without evidence of fatty infiltration. This indicates that approximately two-thirds of the study population had MASLD The high prevalence of MASLD observed in the present study highlights the strong association between metabolic disorders and hepatic steatosis.

**Table 4: Prevalence of** MASLD **Among Study Participants**

| MASLD **Present** | **Frequency** | **Percent** |
|---|---|---|
| No | 24 | 32.88 |
| Yes | 49 | 67.12 |
| **Total** | **73** | **100.00** |

**Association Between** MASLD **and Microalbuminuria Among Study Participants**
The relationship between MASLD and microalbuminuria demonstrated that slightly more than half of the participants had both conditions concurrently. Among the total study population, 38 participants (52.05%) were found to have MASLD along with microalbuminuria, whereas 35 participants (47.95%) did not exhibit this combined presentation. This distribution indicates a modest predominance of patients with coexisting MASLD and microalbuminuria. The presence of microalbuminuria among patients with MASLD may reflect early renal involvement associated with metabolic abnormalities and highlights the potential interrelationship between hepatic steatosis and renal dysfunction.

**Table 5: Distribution of MASLD with Microalbuminuria Among Study Participants**

| MASLD with Microalbuminuria | Frequency | Percent |
|---|---|---|
| No | 35 | 47.95 |
| Yes | 38 | 52.05 |
| **Total** | **73** | **100.00** |

**Association Between** MASLD **and Microalbuminuria**

The association between MASLD and microalbuminuria was assessed to evaluate the relationship between hepatic steatosis and early renal involvement. Among participants without microalbuminuria, 12 individuals (52.17%) had no MASLD while 11 individuals (47.83%) had MASLD. In contrast, among participants with microalbuminuria, a markedly higher proportion had MASLD (38; 76.00%) compared with those without MASLD (12; 24.00%). The difference was statistically significant ($p = 0.0173$), suggesting that MASLD was more frequently observed in individuals with microalbuminuria, indicating a possible association between fatty liver disease and early renal dysfunction.

**Table 6: Association Between MASLD and Microalbuminuria**

| Microalbuminuria | MASLD **Absent** | MASLD **Present** | Total | p-value |
|---|---|---|---|---|
| Yes | 12 (24.00%) | 38 (76.00%) | 50 (100%) | 0.0173 |
| No | 12 (52.17%) | 11 (47.83%) | 23 (100%) | |
| **Total** | **24 (32.88%)** | **49 (67.12%)** | **73 (100%)** | |

**Distribution of** MASLD **According to Microalbuminuria Status**

The distribution of MASLD according to microalbuminuria status further highlights the relationship between these two conditions. Among participants without microalbuminuria, MASLD was present in 11 individuals compared with 12 individuals who did not have MASLD. In contrast, among participants with microalbuminuria, MASLD was observed in a substantially higher number of individuals (38) compared with those without MASLD (12). This distribution demonstrates a greater concentration of MASLD cases among individuals with microalbuminuria, supporting the observed association between hepatic steatosis and renal involvement in the study population.

**Table 7: Distribution of** MASLD **According to Microalbuminuria Status**

| Microalbuminuria | MASLD **Absent** | MASLD **Present** |
|---|---|---|
| No | 12 | 11 |
| Yes | 12 | 38 |

## DISCUSSION

The prevalence of MASLD in the present study was 67.12%, which is 2.04 times higher than the proportion without MASLD (32.88%), indicating a markedly increased burden of hepatic steatosis among diabetic individuals. This prevalence is consistent with previous studies that have reported MASLD prevalence ranging from 60% to 75% in patients with type 2 diabetes mellitus [6]. Minor differences across studies may be attributed to variations in diagnostic methods, population characteristics, and duration of diabetes.

Microalbuminuria was present in 68.49% of participants, which is 2.17 times higher than those without microalbuminuria (31.51%), indicating a high prevalence of early renal involvement. This prevalence is higher than that reported in several earlier studies, where microalbuminuria ranged between 30% and 50% in diabetic populations. The higher proportion observed in the present study may be explained by poorer glycemic control, as reflected by elevated mean HbA1c levels, and the hospital-based nature of the study, which tends to include patients with more advanced metabolic derangements.

A significant association between MASLD and microalbuminuria was observed. Among patients with microalbuminuria, 76.00% had MASLD compared to 47.83% among those without microalbuminuria, demonstrating a 28.17% higher prevalence of MASLD in patients with renal involvement. This association was statistically significant with a p-value of 0.0173, indicating a true relationship between hepatic steatosis and early renal dysfunction. These findings are consistent with earlier studies that have demonstrated a higher prevalence of albuminuria among patients with MASLD, supporting the concept of a shared pathophysiological pathway [7].

From a pathophysiological perspective, the association between MASLD and microalbuminuria can be attributed to shared mechanisms such as insulin resistance, systemic inflammation, oxidative stress, and endothelial dysfunction. Insulin resistance leads to increased hepatic fat accumulation and release of pro-inflammatory cytokines, which in turn contribute to endothelial injury and increased glomerular permeability, resulting in albuminuria [8]. Additionally, oxidative stress and lipotoxicity further exacerbate both hepatic and renal damage, supporting the observed coexistence of these conditions [9].

Overall, the findings of the present study demonstrate a high prevalence of MASLD and microalbuminuria among patients with type 2 diabetes mellitus, with a statistically significant association between the two conditions. These results support

the concept that MASLD represents a multisystem metabolic disorder with important renal implications and highlight the need for early screening and comprehensive management to prevent progression to chronic kidney disease and cardiovascular complications.

**Demographic Characteristics of the Study Population**

The present study evaluated the demographic profile of patients with type 2 diabetes mellitus to understand the distribution of age and sex and their relevance to the coexistence of non- alcoholic fatty liver disease and microalbuminuria. The mean age of the participants was 48.71 ± 14.77 years, with a range of 26 to 74 years, indicating that the majority of patients belonged to the middle-aged group. This finding is consistent with the typical age of presentation of type 2 diabetes mellitus, where metabolic complications tend to manifest after several years of undetected or poorly controlled hyperglycemia [10]. The observed mean age is slightly lower when compared to Kanakamani et al., who reported a mean age of 52.1 ± 9.9 years, representing an absolute difference of 3.39 years [11]. Similarly, the SPRINT study by Kalra Sanjay et al. demonstrated a predominant clustering of diabetic patients in middle and older age groups, which aligns with the present findings [12].

In terms of gender distribution, males constituted 56.16% while females accounted for 43.84%, indicating a male predominance. When expressed as a ratio, males were approximately 1.28 times more represented than females. This distribution is comparable to earlier studies reporting male proportions in the range of 55% to 65%, demonstrating consistency with existing epidemiological patterns. However, Kalra Sanjay et al. reported a relatively higher prevalence of MASLD among females in Indian diabetic populations, which differs from the present findings [12].

Age and gender both play significant roles in the development of MASLD and microalbuminuria. Increasing age is associated with prolonged exposure to hyperglycemia and metabolic abnormalities, leading to progressive hepatic fat accumulation and renal endothelial dysfunction. Gender-related differences in fat distribution and hormonal milieu further influence metabolic risk. Despite these variations, the demographic characteristics observed in the present study fall within the range reported in earlier literature, indicating that the study population is representative of typical diabetic cohorts.

**Prevalence of MASLD in the Study Population**

Metabolic dysfunction associated steatotic liver disease was highly prevalent among patients with type 2 diabetes mellitus in the present study. Ultrasonographic evaluation demonstrated that MASLD was present in 67.12% of participants, while 32.88% had no evidence of hepatic steatosis. This indicates that MASLD prevalence was approximately twice that of non-MASLD, reflecting a substantial burden of hepatic involvement in the study population.

When compared with previous studies, the prevalence observed in the present study shows close agreement. Kalra Sanjay et al. reported a prevalence of 56.5%, while Alsabaani et al. reported a prevalence of 72.8%. Thus, the prevalence in the present study lies within the range of 56% to 73% reported in earlier literature, confirming consistency with previous findings [12].

The slightly higher prevalence observed in the present study may be attributed to suboptimal glycemic control, with a mean HbA1c of 8.07%, indicating persistent hyperglycemia. In addition, associated metabolic abnormalities such as dyslipidemia contribute to increased hepatic fat accumulation through enhanced free fatty acid flux and de novo lipogenesis [6].

The distribution of MASLD severity revealed that mild steatosis was most common (27.40%), followed by moderate (24.66%) and severe (15.07%). Among MASLD patients, mild cases constituted 40.8%, moderate 36.7%, and severe 22.4%, indicating that the majority of cases were in early stages. This predominance of mild disease is consistent with earlier detection due to routine ultrasonographic evaluation.

MASLD is increasingly recognized as a multisystem disorder. The coexistence of MASLD with microalbuminuria in the present study supports its association with systemic endothelial dysfunction and early renal involvement [13].

**Prevalence of Microalbuminuria in the Study Population**

Microalbuminuria was highly prevalent in the present study, observed in 68.49% of participants, which is more than twice the proportion of those without microalbuminuria (31.51%). This indicates a substantial burden of early renal dysfunction among patients with type 2 diabetes mellitus.

When compared with previous studies, the prevalence observed in the present study is considerably higher. Varghese et al. reported 36.3%, while Kanakamani et al. reported 25.5%, and Asghar et al. reported 39.1%, all of which are lower than the present findings [11,14].

These differences indicate a significantly higher burden of microalbuminuria in the present population.

The hospital-based design may also explain the higher prevalence, as patients tend to have more advanced metabolic disease. Microalbuminuria also reflects systemic endothelial dysfunction and is associated with increased cardiovascular risk [15].

**Association Between MASLD and Microalbuminuria**

A statistically significant association between MASLD and microalbuminuria was observed (p =0.0173). MASLD was present in 76.00% of patients with microalbuminuria compared to 47.83% among those without microalbuminuria, representing a 28.17% higher prevalence and approximately 1.59-fold increased likelihood.

In addition, urine albumin –creatinine ratio values were higher in MASLD patients (176.23 mg/g vs 168.19 mg/g; p = 0.0167), indicating greater renal involvement in patients with hepatic steatosis. However, the absolute difference was small, suggesting limited clinical significance despite statistical significance.

These findings are consistent with previous studies reporting approximately 1.5 to 2 times higher prevalence of albuminuria in MASLD patients and an increased risk of diabetic nephropathy. The association is explained by shared mechanisms including insulin resistance, inflammation, and endothelial dysfunction, leading to both hepatic fat accumulation and increased glomerular permeability [8,16].

**Clinical Implications of the Association Between MASLD and Microalbuminuria**

The coexistence of MASLD and microalbuminuria in 52.05% of patients represents a high-risk metabolic phenotype characterized by combined hepatic and renal involvement. Patients with MASLD had a 28.17% higher prevalence of microalbuminuria and a 1.59-fold increased likelihood of renal involvement.

These findings indicate that MASLD can serve as an early marker of systemic metabolic dysfunction and may help identify patients at increased risk of diabetic nephropathy and cardiovascular complications [7]. Early screening using ultrasonography for MASLD and urine albumin –creatinine ratio for microalbuminuria is essential for identifying high-risk individuals. Given the high prevalence of microalbuminuria (68.49%), routine screening is particularly important.

Lifestyle interventions including weight reduction, dietary modification, and increased physical activity improve insulin sensitivity and reduce hepatic fat accumulation. Pharmacological management targeting glycemic control and lipid abnormalities further reduces disease progression [17].

Overall, MASLD and microalbuminuria should be considered interconnected manifestations of metabolic dysfunction, and integrated management is essential to prevent progression to chronic kidney disease and cardiovascular complications.

## CONCLUSION

The present study demonstrates a high prevalence of MASLD (67.12%) and microalbuminuria (68.49%) among patients with type 2 diabetes mellitus, indicating a substantial burden of both hepatic and early renal involvement. A statistically significant association between MASLD and microalbuminuria (p = 0.0173) was observed, with MASLD being 28.17% more prevalent among patients with microalbuminuria and associated with approximately 1.59-fold higher likelihood of renal involvement.

The coexistence of MASLD and microalbuminuria reflects shared pathogenic mechanisms including insulin resistance, chronic inflammation, oxidative stress, and endothelial dysfunction. These processes contribute to both hepatic lipid accumulation and glomerular injury, thereby increasing the risk of progression to chronic kidney disease and cardiovascular complications.

The findings highlight that MASLD should be considered a marker of systemic metabolic dysfunction with important renal implications. Early detection through ultrasonography and routine screening for microalbuminuria can help identify high-risk patients at an early stage.

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