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A REVIEW ON EXERCISE CAPACITY, LUNG FUNCTION AND RESPIRATORY MUSCLE FUNCTION IN SUBSTANCE USE DISORDERS

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ABSTRACT

Substance Use Disorders (SUDs) significantly impact exercise capacity, lung function, and respiratory muscle strength, highlighting the need for comprehensive studies in this area. This review focuses on the detrimental effects of various substances—including alcohol, nicotine, cannabis, opioids, stimulants, and inhalants—on pulmonary health. The misuse of these substances, through varied methods of intake, damages the respiratory system and often results in conditions like obstructed airways, diminished lung function, and weakened respiratory muscles. The review details mechanisms by which substances exert their effects on respiratory health, with findings indicating that individuals with SUDs experience marked reductions in measures of pulmonary function and physical endurance. The common effects include reduced forced expiratory volume (FEV1), forced vital capacity (FVC), and diminished maximal inspiratory and expiratory pressures (MIP and MEP). These adverse impacts are associated with a heightened risk for respiratory complications, especially for individuals with chronic conditions like COPD, where substance misuse exacerbates disease progression. Rehabilitation and targeted interventions are essential to mitigate these effects, offering pathways to restore respiratory function in individuals with SUDs. This review underlines the need for further research to explore early interventions and preventive strategies to address respiratory health in vulnerable populations affected by substance use.

KEYWORDS: Substance use disorder, exercise capacity, lung function, respiratory muscle strength, FEV1, FVC, MIP, MEP, COPD, obstructed airways, diminished lung function, and weakened respiratory muscles.

INTRODUCTION

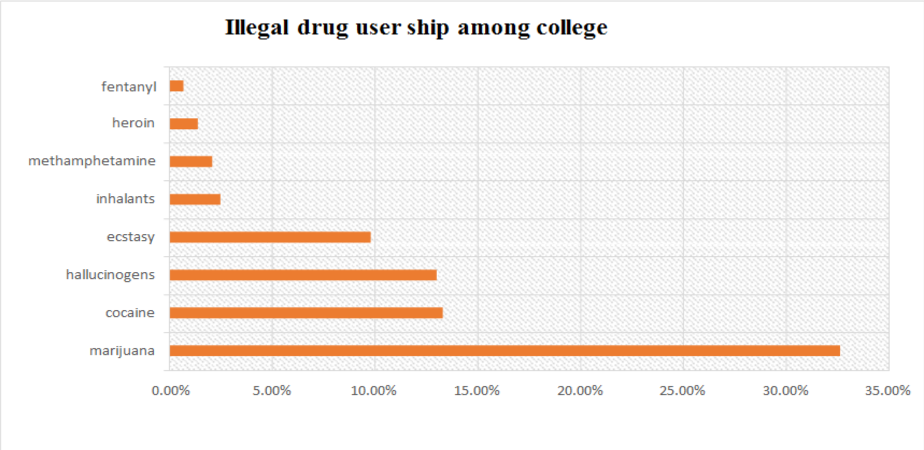
The misuse of substances like alcohol, nicotine, and illicit drugs remains one of the most pressing global public health challenges.[1] Substance use disorders (SUDs) are highly prevalent and profoundly affect individuals' social lives, overall health, and well-being. In cases of addiction, whether moderate or severe, the intense craving for substances and the inability to resist this urge result from enduring changes in brain networks associated with reward, executive functioning, stress response, mood regulation, and self-awareness.[2] Over the past years, drug addiction has emerged as an escalating issue worldwide, posing serious threats to the economy, social structures, legal systems, and public health in both developed and developing nations. Studies suggest that approximately one in four individuals in developed countries will use illicit drugs at some point, while one in six to seven people in developing regions are at risk of developing substance use disorders.[3]

Various factors, such as pollen, mildew, and pollution, can influence the respiratory system, and substance use is no exception. The method of substance administration—whether smoking, snorting, injecting, or oral ingestion—also plays a significant role in affecting respiratory health. Substance misuse is frequently associated with conditions such as pulmonary infections (e.g., pneumonia, tuberculosis, respiratory syncytial virus), bronchospasm (a sudden narrowing of the airways), asthma exacerbations, and "crack lung," which may present with labored breathing, fever, cough, or haemoptysis (coughing up blood) and potentially lead to respiratory failure. Other related issues include black sputum, wheezing, shortness of breath, pulmonary edema (fluid accumulation in the lungs), haemoptysis, pulmonary granulomatosis (nodular immune cell clusters in the lungs), irregular breathing patterns like apnea (paused breathing) and tachypnea (rapid, shallow breathing), acute respiratory distress syndrome (ARDS), which can be life-threatening, and respiratory depression or arrest, often resulting from overdose.[4] As most substances are absorbed through the airways, prolonged and frequent use poses a significant risk to both the upper and lower respiratory tracts, leading to lasting damage to lung health. Evidence from recent studies highlights the detrimental effects of substance addiction on respiratory function. However, there is a lack of comprehensive data on pulmonary function parameters in individuals with substance dependence in our country. Therefore, the objective of our study was to examine these impacts in greater detail.[5]

The impact of smoking substances such as tobacco, marijuana, crack cocaine, and heroin on lung function has been extensively studied in adults, particularly those with a history of long-term and heavy use. However, there remains a significant gap in our knowledge regarding how substance use disorders (SUD) affect adolescents and their respiratory health. Exploring this younger population is crucial for identifying which spirometric parameters may be more affected by early substance misuse.[6]

HERE ARE SOME EXAMPLES OF SUBSTANCES AND THEIR GENERAL MECHANISMS[2]

DRUG CLASS	MECHANISMS OF ACTION
Alcohol	Alcohol impacts several pathways, including the enhancement of GABA activity, activation of mu-opioid receptors, and stimulation of cannabinoid signaling, which collectively lead to an indirect increase in dopamine levels in the nucleus accumbens.
Nicotine	Nicotine acts as an agonist at nicotinic acetylcholine receptors (nAChRs), with its interaction with the α4β2 nAChR subtype being closely linked to its rewarding and reinforcing effects. This action directly stimulates dopamine neurons in the ventral tegmental area while also activating modulatory neurons in the same region.
Cannabinoids	The pleasurable and reinforcing effects of cannabis are primarily attributed to tetrahydrocannabinol (THC), which acts as a partial agonist at CB1 receptors. In contrast, cannabidiol does not produce rewarding effects and is not addictive. Similarly, the rewarding and reinforcing properties of synthetic cannabinoids stem from their agonistic action on CB1 receptors. Activation of CB1 receptors regulates the presynaptic release of GABA and glutamate, leading to the stimulation of dopamine neurons in the ventral tegmental area.
Stimulants	Amphetamines, whether prescribed for ADHD or sourced illegally from clandestine operations such as meth labs, stimulate dopamine release by reversing the dopamine transporter (DAT) and depleting vesicular dopamine reserves in dopaminergic neurons. In contrast, cocaine elevates dopamine levels by blocking DAT, thereby inhibiting dopamine reuptake and causing its accumulation in the synapse.
Opioids	The rewarding effects of opioids arise from their activation of mu opioid receptors. Within the ventral tegmental area, opioids bind to these receptors on GABAergic neurons, reducing their inhibitory control over dopaminergic neurons. This disinhibition enhances dopamine release in the nucleus accumbens, driving their reinforcing effects. The potency of opioid drugs varies, with fentanyl being much stronger than heroin, and heroin being more potent than morphine.
Inhalants	Inhalants impact multiple neurotransmitters and their receptors, including a reduction in NMDA activity, an increase in glycine and GABAA activity, a decrease in nACh activity, and an elevation in dopamine levels, thereby boosting dopamine release.
Benzodiazepines	Benzodiazepines and barbiturates, commonly prescribed for conditions like anxiety, insomnia, seizures, and sedation during anesthesia, are often misused for their pleasurable effects. They boost GABAA receptor activity, leading to increased firing of dopaminergic neurons in the ventral tegmental area by reducing inhibition, which contributes to their reinforcing effects.

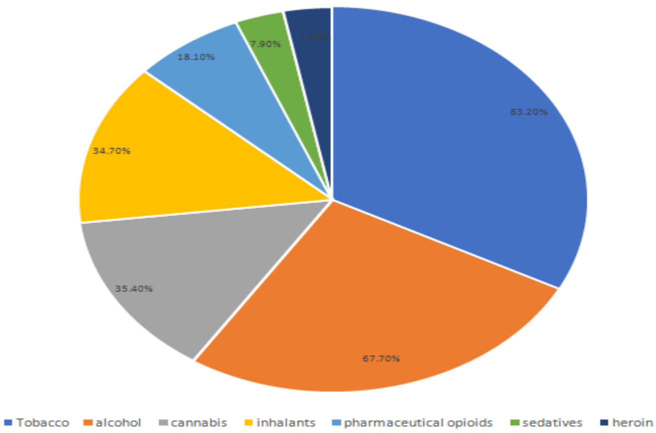


EPIDEMIOLOGY

Global epidemiological data reveal that roughly 20% of individuals aged 16 to 24 reports having used at least one illicit drug in the past year. Furthermore, it is estimated that a concerning 19.33% of adolescents between the ages of 13 and 15 have smoked cigarettes. Data from the US Centers for Disease Control and Prevention also show a similarly high rate of tobacco use (17.6%) among individuals transitioning from adolescence to adulthood (ages 18-24). Additionally, recent years have seen an increase in the estimated prevalence of cannabis use among adolescents.[6]

According to data from the World Health Organization (WHO), alcohol misuse causes 2.5 million deaths annually, and at least 15.3 million people are affected by substance use disorders (SUDs).[1] The prevalence of SUDs varies across countries, types of substances (with alcohol and tobacco being the most common), and demographic and socioeconomic factors. SUD rates tend to decrease with age for both men and women, with younger individuals and men experiencing higher rates compared to women.[2]

In 2013, the National Commission for Prevention of Child Rights conducted a nationwide survey involving 4,000 individuals under 18 years old from 100 cities across 29 states and union territories. All participants reported using at least one substance (other than tobacco) in the past year. Alcohol (67.7%) and tobacco (83.2%) were the most commonly abused substances. Other substances included cannabis (35.4%), inhalants (34.7%), prescription opioids (18.1%), sedatives (7.9%), and heroin/smack (7.9%).[7]



A nationwide study was conducted by the National Commission for Prevention of Child Rights in 2013.

THE SIGNIFICANCE OF EXAMINING EXERCISE CAPACITY, LUNG FUNCTION, AND RESPIRATORY MUSCLE FUNCTION IN INDIVIDUALS WITH SUBSTANCE USE DISORDERS

Recent studies investigating the acute and chronic effects of narcotic use on the respiratory system have shown that short-term narcotic use primarily impacts bronchial dynamics. Acute use has been found to reduce airway resistance through bronchodilation. However, prolonged use of these substances can lead to symptoms such as coughing, abnormal sputum production, airway obstruction, hyperinflation, and changes in respiratory function.[3] Regular exercise and physical activity are well recognized for their positive effects on various aspects of mental health and are known to improve the ability to perform physical tasks, thereby reducing the risk of metabolic diseases.[8]

Reduced respiratory capacity can be improved through respiratory muscle strengthening exercises. These exercises, commonly used in pulmonary rehabilitation, focus on alleviating dyspnea by enhancing respiratory capacity.[9] Respiratory muscles, like the diaphragm, are structurally and functionally similar to skeletal muscles, and they respond to exercise loads in the same way. Strengthening the diaphragm, which is the most important respiratory muscle, has a positive impact on overall respiratory function.[10]

Individuals with substance use disorders (SUD) are at an increased risk of contracting COVID-19 and experiencing more severe complications due to various physiological and social factors. Common comorbidities in people with SUD, such as cardiovascular diseases, chronic respiratory conditions, diabetes, obesity, and cancer, heighten vulnerability to COVID-19 and are linked to more severe symptoms, complications, and higher mortality rates.[11]

Long-term alcohol abuse negatively impacts lung health, leading to a reduced cough reflex, impaired mucus clearance, a heightened vulnerability to lung infections, and an increased likelihood of acute respiratory illnesses.[10]

Cannabis is obtained from the female Cannabis sativa plant, with its psychoactive component being delta-9 tetrahydrocannabinol (THC). The highest concentration of THC is found in the plant's flowering tops, while lower levels are present in the leaves, stems, and seeds. Marijuana, prepared from dried flowering tops and leaves, contains 0.5–5% THC, whereas hashish, made from compressed flowers and dried resin, has a THC concentration ranging from 2–20%. The pulmonary effects of cannabis smoking remain under-researched; however, similar to tobacco smoking, it has been linked to airway inflammation and bronchitis symptoms, though evidence of airway obstruction is not definitive.[11] Current studies suggest that cannabis smoking leads to hyperinflation and air trapping without significant reductions in FEV1, in contrast to tobacco smoking, which reduces FEV1 and contributes to chronic obstructive pulmonary conditions.[12]

In recent years, upper respiratory and pulmonary complications associated with cocaine addiction have been increasingly reported, particularly due to the rising use of inhalable or smokable forms of cocaine. Most reported issues have been cardiopulmonary (56.2%), neurological (39.1%), and psychiatric (35.8%) in nature. Chest pain, though infrequently ischemic, has been the most commonly reported symptom.[13]

Cigarette addiction, strongly linked to the onset of respiratory disorders, leads to a decline in respiratory function. According to the World Health Organization, smoking increases the risk of lung diseases and contributes to the development of various health conditions. Whether through active or passive exposure, smoking causes significant issues such as vascular stiffness, restricted airflow to the alveoli, reduced diffusion capacity, increased airway resistance, and decreased oxygen absorption in the blood. Additionally, smoking- related cardiovascular and respiratory complications result in a loss of muscle strength.[9] Studies in animals have shown that methamphetamine inhalation increases airway resistance, accompanied by a reduction in serotonin levels. Children living near methamphetamine production areas have exhibited temporary asthma symptoms. Alcohol is also known to negatively impact lung health, primarily by impairing pulmonary defense mechanisms and increasing the vulnerability of individuals with alcohol dependence to infections.[14]

Opioid use disorder (OUD) is a complex physical and emotional condition that significantly affects mood and induces anhedonia. It also contributes to the development of comorbid medical and infectious diseases that necessitate evaluation and treatment. By altering the brain, behavior, and motivational priorities through neuroplasticity, OUD leads to chronic and progressive neurodysregulation. This condition shortens life expectancy, limits career opportunities and earning potential, increases the risk of other illnesses, and often results in fatal outcomes.[15]

Benzodiazepine use is prevalent among older adults with chronic obstructive pulmonary disease (COPD). Individuals with COPD may use benzodiazepines to manage common issues such as insomnia, depression, anxiety, and persistent dyspnea. However, benzodiazepines are linked to various negative respiratory effects in COPD, including reduced minute ventilation, hypoxemia, hypercapnia, diminished respiratory drive, impaired chemoreceptor response to hypercapnia, weakened respiratory muscle strength, and ventilation- perfusion imbalance.[16]

Volatile substance abuse (VSA) is a particularly concerning issue because inhalants are commonly used substances, often initiated at an early age, and can serve as a gateway to the abuse of more dangerous drugs. The most significant acute consequence of VSA is sudden death, which is believed to result from vagal inhibition, anoxia, respiratory failure, or cardiac arrhythmia. Prolonged low-dose inhalant abuse can lead to nervous system damage, including muscle weakness, tremors, peripheral neuropathy, cerebellar dysfunction, chronic encephalopathy, and dementia.[17]

EXERCISE CAPACITY IN SUD PATIENTS

The 6-minute walk test (6MWT), a reliable and validated method for assessing exercise capacity, was conducted following the guidelines of the European Respiratory Society (ERS) and the American Thoracic Society (ATS).[3] Evaluating exercise capacity is a crucial component in the assessment of patients with cardiopulmonary diseases. The 6MWT provides valuable insight into functional capacity, treatment response, and prognosis across various chronic cardiopulmonary conditions. Walking distances of less than 350 meters are linked to higher mortality rates in chronic obstructive pulmonary disease (COPD), chronic heart failure, and pulmonary hypertension. In patients with interstitial lung disease, oxygen desaturation during the test serves as an important prognostic marker. The 6MWT is responsive to commonly used therapies for COPD, including pulmonary rehabilitation, supplemental oxygen, prolonged use of inhaled corticosteroids, and lung volume reduction surgery.[18]

LUNG FUNCTION IN SUD PATIENTS

Prolonged use of inhaled psychostimulants has been linked to negative pulmonary outcomes, including bronchitis, acute lung injury, and COPD. Research indicates that cigarette smoking causes various lung alterations, with damage potentially worsened by the polysubstance use patterns often observed in individuals with cocaine-related issues. Evidence also suggests that airway obstruction is common among heroin users, with frequent inhalation of the drug posing a significant risk for developing COPD. Additionally, long-term heroin and crack cocaine use has been associated with conditions like pulmonary emphysema and asthma. Chronic cannabis use has been shown to impair lung function, as reflected by a notable reduction in FEV1 measured through spirometry. Pulmonary function tests further revealed that the incidence of COPD related to restrictive lung disease was 50% lower in heroin smokers compared to cigarette smokers and non-smokers, although COPD prevalence remained high among heroin smokers.[8]

Spirometry was conducted following the American Thoracic Society/European Respiratory Society guidelines for acceptability and reproducibility. All measurements were adjusted for local barometric pressure and temperature on the test day. Baseline weight and height were recorded using a scale and measuring tape. The tests were carried out individually, with participants standing, without nose clips, using a KOKO spirometer (Longmont, CO, USA). The assessed parameters included FVC, FEV, FEV/FVC ratio, and FEF25–75%. To enhance the clarity of the results, spirometry values were presented both as absolute values and as percentages of predicted values based on international reference equations. In the substance use disorder (SUD) group, spirometry was performed in the second week of withdrawal to minimize the effects of acute withdrawal.[6]

RESPIRATORY MUSCLE FUNCTION IN SUD PATIENTS

The diaphragm and the intercostal muscles are the primary components of the respiratory system responsible for breathing. The main function of this system is to regulate the oxygen levels in the arterial blood through the exchange of oxygen (O2) and carbon dioxide (CO2). For efficient oxygen intake, these respiratory muscles need to be strong. When these muscles weaken, breathing capacity is impaired, which in turn hampers daily activities by limiting the delivery of oxygen.[9]

Respiratory muscle strength was measured using maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) following ATS/ERS guidelines with a portable Micro RPM device (Micro Medical, Basingstoke, UK). The highest value from five acceptable and repeatable trials (with no more than a 10% variation between values) was recorded and presented as an absolute value (cmH2O). The predicted percentages for PIM and PEM were calculated based on the method outlined by Black and Hyatt.[3]

DISCUSSION

This review underscores the substantial negative impacts that substance use disorders (SUDs) have on exercise capacity, lung function, and respiratory muscle strength. The evidence suggests that chronic substance use, especially through inhalation or smoking, leads to significant reductions in pulmonary function metrics like FEV1 and FVC, and weakens respiratory muscles as shown by decreased MIP and MEP values. These effects collectively increase the respiratory complications risk in individuals with SUDs. This area remains understudied, particularly for adolescents and in populations with varying types of substance use, highlighting an urgent need for more targeted research to develop effective rehabilitation strategies.

AUTHORS	SUBJECT GROUP	EXERCISE CAPACITY	LUNG FUNCTION	RESPIRATORY MUSCLE STRENGTH
R. Mustafaoglu et., al	SUD Patients	Lower 6-MWT distance and higher exertion post-test compared to controls	Lower FVC, FEV1, FEV1/FVC compared to non-smokers, with frequent symptoms (shortness of breath, wheezing)	Lower MIP and MEP values than non-smokers and cigarette smokers
Piskin et., al	Cigarette smokers	-	Reduced FVC FEV1, PEF, FEV1/FVC ratio decreased to 23%.	Reduced MIP & MEP values
Rustem Mustafaoglu et., al	Substances were Heroin (n=23) Cannabis (n=12) and Bonzai (n=8)	-	Spirometric values (FVC, FEV1, FEV1/FVC, FEV3, FEV6, FEF 25- 75%) were similar between groups.	respiratory muscle strength showed a significant difference: Maximum Inspiratory Pressure (MIP): 75.11±21.68 cmH_2O (substance-dependent) vs. 88.89±16.28 cmH_2O (healthy), Maximum Expiratory Pressure (MEP): 102.30±32.14 cmH_2O (substance-dependent) vs. 131.33±37.66 cmH_2O (healthy)
Buker et al.	Inhalants	-	FVC, FEV1, PEF, MEF25-75	-

Hana Salah Musa Mohamed et., al	Alcohol	-	Mild decrease in FEV1/FVC ; airflow slightly affected	-
Hana Salah Musa Mohamed et., al	Cannabis	-	Significant airflow obstruction; lowest FEV1/FVC ratio.	-
Hana Salah Musa Mohamed et., al	Heroin	-	Moderate reduction in FEV1/FVC ratio, indicati ng obstruction.	-
Hana Salah Musa Mohamed et., al	Methampheta mine	-	Reduced FEV1/FVC, indicative of air flow restriction.	-

CONCLUSION

This review highlights the significant impact of substance use disorders (SUDs) on physical health, particularly lung function, exercise capacity, and respiratory muscle strength. Whether due to alcohol, tobacco, cannabis, or opioids, people suffering from substance use disorders often suffer from reduced endurance, reduced lung function, and impaired respiratory muscles. These effects vary depending on the substance and method of ingestion. For example, smoking tobacco or cannabis tends to cause airway obstruction, while opioids and benzodiazepines can slow or inhibit breathing.

The findings highlight the need for targeted rehabilitation efforts to help individuals with substance use disorders regain their respiratory health and strength, both of which are essential to improving overall well- being and resilience. There is also an urgent need for further research, especially aimed at understanding how early and persistent substance exposure impacts lung health and physical function over the long term. Addressing these health challenges through both treatment and prevention can ultimately contribute to improved health outcomes and quality of life for people affected by substance use disorders.

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