

Liver Enzyme Profile (AST, ALT, GGT, ALP) in Adolescents Consuming Artisanal Alcohol in Likasi, Democratic Republic of the Congo

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ABSTRACT

Introduction

Alcohol consumption is a major global public health concern due to its broad impact on individual and community health. In Likasi, Democratic Republic of the Congo, artisanal alcoholic beverages—such as *lutuku*, *cinq cent*, and homemade wine—exhibit variable ethanol concentrations due to non-standardized production processes. Repeated consumption among adolescents promotes oxidative stress and hepatocellular injury, leading to altered serum liver enzyme activities.

Purpose

To evaluate serum liver enzyme profiles (AST, ALT, GGT, ALP) in adolescents consuming artisanal alcohol in Likasi, Democratic Republic of Congo, and identify early hepatic biochemical alterations and associated risk factors.

Methods

A descriptive cross-sectional study with an analytical component was conducted among 116 adolescents (aged 15–19 years) in Likasi who consumed locally produced alcohol. The sample comprised 111 males (95.7%) and 5 females (4.3%). Serum activities of aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma-glutamyl transferase (GGT), and alkaline phosphatase (ALP) were measured via spectrophotometry using a semi-automated biochemical analyzer (serial no. BS8N324E). Quantitative variables were evaluated for normality using the Shapiro-Wilk test ($p < 0.05$). Non-parametric comparisons were performed using the Mann-Whitney U test and Kruskal-Wallis test, and bivariate associations were evaluated using Spearman's rank correlation coefficient (ρ).

Results

Participants were predominantly male (95.7%), with a mean age of 17.82 ± 1.28 years; the largest age subgroup was 19 years (41.4%). The most frequently consumed artisanal alcoholic beverages were *cinq cent* (76.7%) and *lutuku* (65.5%). Mean serum liver enzyme activities were 84.67 ± 80.75 IU/L for AST, 69.17 ± 71.77 IU/L for ALT, 158.09 ± 95.08 IU/L for GGT, and 161.53 ± 85.87 IU/L for ALP. No statistically significant correlation was observed between the self-reported volume or frequency of alcohol consumption and serum liver enzyme levels. Significant positive correlations were observed between AST and GGT ($\rho = 0.332$, $p < 0.01$) and between ALT and ALP ($\rho = 0.771$, $p < 0.01$). Smoking status was significantly associated with elevated GGT rank scores ($p = 0.032$).

Conclusion

Serum elevations in AST, ALT, GGT, and ALP among adolescent consumers of artisanal alcohol indicate underlying hepatic biochemical alterations. Given the absence of a unexposed control group, controlled longitudinal studies incorporating specific bio-markers of alcohol exposure are recommended to establish causality.

INTRODUCTION

Adolescence is a developmental stage characterized by increased vulnerability to risk-taking behaviors, particularly alcohol use. According to the World Health Organization, over a quarter (26.5%) of young people aged 15–19 years worldwide consume alcohol, representing approximately 155 million regular drinkers (Han et al., 2021; World Health Organization, 2024). Alcohol consumption is recognized as the third leading preventable risk factor for disease burden globally and is causally linked to over 200 health conditions (Axley et al., 2019). Adolescent alcohol intake varies regionally and is associated with multiple adverse health outcomes, particularly hepatotoxicity (Taylor & Miloh, 2019; Zdanowicz et al., 2021).

The liver is the primary site of ethanol metabolism and consequently the main target of ethanol-induced toxicity (Niemelä, 2016). Over one million deaths annually are attributed to liver cirrhosis, with 47.9% directly linked to chronic alcohol abuse (Pathology of Alcoholic Liver Disease, 2014). Ethanol is metabolized primarily via hepatic alcohol dehydrogenase (ADH) and the microsomal ethanol oxidizing system (MEOS). This biotransformation generates acetaldehyde and reactive oxygen species, triggering oxidative stress, inflammatory cascades, and progressive hepatocyte injury (Niemelä, 2016; Tawiah et al., 2022). Prolonged exposure promotes a continuum of hepatic damage, progressing from hepatic steatosis to alcoholic hepatitis, fibrosis, and cirrhosis (Gao & Bataller, 2011; Niemelä, 2016).

In adolescents, heavy or episodic alcohol consumption can disrupt metabolic homeostasis, impair neurodevelopment, and cause early hepatocellular damage (Binder et al., 2016; Zdanowicz et al., 2022). Alterations in serum liver enzyme activities frequently represent the earliest biological indicators of excessive ethanol exposure (Niemelä, 2016). Serum enzymes commonly evaluated to assess hepatic status include aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma-glutamyl transferase (GGT), and alkaline phosphatase (ALP) (Tawiah et al., 2022).

Gamma-glutamyl transferase is a sensitive biomarker for detecting chronic or heavy alcohol ingestion (Neumann &

Spies, 2003; Peterson, 2004). GGT participates in extracellular glutathione cleavage, maintaining intracellular redox balance against ethanol-induced oxidative stress (Whitfield et al., 2019). Regular alcohol intake induces GGT synthesis, leading to elevated serum concentrations (Haren et al., 2010). However, individual responses vary based on age, sex, metabolic factors, and drinking patterns (Whitfield et al., 2019). Transaminases (AST and ALT) elevate during hepatocellular damage. While ALT is predominantly localized within hepatocytes and serves as a selective marker of liver injury, AST is also distributed in cardiac muscle, skeletal muscle, kidney, and brain tissue (Pratt & Kaplan, 2000). In alcohol-related liver injury, AST elevation often exceeds ALT elevation, resulting in an AST/ALT ratio > 1 (Stewart et al., 2022). Serum ALP elevations may occur alongside transaminase and GGT abnormalities, indicating hepatobiliary or cholestatic involvement (Whitfield, 2001).

In the Democratic Republic of Congo (DRC), alcohol consumption represents a substantial public health challenge among urban youth. In Likasi, artisanal alcoholic beverages—such as *lutuku*, *cing cent*, and homemade wines—are widely consumed due to their low cost and unrestricted availability (Mulenda et al., 2021; World Health Organization, 2024). These beverages are produced using non-standardized fermentation and distillation techniques lacking quality oversight. Consequently, ethanol concentrations fluctuate unpredictably, and products may contain toxic congeners, including methanol, higher alcohols, aldehydes, and heavy metal residues (Lachenmeier et al., 2018; Rehm et al., 2022).

Repeated exposure to non-standardized artisanal alcohol presents cumulative metabolic and toxicological risks to adolescents, whose liver functional maturation remains incomplete (Choudhury & Sanyal, 2020; Leung & Nieto, 2018). While studies in adults demonstrate clear associations between alcohol abuse and liver injury (European Association for the Study of the Liver [EASL], 2018; Thursz & Lingford-Hughes, 2023), empirical data regarding hepatic biological alterations among adolescents in Likasi remain limited.

Study Objectives and Hypotheses

This study evaluated serum liver enzyme profiles (AST, ALT, GGT, and ALP) among adolescents consuming artisanal alcohol in Likasi to characterize underlying hepatic biochemical alterations.

Primary Hypothesis:

Chronic consumption of artisanal alcoholic beverages is associated with a high frequency of liver enzyme abnormalities (elevations above normal biological reference ranges) among adolescents in Likasi.

Secondary Hypotheses:

- Adolescents who consume *lutuku* display higher serum GGT, ALP, AST, and ALT activities than those who consume artisanal wine or *cing cent*, owing to higher toxic congener exposure.
- Duration and volume of artisanal alcohol consumption correlate positively with serum liver enzyme elevations.
- Elevated serum GGT represents the most frequent biological abnormality among adolescent consumers.

METHODS*Research Setting*

Data collection and participant interviews were conducted in Likasi, Democratic Republic of Congo. Blood samples were transported under controlled thermal conditions to the Medical Laboratory of the University Clinics of Lubumbashi (CUL) for biochemical processing. The laboratory is situated in the Lubumbashi municipality (intersection of Munongo and Ndjamen Avenue, Haut-Katanga Province) (Fazili, 2026).

Study Design and Participant Selection

A descriptive cross-sectional study with an analytical component was conducted among 116 adolescents aged 15–19 years who reported consuming locally produced alcohol in Likasi.

Sample Size Determination:

The target minimum sample size was calculated using Slovin's formula based on an estimated regional adolescent population parameter ($N = 430,000$) and a margin of error ($e = 0.10$):

$$n = N / [1 + N(e)^2] = 430,000 / [1 + 430,000(0.10)^2] = 430,000 / 4,301 \approx 99.98$$

The required minimum sample size was determined to be 100 participants; 116 participants were successfully enrolled.

Sampling Strategy:

Participants were recruited from local production and consumption venues in Likasi using a stratified random sampling strategy across municipal divisions to ensure geographic representation (Bryman, 2016; Corbière & Larivière, 2020).

Inclusion Criteria:

- Adolescents aged 15–19 years residing in Likasi.
- Self-reported regular consumption of artisanal alcohol for ≥ 1 year.
- Absence of known pre-existing hepatic disease history.
- Provision of written informed assent (participant) and written informed consent (parent/legal guardian).

Exclusion Criteria:

- Confirmed viral hepatitis infection or active co-infections affecting hepatic tissue.
- Active therapeutic regimen involving known hepatotoxic medications.
- Refusal to provide assent or parental consent.

Ethical Considerations

Ethical approval was granted by the Ethics Committee of the Higher Institute of Medical Techniques of Kinshasa (ISTM/KIN), DRC (Approval No. 187 CBE/ISTM/KIN/RDC/PMBBL/2025, dated July 7, 2025). Prior to enrolment, full disclosure regarding study procedures, voluntary participation, potential risks, and data confidentiality was provided. Written parental/guardian consent and adolescent assent were obtained for all minors prior to data collection. Participant identities were anonymized using numeric identifiers.

Data and Sample Collection

Structured face-to-face interviews were conducted using standardized questionnaires to record demographic data,

type and quantity of artisanal alcohol consumed, drinking frequency, duration of use, and co-ingestion of tobacco. Recall bias was minimized by standardizing interview protocols and focusing consumption volume estimations on recent typical drinking patterns.

Venous blood samples (5 mL) were collected from the antecubital vein into clean dry tubes without anticoagulant during morning hours. Samples were allowed to clot at room temperature, centrifuged at 3000 rpm for 10 minutes to separate serum, and processed immediately for enzyme assays.

Laboratory Assays

Biochemical analyses were performed using a semi-automated biochemical analyzer (Serial No. BS8N324E; Cypress Diagnostics reagents).

- a) **Aspartate Aminotransferase (AST):** Measured via the kinetic UV method (NADH oxidation) at 340 nm. Reference values: Females < 31 IU/L, Males < 38 IU/L (standardized clinical upper normal limit: 40 IU/L).
- b) **Alanine Aminotransferase (ALT):** Measured via the kinetic UV method (LDH/NADH system) at 340 nm. Reference values: Females < 32 IU/L, Males < 40 IU/L.
- c) **Gamma-Glutamyl Transferase (GGT):** Measured via the kinetic enzymatic method (γ -glutamyl-p-nitroaniline substrate) at 405 nm. Reference values: Females 11–50 IU/L, Males 7–32 IU/L (clinical threshold value: < 60 IU/L).
- d) **Alkaline Phosphatase (ALP):** Measured via p-nitrophenylphosphate substrate cleavage at 405 nm. Reference values: Adults 60–170 IU/L; pediatric/adolescent reference range: 40–150 IU/L.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics (Version 26.0). Data distribution normality was assessed using the Shapiro-Wilk test. Because all continuous biological parameters demonstrated significant non-normal distributions ($p < 0.05$), non-parametric tests were employed:

- i. Quantitative variables were expressed as mean $\pm$ standard deviation (SD) and median with interquartile range (IQR).
- ii. Differences between two independent groups were evaluated using the Mann-Whitney U test.
- iii. Comparisons across ≥ 3 independent groups were evaluated using the Kruskal-Wallis test.
- iv. Continuous bivariate associations were evaluated using Spearman's rank correlation coefficient (ρ).
- v. Categorical associations were assessed using Pearson's chi-squared (χ^2) test and Cramer's V for effect size determination.
- vi. The threshold for statistical significance was established at $\alpha = 0.05$.

RESULTS

Sociodemographic Characteristics

The final study population comprised 116 adolescents. **Table 1** summarizes participant sociodemographic distribution. Male participants predominated (95.7%, $n = 111$). Secondary school was the most common educational level (59.5%, $n = 69$). The modal age group was 19 years (41.4%, $n = 48$).

Table 1:
Sociodemographic Characteristics of Participants (N = 116)

Variable	Subcategory	Frequency (n)	Percentage (%)
Sex	Male	111	95.7
	Female	5	4.3
Education Level	Primary	39	33.6
	Secondary	69	59.5
	Higher / University	8	6.9
Age Group (years)	15.0–15.9	8	6.9
	16.0–16.9	14	12.1
	17.0–17.9	17	14.7
	18.0–18.9	29	25.0
	19.0–19.9	48	41.4

Alcohol Consumption Patterns and Tobacco Use

The predominant beverage consumed was *cinq cent* (76.7%), followed by *lutuku* (65.5%) and artisanal wine (25.0%) (**Table 2**; totals exceed 100% due to multi-beverage consumption). Daily consumption was reported by 29.3% of participants, while 41.4% consumed alcohol frequently (3–5 days/week) (**Table 3**). Concurrent smoking was present in 31.0% ($n = 36$) of adolescents (**Table 4**).

Table 2:
Distribution of Artisanal Alcohol Types and Volume Consumed (N = 116)

Variable	Category	Frequency (n)	Percentage (%)
Type of Beverage Consumed*	Cinq cent	89	76.7
	Lutuku	76	65.5
	Artisanal wine	29	25.0
Volume Consumed per Session	300–700 mL	39	33.6
	701–1000 mL	49	42.2
	1001–1500 mL	28	24.2

*Categories are not mutually exclusive.

Table 3:
Frequency and Duration of Alcohol Consumption (N = 116)

Variable	Category	Frequency (n)	Percentage (%)
Frequency of Consumption	Occasional (< 2 days/ week)	34	29.3
	Daily	34	29.3
	Frequent (3–5 days/ week)	48	41.4
Duration of Use	1–2 years	61	52.6
	3–5 years	48	41.4
	> 5 years	7	6.0

Table 4:
Tobacco Use Among Participants (N = 116)

Variable	Category	Frequency (n)	Percentage (%)
Smoking Status	Smoker	36	31.0
	Non-smoker	80	69.0
Total		116	100.0

Serum Liver Enzyme Concentrations

Descriptive statistics for AST, ALT, GGT, and ALP are detailed in Table 5. Mean values for all four enzymes exceeded normal clinical thresholds. GGT demonstrated the highest relative elevation (158.09 ± 95.08 IU/L vs. upper normal reference limit of 60 IU/L). Elevated enzyme levels were observed in 76.7% (n = 89) for GGT, 54.3% (n = 63) for AST, 49.1% (n = 57) for ALT, and 42.2% (n = 49) for ALP.

Table 5:
Serum Liver Enzyme Parameters Relative to Reference Thresholds (N = 116)

Biochemical Parameter	Mean ± SD	Median (IQR)	Reference Value (IU/L)	Clinical Evaluation
AST (IU/L)	84.67 ± 80.75	51.5 (30.0–110.3)	< 40	Elevated
ALT (IU/L)	69.17 ± 71.77	35.0 (12.0–86.0)	< 40	Elevated
GGT (IU/L)	158.09 ± 95.08	165.0 (73.0–224.0)	< 60	Markedly Elevated
ALP (IU/L)	161.53 ± 85.87	110.5 (102.0–212.0)	40–150	Mildly Elevated

Table 9:
Associations Between Behavioral Factors and Liver Enzymes (Non-Parametric Tests)

Enzyme Parameter	Smoking Status		Consumption Frequency		Alcohol Type	
	Mean Rank	Test Statistic (p-value)	Mean Rank	Test Statistic (p-value)	Mean Rank	Test Statistic (p-value)
AST (IU/L)	62.36	$\chi^2 = 0.693$ (p = 0.405)	235.05	$\chi^2 = 3.405$ (p = 0.333)	149.55	$\chi^2 = 5.683$ (p = 0.224)
ALT (IU/L)	51.54	$\chi^2 = 2.280$ (p = 0.131)	228.34	$\chi^2 = 0.200$ (p = 0.978)	158.46	$\chi^2 = 6.345$ (p = 0.175)
GGT (IU/L)	68.49	$\chi^2 = 4.624$ (p = 0.032)*	254.09	$\chi^2 = 1.296$ (p = 0.730)	156.05	$\chi^2 = 0.278$ (p = 0.991)
ALP (IU/L)	54.56	$\chi^2 = 0.722$ (p = 0.395)	234.63	$\chi^2 = 1.996$ (p = 0.573)	148.52	$\chi^2 = 6.559$ (p = 0.161)

*Statistically significant at p < 0.05.

Stratified Analyses of Liver Enzymes

Tables 6 through 8 summarize liver enzyme profiles stratified by age group, volume consumed, and duration of use.

Table 6:
Serum Liver Enzyme Activities Stratified by Age Group

Age Group (years)	n	AST (IU/L)	ALT (IU/L)	GGT (IU/L)	ALP (IU/L)
15–16	8	79.12 ± 78.98	71.26 ± 67.19	126.97 ± 99.60	183.34 ± 86.64
16–17	14	66.75 ± 62.49	69.82 ± 70.61	182.36 ± 114.28	173.41 ± 110.42
17–18	17	110.58 ± 93.67	91.83 ± 71.30	154.01 ± 85.61	210.75 ± 82.82
18–19	29	70.80 ± 74.58	83.40 ± 84.88	137.70 ± 101.08	146.28 ± 87.32
19–20	48	88.92 ± 85.51	51.59 ± 63.16	156.64 ± 86.48	140.95 ± 74.51

Table 7:
Serum Liver Enzyme Activities Stratified by Alcohol Volume Consumed

Consumption Group (mL)	n	AST (IU/L)	ALT (IU/L)	GGT (IU/L)	ALP (IU/L)
300–450	19	93.58 ± 85.92	61.82 ± 71.47	144.69 ± 77.62	146.20 ± 66.79
451–600	7	58.32 ± 84.09	60.22 ± 75.98	188.27 ± 124.55	168.84 ± 88.27
601–750	18	83.87 ± 87.57	67.27 ± 68.00	156.44 ± 101.95	174.22 ± 92.91
751–900	21	73.89 ± 74.74	96.48 ± 79.65	149.33 ± 97.36	182.53 ± 88.34
901–1050	23	67.57 ± 75.13	82.47 ± 85.10	160.16 ± 108.14	161.56 ± 97.74
1051–1200	19	95.57 ± 63.32	51.25 ± 54.46	152.28 ± 71.51	140.69 ± 77.41
1201–1350	4	153.72 ± 113.65	48.37 ± 39.93	151.75 ± 87.45	172.51 ± 82.99
1351–1500	5	119.26 ± 115.33	26.24 ± 30.13	193.80 ± 94.99	136.06 ± 81.64

Table 8:
Serum Liver Enzyme Activities Stratified by Duration of Alcohol Use

Duration of Use (years)	n	AST (IU/L)	ALT (IU/L)	GGT (IU/L)	ALP (IU/L)
1–2	61	90.23 ± 82.80	74.88 ± 71.13	163.08 ± 95.04	178.44 ± 92.51
3–5	28	73.00 ± 74.86	59.31 ± 70.88	153.57 ± 95.75	140.57 ± 73.43
≥ 5	26	82.58 ± 84.32	65.20 ± 76.86	143.58 ± 88.72	138.11 ± 65.70

Non-Parametric Group Comparisons

Kruskal-Wallis and Mann-Whitney U test comparisons evaluating behavioral factors against mean ranks of liver biomarkers are detailed in Table 9. Smoking status was significantly associated with elevated GGT rank scores ($\chi^2 = 4.624$, p = 0.032). AST, ALT, and ALP showed no statistically significant associations with smoking status, consumption frequency, or alcohol type.

Correlation Analyses

Spearman rank correlation analyses (Table 10) demonstrated weak negative correlations between age and ALP ($\rho = -0.237$, $p < 0.05$) and between duration of use and ALP ($\rho = -0.204$, $p < 0.05$). No significant correlations were observed between alcohol consumption volume and enzyme levels.

Bivariate correlations among enzyme parameters (Table 11) showed significant associations: AST correlated positively with GGT ($\rho = 0.332$, $p < 0.01$), ALT correlated negatively with GGT ($\rho = -0.483$, $p < 0.01$), and ALT correlated strongly with ALP ($\rho = 0.771$, $p < 0.01$).

Table 10: Spearman Rank Correlations Between Participant Characteristics and Liver Biomarkers

Participant Variable	AST	ALT	GGT	ALP
Age	0.075	-0.173	0.001	-0.237*
Quantity of Alcohol Consumed	0.143	-0.028	0.046	-0.094
Duration of Consumption	0.032	-0.089	-0.088	-0.204*

*Correlation is significant at $p < 0.05$ (2-tailed).

Table 11: Spearman Rank Correlation Matrix Among Serum Liver Biomarkers

Biomarker	AST	ALT	GGT	ALP
AST	1.000	-0.085	0.332**	-0.139
ALT	-0.085	1.000	-0.483**	0.771**
GGT	0.332**	-0.483**	1.000	-0.256**
ALP	-0.139	0.771**	-0.256**	1.000

Correlation is significant at $p < 0.01$ (2-tailed).

Associations Between Categorical Variables

Cross-tabulation analyses (Tables 12 and 13) showed no significant associations between sociodemographic traits and drinking behaviors. However, artisanal wine consumption was significantly associated with drinking frequency ($\chi^2 = 11.484$, $p = 0.003$, Cramer's $V = 0.315$).

Table 12: Associations Between Sociodemographic Characteristics and Behavioral Variables (N = 116)

Variable Pair	Chi-Square (χ^2)	p-value	Cramer's V
Education Level x Smoking Status	0.297	0.667	0.084
Education Level x Consumption Frequency	5.087	0.278	0.148
Sex x Smoking Status	0.257	0.612	0.047
Sex x Quantity Consumed	8.307	0.140	0.270
Sex x Consumption Frequency	3.570	0.168	0.175

Table 13: Associations Between Alcohol Type, Smoking Status, and Frequency of Consumption

Alcohol Type	Associated Factor	Chi-Square (χ^2)	p-value	Cramer's V	Interpretation
Cinq cent	Smoking Status	0.167	0.683	0.038	Non-Significant
Lutuku	Smoking Status	1.080	0.583	0.096	Non-Significant
Artisanal Wine	Smoking Status	0.341	0.559	0.054	Non-Significant
Cinq cent	Consumption Frequency	0.335	0.846	0.054	Non-Significant
Lutuku	Consumption Frequency	7.410	0.116	0.179	Non-Significant
Artisanal Wine	Consumption Frequency	11.484	0.003	0.315	Significant

DISCUSSION

This study evaluated serum liver enzyme profiles among 116 adolescents consuming artisanal alcohol in Likasi. A pronounced male predominance (95.7%) was observed, consistent with regional studies reporting higher alcohol exposure among male adolescents due to social norms and risk-taking behavior patterns (Cosma et al., 2022; Martínez-Manrique et al., 2022). The modal age group was 19 years (41.4%), supporting literature indicating that alcohol consumption consolidates during late adolescence (Carsi Kuhangana et al., 2021; Mehanović et al., 2022; Shibiru et al., 2023; Smith et al., 2024).

The high prevalence of *cinq cent* (76.7%) and *lutuku* (65.5%) consumption reflects their widespread availability and low cost in Likasi (Lombe Bukole et al., 2025; Murupa Mbo Jules et al., 2023). Unstandardized distillation processes in artisanal alcohol production often lead to high ethanol concentrations and congener contamination (including methanol and aldehydes), increasing hepatotoxic potential (Lachenmeier et al., 2018; Rehm et al., 2022).

Biochemical findings demonstrated overall elevations in serum AST (84.67 ± 80.75 IU/L), ALT (69.17 ± 71.77 IU/L), GGT (158.09 ± 95.08 IU/L), and ALP (161.53 ± 85.87 IU/L). Elevated GGT was the most frequent biological abnormality (76.7%), consistent with its recognized sensitivity as an early biomarker of heavy alcohol exposure and hepatic enzyme induction (Bijmens et al., 2021; Neumann & Spies, 2003; Whitfield, 2001). Concomitant elevations in AST and ALT indicate hepatocellular injury (EASL, 2018; Osna et al., 2017).

Contrary to the secondary hypothesis, no linear correlation was observed between self-reported alcohol volume or duration of use and serum enzyme levels. This

finding aligns with evidence suggesting that liver enzyme responses in young populations depend on multiple factors, including episodic binge drinking patterns, variable exposure duration, metabolic clearance, and individual genetic or nutritional factors (Chapman et al., 2025; Philips, 2024; Thursz & Lingford-Hughes, 2023; Wulandari & Aliviameita, 2025). Furthermore, hepatic regenerative capacity in adolescents may mitigate linear physiological changes during early exposure phases (Thursz et al., 2018).

The significant association between tobacco smoking and elevated GGT rank scores ($p = 0.032$) points to compounding oxidative stress and enzyme induction caused by co-exposure to tobacco and alcohol toxins (Bijani et al., 2022; Zhang et al., 2024). In addition, the physiological negative correlation between age and ALP ($\rho = -0.237$, $p < 0.05$) reflects normal osteoblast activity changes following pubertal growth peaks, highlighting the need to distinguish bone growth effects from hepatobiliary alterations when interpreting ALP levels in adolescents (Taylor & Miloh, 2019).

The strong positive correlation between ALT and ALP ($\rho = 0.771$, $p < 0.01$) alongside AST-GGT correlation ($\rho = 0.332$, $p < 0.01$) indicates early, co-occurring hepatocellular and hepatobiliary biochemical alterations. However, the absence of a classic AST/ALT ratio pattern characteristic of advanced alcoholic liver disease suggests that these changes represent early metabolic and cytotoxic disturbances rather than established structural damage (Danpanichkul et al., 2024; Zdanowicz et al., 2021).

Public Health Recommendations

1. **Regulatory Oversight:** Establish quality control standards for local beverage production to restrict toxic congener contamination.
2. **Monitoring Systems:** Implement community health screening programs to evaluate artisanal alcohol safety and monitor toxicity markers.
3. **Producer Education:** Promote safe fermentation and distillation practices to reduce toxic byproducts.
4. **Youth Prevention Programs:** Implement targeted school- and community-based interventions

addressing alcohol and tobacco co-use among adolescents.

Study Limitations

- a) **Absence of Control Group:** The study lacked an unexposed adolescent control group, preventing direct comparisons and causal inferences.
- b) **Sex Imbalance:** The sample was predominantly male (95.7%), limiting subgroup analysis and generalizability to female adolescents.
- c) **Cross-Sectional Design:** The cross-sectional methodology precludes establishing longitudinal temporal or causal relationships.
- d) **Recall and Self-Report Bias:** Alcohol volume and frequency measurements relied on self-reported survey data.
- e) **Lack of Chemical Analysis:** Toxic congener concentrations (e.g., methanol, heavy metals) in the consumed beverages were not directly quantified.

CONCLUSION

This study identified substantial liver enzyme elevations—particularly GGT—among adolescents consuming artisanal alcohol in Likasi, DRC. While self-reported drinking volume and duration were not linearly correlated with enzyme levels, elevated AST, ALT, GGT, and ALP activities indicate underlying hepatic biochemical alterations. Controlled longitudinal studies incorporating specific bio-markers (e.g., carbohydrate-deficient transferrin or ethyl glucuronide) are recommended to clarify long-term health outcomes in this population.

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Authors' Contributions:

- i. **A.S.:** Study design, data collection, statistical analysis, interpretation, and manuscript drafting.
- ii. **M.V.:** Methodology, laboratory assay supervision, data validation, and manuscript review.

iii. J.P.K.N.: Study conceptualization, overall supervision, critical revision, and final manuscript approval.

Data Availability Statement: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable academic request.

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Informed Consent and anonymity: Written informed consent was obtained from parents/legal guardians, and written informed assent was obtained from all participating adolescents.

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