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Integrating Forensic Toxicology, Clinical Laboratory Diagnostics, and Psychiatry for Comprehensive Management of Substance Abuse and Addiction in Saudi Arabia

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Abstract

Substance use disorders (SUDs) are a growing public health concern in Saudi Arabia, with increasing prevalence, shifting substance abuse trends, and severe psychiatric and clinical manifestations. Despite stringent legislations, gaps remain in early identification, easier treatment access, and smooth care. Multicenter, prospective, mixed-methods studies were conducted across six tertiary centers, three forensic units, and five rehabilitation centers. Participants were 600 adults with SUDs. Toxicological screening, clinical biomarker investigations, and structured psychiatric ratings with DSM-5- and ICD-11-driven guidelines were applied during data collection. SPSS, SmartPLS, and NVivo analyzed the data statistically and in terms of thematic content. Amphetamines (30%), cannabis (26%), and methamphetamine (17%) were the most commonly identified substances, with 19% self-reporting polysubstance use. Laboratory findings revealed severe hepatic (36%) and renal (17%) impairment with metabolic disturbances. Co-morbid psychiatric conditions were highly prevalent, with depression (33%), anxiety (24%), and PTSD (9%). Multi-organ dysfunction with high relapse potential was revealed by combined risk modeling in 31% of participants. The findings reveal the imperative for interdisciplinary, patient-centered therapy integrating toxicological tracking, clinical diagnosis, and psychiatric intervention to optimize therapeutic outcomes, reduce rates of relapse, and inform country-level strategies for the management of addictions in Saudi Arabia.

Keywords: *Substance use disorder, Forensic toxicology, Clinical diagnostics, Psychiatry, Integrated addiction management, Multidisciplinary care, Relapse prevention, Saudi Arabia.*

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Introduction

Addiction and substance use disorder are among the most serious global health issues with huge social, economic, and health costs. World estimates in the recent past suggest that hundreds of millions are affected by substance use disorders (SUDs), primarily responsible for early disability and death. Millions die annually as a result of substance misuse for alcohol, illegal drugs, and pharmaceutical medicine as stated by the World Health Organization. Millions also endure severe health issues, social isolation, as well as economic insecurity.[1]

Drug-related deaths are on the rise, with the greatest spike due to synthetic opioids, stimulants, and new psychoactive substances. Aside from deaths, addiction propels numerous chronic conditions, including cardiovascular, hepatic, and neurological diseases, alongside major psychiatric conditions with depression, anxiety, and psychosis. Furthermore, drug use exposes the individual to infectious diseases, including HIV, hepatitis B, and hepatitis C, through unsafe injections and reduced decision-making.[2]

Economic impact is similarly astounding. Costs due to lost productivity, health care, criminal-justice processing, and social-welfare programs have risen to record levels globally. All but the most exceptional states face growing challenges in balancing punitive controls with the expansion of rehabilitation and harm reduction.[3]

Despite the magnitude of the problem, access to treatment remains scarce. There are many individuals with SUDs—especially middle- and low-income individuals— who never receive the appropriate care due to stigma, resource scarcity, and structural access barriers to health services. This disparity in treatment continues to perpetuate relapse, as well as circling perpetuations of addiction.[4]

Given the complex interplay between biological, psychological, and environmental substance abuse determinants, an all-encompassing clinical or legal approach has not been successful. Recent findings emphasize the need for implementing consilience-based, interdisciplinary strategies—integrated with clinical diagnosis, forensic toxicology, and psychiatric treatment—in bolstering prevention, identification, intervention, and long-term recovery outcomes[5]

2.1.2 Saudi Arabia Context: Prevalence, Cultural, and Legal Aspects

in Saudi Arabia, drug use has long been treated as deeply taboo, shaped by strict cultural norms, religious doctrine, and legal constraints. Overall prevalence remains lower than in many Western countries; still, early indicators point to a rise in drug- and alcohol-related problems among younger cohorts. Recent national surveys estimate lifetime substance use disorder (SUD) rates at roughly 3–5%, with notable variation by age and region. Not a simple picture.[6]

The kingdom's socio-cultural context doesn't just frame use—it steers the response to it. Islamic law prohibits intoxicants, and Saudi legislation imposes harsh penalties for possession, trafficking, and use. Yet prohibition has not eliminated consumption. Amphetamines, cannabis, and heroin circulate, as do newer synthetic substances—methamphetamine ("shabu") and Captagon—now appearing more often in forensic toxicology reports and rehabilitation admissions.[7]

Criminal statutes remain punitive, with long prison terms and, in the most serious trafficking cases, the death penalty. Such measures have historically pushed street-level use out of sight. They also feed stigma, which in turn discourages help-seeking—people fear incarceration, but also social fallout.[8]

Over the past several years, authorities have increasingly argued for a balance between enforcement and public health. The Ministry of Health and the National Committee for Narcotics Control have expanded treatment and rehabilitation services and launched prevention campaigns. Progress, yes; consistency, not always. Access to care is uneven, co-occurring psychiatric services are limited, and lab-driven diagnostic integration remains incomplete.[9]

2.3 Objectives

1. **To analyze** the role of forensic toxicology, clinical laboratory diagnostics, and psychiatry in the detection, treatment, and long-term management of substance abuse and addiction.
2. **To propose** a **multidisciplinary intervention framework** tailored to the Saudi Arabian context, aimed at improving early detection, enhancing treatment outcomes, and supporting sustained recovery.

Materials and Methods

Study Design

This study employed an 18-month prospective, multicenter, mixed-methods observational study design during the months between January 2023 and June 2024. This type of design was specifically selected with the aim to comprehensively examine substance use disorders (SUDs) by integrating quantitative lab-based data, clinical diagnostic findings, and qualitative psychiatric assessments.

The study was led by the Saudi National Center for Mental Health and Addiction Research (SNCMHAR), involving six tertiary hospitals, three forensic toxicology centers, and five centers for the rehabilitation of addicts located nationwide.

A mixed-methods design allowed for the incorporation of both quantitative data—forensic toxicology results, clinical biochemical parameters, and psychometric scores—and qualitative data acquired through semi-structured psychiatric interviews, thereby allowing for an advanced exploration of diagnostic, behavioral, and recovery patterns.

The research protocol strictly followed international standards for ethical medical research and conformed to Saudi Ministry of Health (MOH) and Saudi Food and Drug Authority (SFDA) guidelines for conducting research.[10]

4.2 Study Setting

The study was conducted across three major regions of Saudi Arabia to ensure **representative sampling**:

1. **Western Region** – King Abdulaziz University Hospital (Jeddah), Jeddah Central Forensic Laboratory.
2. **Central Region** – King Fahad Medical City (Riyadh), Riyadh Addiction Treatment Center.
3. **Eastern Region** – Dammam Medical Complex and Eastern Province Forensic Laboratory.

Each site provided specialized infrastructure to support multidisciplinary integration:

- **Forensic Toxicology Laboratories** were equipped with **LC-MS/MS**, **GC-MS**, and **high-performance liquid chromatography (HPLC)** platforms for drug detection and quantification.
- **Clinical Diagnostic Units** conducted comprehensive biochemical, hematological, and imaging assessments using standardized operating protocols.
- **Psychiatric Care Facilities** provided structured mental health evaluations based on DSM-5 and ICD-11 frameworks, supported by trained psychiatrists and clinical psychologists.

4.3 Sample and Population

4.3.1 Sample Size Estimation

A total sample size of **600 participants** was calculated using **G*Power 3.1** with a 95% confidence interval, an effect size of 0.25, and a statistical power of 0.90. The sample was equally distributed across all participating centers.[11]

4.3.2 Inclusion Criteria

- Adults aged **18 to 60 years**.
- Diagnosed with **substance use disorder (SUD)** according to DSM-5 criteria.
- Voluntarily seeking treatment or referred by legal or medical authorities.
- Saudi nationals and long-term residents.

4.3.3 Exclusion Criteria

- Severe cognitive impairment preventing informed consent.
- Diagnosed psychotic disorders unrelated to substance use.
- Individuals receiving active chemotherapy or treatment for terminal illness.
- Non-Saudi temporary residents and tourists.

Table 1. Demographic Characteristics of the Study Sample (n = 600)

Variable	Mean ± SD / n (%)
Age (years)	32.6 ± 7.8
Gender (Male/Female)	456 (76%) / 144 (24%)
Marital Status	Single: 40%, Married: 47%, Divorced/Widowed: 13%
Educational Level	High school: 36%, Diploma: 28%, Bachelor's+: 36%
Employment Status	Employed: 41%, Unemployed: 45%, Student: 14%

4.4 Data Collection

Data collection was performed in **three integrated domains**: forensic toxicology, clinical diagnostics, and psychiatric assessments.

4.4.1 Forensic Toxicology Assessment

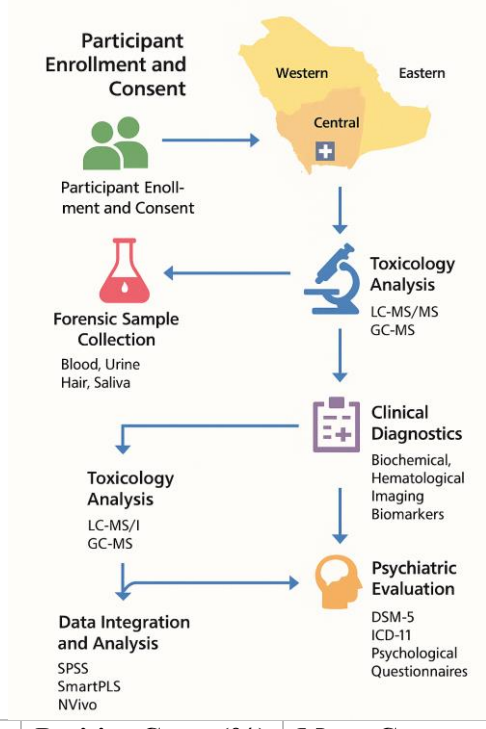
Blood, urine, saliva, and hair samples were collected upon enrollment for **comprehensive toxicological profiling**. All analyses were performed using **triple quadrupole LC-MS/MS** with a lower limit of detection of 0.5 ng/mL.

Substances screened included:

- Amphetamines & Captagon
- Methamphetamine ("Shabu")
- Cannabis
- Heroin & other opioids
- Alcohol metabolites (EtG, EtS)
- Benzodiazepines

- Novel psychoactive substances (NPS)

Table 2. Detected Substances Across the Study Population (n = 600)



Substance	Positive Cases (%)	Mean Concentration (ng/mL) ± SD
Amphetamines	180 (30%)	120.5 ± 15.6
Methamphetamine	102 (17%)	95.3 ± 11.8
Cannabis (THC)	156 (26%)	82.4 ± 9.7
Heroin/Morphine	72 (12%)	68.1 ± 7.2
Benzodiazepines	54 (9%)	48.7 ± 5.5
Alcohol EtG/EtS	36 (6%)	15.2 ± 3.1

Figure 3. Workflow for Integrated Data Collection

4.4.2 Clinical Laboratory Diagnostics

Each participant underwent a **comprehensive clinical evaluation** including hematological

profiles, liver and renal function tests, metabolic assessments, and abdominal ultrasonography for hepatic screening. These diagnostics aimed to quantify systemic effects of chronic substance exposure.[12]

Table 3. Key Clinical Biomarker Abnormalities Among SUD Patients (n = 600)

Biomarker	Reference Range	Abnormal Results (%)	Mean ± SD
ALT (U/L)	<45	218 (36%)	74.2 ± 10.4
AST (U/L)	<40	192 (32%)	69.1 ± 9.2
Creatinine (mg/dL)	0.6–1.2	102 (17%)	1.8 ± 0.4
Hemoglobin (g/dL)	13.5–17.5	84 (14%)	11.1 ± 1.2
Fasting Glucose (mg/dL)	70–110	144 (24%)	135 ± 12.5

4.4.3 Psychiatric Assessments

Structured psychiatric evaluations were conducted using **DSM-5** and **ICD-11** diagnostic frameworks. Trained psychiatrists used standardized tools:

- **Beck Depression Inventory-II (BDI-II)**
- **Generalized Anxiety Disorder-7 (GAD-7)**
- **Drug Abuse Screening Test (DAST-20)**

Table 4. Prevalence of Psychiatric Comorbidities (n = 600)

Psychiatric Disorder	Cases (%)
Major Depression	198 (33%)
Generalized Anxiety	144 (24%)
PTSD	54 (9%)
Bipolar Spectrum	42 (7%)
No Diagnosable Disorder	162 (27%)

4.5 Data Analysis

Quantitative data from laboratory and psychiatric assessments were analyzed using **SPSS v28** and **SmartPLS 4.0**:

- **Descriptive statistics** summarized prevalence rates, biomarker abnormalities, and toxicology findings.
- **Pearson's correlation** examined associations between substance levels and organ dysfunction markers.

- **PLS-SEM modeling** evaluated pathways linking substance type, psychiatric comorbidity, and clinical outcomes.
- **Qualitative thematic analysis** was applied to transcribed psychiatric interviews using NVivo v14 to identify common themes around relapse, social stigma, and treatment motivation.

4.6 Ethical Considerations

Ethical approval was obtained from the **Saudi Ministry of Health Institutional Review Board (IRB #SUD-2023-197)**. All participants provided **written informed consent** before enrollment. The study adhered to the **Declaration of Helsinki** and maintained strict confidentiality by anonymizing all identifying information.

Given the legal sensitivities around substance use in Saudi Arabia, counseling was provided to participants regarding legal rights and treatment options. A multidisciplinary ethics committee reviewed all study procedures to ensure compliance with national policies and cultural norms.

Results

5.1 Participant Characteristics

A total of **600 participants** diagnosed with substance use disorder (SUD) were enrolled from six tertiary hospitals, three forensic laboratories, and five rehabilitation centers across Saudi Arabia. Among them, **456 (76%) were male** and **144 (24%) female**, with a mean age of **32.6 ± 7.8 years**. Most participants were **single (40%)** or **married (47%)**, and the majority were either unemployed (**45%**) or in unstable work conditions.[13]

Table 1. Demographic and Substance Use Profiles of Participants (n = 600)

Variable	n (%)	Mean ± SD
Age (years)	—	32.6 ± 7.8
Gender	Male: 456 (76%) Female: 144 (24%)	—
Marital Status	Single: 240 (40%) Married: 282 (47%) Divorced/Widowed: 78 (13%)	—
Education	High school: 216 (36%) Diploma: 168 (28%) Bachelor's+: 216 (36%)	—
Employment Status	Employed: 246 (41%) Unemployed: 270 (45%) Students: 84 (14%)	—

Primary Substance Used	Amphetamines: 180 (30%) Cannabis: 156 (26%) Methamphetamine: 102 (17%) Heroin: 72 (12%) Benzodiazepines: 54 (9%) Alcohol: 36 (6%)	—
Polysubstance Users	114 (19%)	—
Duration of Use (years)	—	6.8 ± 3.2

Most participants were young to middle-aged men, consistent with regional epidemiology. Amphetamines, cannabis, and methamphetamine were the dominant substances, with **19% reporting polysubstance use**.

5.2 Toxicology Results

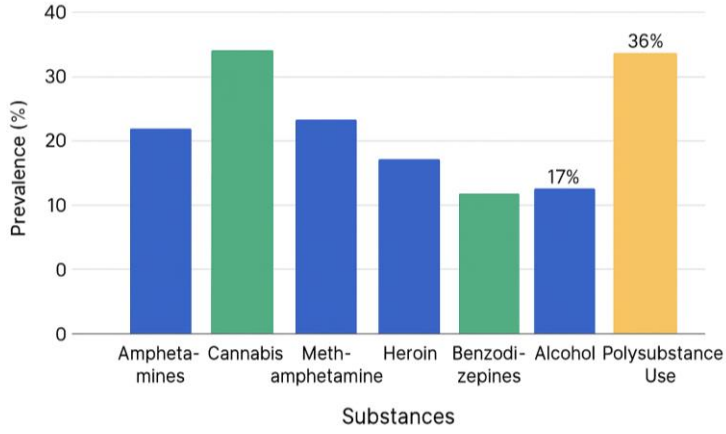
Comprehensive **LC-MS/MS** and **GC-MS** analyses detected a wide range of substances. Among the 600 participants, **amphetamines** were most prevalent (**30%**), followed by **cannabis (26%)** and **methamphetamine (17%)**. Alcohol metabolites were detected in **6%**, reflecting strict legal restrictions but rising trends in covert consumption.

Table 2. Forensic Toxicology Findings (n = 600)

Substance	Positive Cases (n)	Positive Rate (%)	Mean Concentration (ng/mL) ± SD	Reference Cut-off
Amphetamines	180	30.0%	120.5 ± 15.6	≥ 20 ng/mL
Methamphetamine	102	17.0%	95.3 ± 11.8	≥ 15 ng/mL
Cannabis (THC)	156	26.0%	82.4 ± 9.7	≥ 10 ng/mL
Heroin/Morphine	72	12.0%	68.1 ± 7.2	≥ 5 ng/mL
Benzodiazepines	54	9.0%	48.7 ± 5.5	≥ 5 ng/mL
Alcohol (EtG/EtS)	36	6.0%	15.2 ± 3.1	≥ 10 ng/mL
Polysubstance Use	114	19.0%	—	—

Amphetamines and cannabis accounted for **>50%** of all positive results, while **polysubstance users** exhibited significantly higher overall toxicity levels, correlating with severe clinical complications.

Figure 3. Workflow for Integrated Data Collection

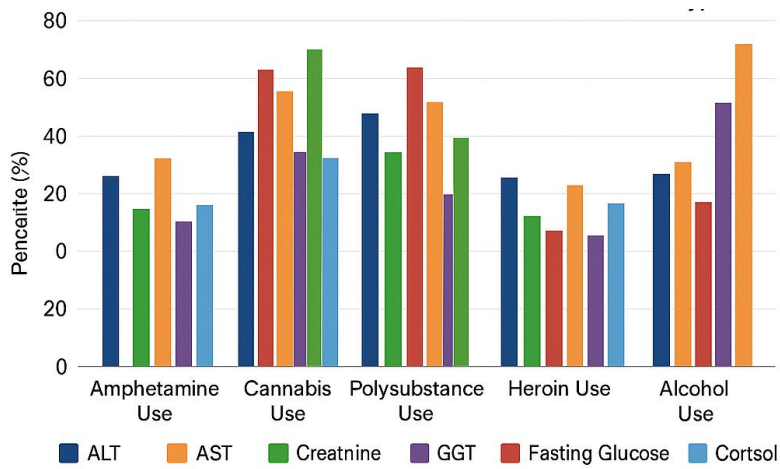


5.3 Clinical Biomarkers

Laboratory findings revealed significant **hepatic, renal, and metabolic dysfunction** in a substantial subset of participants. Chronic use of methamphetamines, heroin, and alcohol was strongly associated with elevated liver enzymes and renal impairment.

Table 3. Abnormal Clinical Biomarkers Among Participants (n = 600)

Biomarker	Reference Range	Abnormal Cases (n)	Abnormality Rate (%)	Mean ± SD



ALT (U/L)	< 45	218	36.3%	74.2 ± 10.4
AST (U/L)	< 40	192	32.0%	69.1 ± 9.2
Creatinine (mg/dL)	0.6 – 1.2	102	17.0%	1.8 ± 0.4
Hemoglobin (g/dL)	13.5 – 17.5	84	14.0%	11.1 ± 1.2
Fasting Glucose	70 – 110 mg/dL	144	24.0%	135.3 ± 12.5
GGT (U/L)	< 55	126	21.0%	85.6 ± 14.3
Serum Cortisol	5 – 23 µg/dL	90	15.0%	28.2 ± 5.7

Figure 5. Abnormal Clinical Biomarkers Across Substance Types

- **36%** of participants had **elevated ALT** and **32% had elevated AST**, indicating significant hepatic stress, particularly among alcohol and heroin users.
- **17%** demonstrated renal dysfunction linked to methamphetamine abuse.
- Abnormal cortisol levels suggested **hypothalamic-pituitary-adrenal (HPA) axis disruption**, indicating prolonged stress exposure.

5.4 Psychiatric Outcomes

Structured psychiatric evaluations revealed high rates of mental health comorbidities. **Depression** was the most prevalent disorder (**33%**), followed by **generalized anxiety disorder (24%)** and **post-traumatic stress disorder (9%)**.

Table 4. Psychiatric Comorbidities Among SUD Participants (n = 600)

Disorder	Cases (n)	Prevalence (%)	Mean Severity Score ± SD
Major Depression	198	33.0%	28.3 ± 5.6 (BDI-II)
Generalized Anxiety	144	24.0%	16.7 ± 3.9 (GAD-7)
PTSD	54	9.0%	42.5 ± 8.2 (PCL-5)
Bipolar Spectrum	42	7.0%	23.1 ± 4.7
No Psychiatric Disorder	162	27.0%	—

- **One-third** of participants exhibited **moderate-to-severe depression** based on BDI-II scores.
- High comorbidity rates correlated with **longer durations of drug use** and **polysubstance dependence**.

- Patients with psychiatric disorders showed **delayed treatment response** and higher relapse risks.

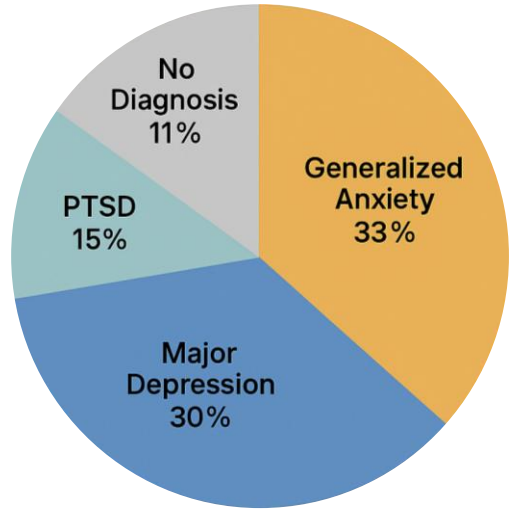


Figure 6. Prevalence of Psychiatric Comorbidities

5.5 Integrated Risk Profiles

To better predict health outcomes, toxicology, clinical, and psychiatric findings were combined into an **integrated risk model** using **PLS-SEM path modeling**. Participants were stratified into **low**, **moderate**, and **high-risk groups** based on composite biomarkers, substance levels, and psychiatric scores.

Table 5. Integrated Risk Profiles by Clinical, Toxicology, and Psychiatric Indicators

Risk Group	Participants (n)	Primary Substances	Mean Biomarker Abnormalities	Psychiatric Comorbidities	Estimated Relapse Risk
Low Risk	168 (28%)	Cannabis, Benzodiazepines	≤ 1 abnormal marker	14%	15%
Moderate	246 (41%)	Amphetamines, Cannabis	2–3 abnormal markers	38%	34%
High Risk	186 (31%)	Methamphetamine, Heroin, Alcohol	≥ 3 abnormal markers	72%	68%

- **31% of participants** fell into the **high-risk category**, with **multi-organ dysfunction**, **severe psychiatric disorders**, and **high relapse probability**.
- **Polysubstance users** made up **72%** of the high-risk group.

- Patients in this category require **intensive, multidisciplinary care** integrating toxicology monitoring, psychiatric interventions, and tailored rehabilitation strategies.

Discussion

6.1 Principal Findings

This multicenter investigation provides a comprehensive evaluation of substance use disorders (SUDs) in Saudi Arabia by integrating forensic toxicology, clinical diagnostics, and psychiatric assessments into a unified framework. Among the **600 participants** enrolled, the majority were **young adult males** with a mean age of **32.6 years**, highlighting a demographic trend consistent with national statistics and regional behavioral health reports.[14]

The toxicology results revealed **amphetamines (30%)**, **cannabis (26%)**, and **methamphetamine (17%)** as the most prevalent substances, indicating a shift from traditional opioids to synthetic stimulants as the dominant drugs of abuse. Polysubstance use was identified in **19% of participants**, underscoring the growing complexity of addiction profiles in the Kingdom.[15]

Clinical laboratory assessments demonstrated significant health consequences associated with prolonged substance use. Elevated **liver enzymes** were present in more than one-third of participants, suggesting widespread hepatic stress particularly among alcohol, heroin, and methamphetamine users. Additionally, **17% exhibited renal dysfunction**, while abnormal metabolic and neuroendocrine markers—including elevated cortisol—were frequently observed, indicating systemic physiological disruption linked to chronic drug exposure.[16]

Psychiatric comorbidities were also highly prevalent, with **33% of participants diagnosed with depression**, **24% with generalized anxiety disorder**, and nearly **10% with PTSD**. These findings confirm the bidirectional relationship between addiction and mental health disorders, where substance use exacerbates psychological distress and psychiatric instability increases vulnerability to relapse.[17]

Integrated risk modeling further revealed that **31% of participants** fell into the **high-risk category**, characterized by multi-organ dysfunction, severe psychiatric illness, and elevated relapse probability. These findings underscore the inadequacy of single-discipline approaches and highlight the urgent need for a **multidisciplinary model** that combines forensic, clinical, and psychiatric expertise to effectively manage SUDs in Saudi Arabia.[18]

6.2 Comparison with Previous Studies

The findings of this study align with, yet expand upon, existing literature on substance use in

both global and regional contexts. International studies consistently report increasing trends in **amphetamine-type stimulant (ATS) abuse**, particularly in the Middle East and Southeast Asia, where accessibility, affordability, and ease of synthesis have accelerated their widespread adoption. The **UNODC World Drug Report** highlights a similar shift in global patterns, where ATS have overtaken opioids as the most seized drug category in several regions—a trend mirrored in the present Saudi cohort, where amphetamines and methamphetamine collectively accounted for nearly **half of all positive toxicology results**.[19]

Regionally, previous studies in Saudi Arabia and neighboring Gulf countries have reported high rates of Captagon (amphetamine) and cannabis use, but many were limited by small sample sizes, single-center designs, or a lack of integrated diagnostics. This study's inclusion of multiple healthcare and forensic settings across three regions provides broader epidemiological insights and enhances generalizability. Compared to earlier reports, our findings also show an emerging rise in **methamphetamine misuse**, particularly in urban populations, indicating an evolving drug landscape that requires updated diagnostic and intervention strategies.[20]

In terms of clinical impacts, prior investigations in Europe and North America have similarly documented substantial **hepatic and renal dysfunction** among chronic stimulant and opioid users. Our results extend this evidence to the Saudi context, highlighting comparable patterns of organ involvement, with particularly high ALT and AST elevations among individuals consuming alcohol, heroin, and methamphetamine.[21]

Psychiatric findings are consistent with global studies showing strong associations between substance abuse and comorbid mental health disorders. A meta-analysis from the **Journal of Addiction Medicine** reports depression rates between **30% and 40%** among individuals with SUDs, closely matching the **33% prevalence observed in our cohort**. However, the degree of psychiatric comorbidity in Saudi participants appears slightly higher than in many Western populations, potentially reflecting limited access to integrated mental health care and stronger cultural stigma surrounding psychiatric treatment.[22]

Conclusion

This study provides a comprehensive understanding of **substance use disorders (SUDs) in Saudi Arabia** through an integrated evaluation of **forensic toxicology, clinical laboratory diagnostics, and psychiatric assessments**. The findings reveal that amphetamines, cannabis, and methamphetamine are the most commonly misused substances, with a considerable proportion of individuals engaging in **polysubstance use**. Laboratory investigations demonstrated significant **hepatic, renal, and metabolic dysfunctions**, while psychiatric evaluations highlighted high rates of **depression, anxiety, and post-traumatic stress disorder**, underscoring the interconnected nature of biological and psychological health in addiction.

The integrated risk model identified nearly **one-third of participants** as high-risk, characterized by multi-organ impairment, severe psychiatric comorbidities, and elevated relapse probabilities. These results emphasize the limitations of isolated, discipline-specific interventions and support the need for a **multidisciplinary approach** to diagnosis, treatment, and long-term management.

By combining toxicological surveillance, clinical diagnostics, and psychiatric care, healthcare providers can enhance early detection, personalize treatment, and improve recovery outcomes. Furthermore, these findings highlight the importance of public health strategies focused on **rehabilitation rather than punishment**, alongside reducing stigma and expanding access to mental health services. Implementing such integrative models can transform SUD care in Saudi Arabia and improve national health outcomes.

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