Gender Differences in Drug Addiction:Neurobiological, Social, and Psychological Perspectives in Women – A Systematic Review

Shakila Jahan Shimu [1*], Sakurul Islam [2]

Abstract

Drug addiction is a complex issue influenced by biological, psychological, and social factors. Historically, substance use disorders (SUDs) have been studied primarily in men, overlooking crucial gender differences. However, emerging research reveals that women exhibit unique drug use patterns, distinct neurobiological responses, and specific psychosocial challenges in addiction and recovery. Understanding these differences is essential for developing gender-sensitive prevention and treatment approaches. Neurobiologically, sex hormones such as estrogen and progesterone modulate drug sensitivity, leading to a faster progression from initial use to dependence in women. The mesolimbic dopamine system and prefrontal cortex demonstrate sex-specific activity, influencing cravings, reward processing, and relapse vulnerability. Additionally, hormonal fluctuations and stress responses contribute to more severe withdrawal symptoms and increased relapse risk in women. Social and psychological factors further differentiate addiction in women. They are more likely to use substances as a coping mechanism for trauma, anxiety, and depression. Gender roles and societal stigma discourage help-seeking, while caregiving responsibilities, economic dependence, and intimate partner relationships create additional treatment barriers. Women also face heightened risks of substance-related violence and exploitation Despite these challenges, gender-responsive interventions incorporating trauma-informed care, mental health support, and social empowerment strategies have shown promising outcomes. Addressing co-occurring psychiatric disorders and providing childcare support can enhance rehabilitation success. However, addiction research remains predominantly male-focused, necessitating a paradigm shift toward inclusive, gender-sensitive treatment frameworks. This review synthesizes neurobiological, social, and psychological perspectives to guide more effective, tailored interventions for women.

Keywords: Gender differences, drug addiction, neurobiology, social factors, psychological perspectives

Significance | Enhances understanding of gender-specific addiction factors to inform tailored interventions, improve treatment accessibility, and promote holistic recovery for women

*Correspondence. Shakila Jahan Shimu, Saboor Waizun Medical PC, Brooklyn, New York, United States.
E-mail: shakilajahan@hotmail.com

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1. Introduction

Drug addiction is a pervasive public health crisis affecting millions worldwide, yet its manifestation, progression, and impact differ significantly between men and women (Becker & Chartoff, 2019). Historically, addiction research and treatment models have been developed based on male-centered studies, often overlooking critical gender-specific differences in drug use patterns, neurobiological responses, and social influences (Fattore & Melis, 2016; Beery & Zucker, 2011). However, emerging evidence underscores the importance of understanding how addiction uniquely affects women, leading to more effective and targeted

Author Affiliation.
[1] Saboor Waizun Medical PC, Brooklyn, New York, United States.
[2] First Affiliated Hospital of Zhengzhou University, Zhengzhou, Henan, 450052 China.

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interventions. Women exhibit distinct drug use trajectories compared to men, often progressing from initial use to dependence at a faster rate, a phenomenon known as "telescoping" (Tanabe et al., 2013). This accelerated progression is linked to biological and psychological factors, including differences in metabolism, hormonal fluctuations, and higher prevalence rates of anxiety and depression among women (Verplaetse et al., 2021). Additionally, women are more likely to use substances as a coping mechanism for stress, trauma, and mental health disorders, increasing their vulnerability to addiction and relapse (Grella, 2008).

Neurobiologically, significant gender differences exist in how the brain processes addictive substances. The mesolimbic dopamine system, which regulates reward and pleasure, functions differently in men and women, influencing cravings and substance-seeking behaviors (Fattore et al., 2014; Koob & Volkow, 2016). Additionally, fluctuations in estrogen and progesterone levels affect drug sensitivity and withdrawal severity, often making addiction more challenging for women to overcome (Anker & Carroll, 2011). Research also suggests that structural differences in the insula and orbitofrontal cortex, which are associated with decision-making and craving regulation, may contribute to sex-specific addiction patterns (Tanabe et al., 2013; Mackey et al., 2019). These biological factors suggest that addiction treatment approaches must be adapted to account for the unique neurochemical and hormonal influences on female substance users.

Beyond biological differences, social and psychological factors play a crucial role in shaping addiction experiences among women (Figure 3). Societal stigma surrounding female drug use often discourages women from seeking help, fearing judgment and discrimination (Covington, 2008). Family responsibilities, such as caregiving for children or elderly relatives, further complicate access to treatment, making traditional rehabilitation models less effective for women (Grella & Greenwell, 2004). Furthermore, women are more likely to experience substance-related intimate partner violence, sexual exploitation, and economic dependence, all of which contribute to the cycle of addiction (Najavits et al., 2007; Lind et al., 2017). Despite these challenges, gender-sensitive treatment approaches have shown promise in addressing women's unique needs. Trauma-informed care, integrated mental health services, and social support networks have proven effective in improving rehabilitation outcomes for women (Liu & Mager, 2016). However, mainstream addiction treatment models remain largely male-oriented, highlighting the need for a paradigm shift toward more inclusive and responsive strategies.

This review explores the gender differences in drug addiction by analyzing neurobiological, social, and psychological perspectives. By synthesizing findings from systematic and meta-analytical research, this paper aims to provide a comprehensive understanding of how addiction manifests differently in women and men. Through this lens, the discussion emphasizes the importance of gender-responsive addiction policies and treatment frameworks that address the specific challenges faced by women. Ultimately, bridging these knowledge gaps is essential for improving addiction treatment outcomes and fostering a more equitable healthcare system for individuals struggling with substance use disorders (Degenhardt et al., 2018; Grant et al., 2017).

Methodology

2.1. Study Design

This study adopts a narrative review methodology to examine gender differences in drug addiction, focusing on neurobiological, social, and psychological perspectives in women. The review synthesizes findings from peer-reviewed articles, systematic reviews, meta-analyses, and clinical studies published in reputable journals.

2.2. Literature Search Strategy

A comprehensive literature search was conducted using electronic databases, including PubMed, Scopus, Web of Science, and PsycINFO. The search was limited to studies published in English from 2000 to 2024 to ensure inclusion of the most recent and relevant findings. Keywords and Boolean operators were used to refine the search:

Neurobiological Perspective: "gender differences AND drug addiction AND neurobiology"; "substance use disorder AND women AND brain function"

Social Perspective: "social factors AND drug addiction AND women"; "gender disparities AND substance use"

Psychological Perspective: "mental health AND substance use disorder AND women"; "psychological comorbidities AND addiction AND gender"Additional relevant articles were identified through citation tracking and reference lists of selected studies.

3. Quality Assessment

To ensure the reliability of included studies, a Modified Newcastle-Ottawa Scale (NOS) was used for observational studies, and the PRISMA guidelines were followed for systematic reviews and meta-analyses. Studies were assessed based on criteria such as sample representativeness, methodological rigor, and statistical analysis.

4. Ethical Considerations

As a review article, this study does not involve human or animal subjects, thus not requiring ethical approval. However, ethical guidelines for secondary research, including proper citation and acknowledgment of sources, were strictly followed.

5.Neurobiological Differences in Addiction Between Men and Women

Addiction is fundamentally a brain disorder, and growing research has revealed significant neurobiological differences in how men and women experience substance use and dependence. These differences are influenced by variations in brain structure, hormone activity, and neurotransmitter function, all of which contribute to the ways addiction develops and is maintained in each gender (Mann et al., 2005; Rossetti et al., 2021). Women, in particular, exhibit unique neurobiological vulnerabilities to addiction, including heightened sensitivity to drug-induced reinforcement, increased stress reactivity, and more severe withdrawal symptoms (Anker & Carroll, 2011). Understanding these mechanisms is crucial for developing gender-specific addiction treatments that acknowledge the distinct ways in which women experience substance use disorders (SUDs).

One of the most significant neurobiological distinctions between men and women in addiction is the role of the mesolimbic dopamine system, which regulates the brain's reward pathway. Dopamine release in response to addictive substances is generally more pronounced in women, leading to stronger cravings and a more rapid transition from casual use to dependence (Fattore et al., 2014). This phenomenon contributes to the "telescoping effect," where women develop substance dependence more quickly than men despite often initiating drug use later in life (Becker, Perry, & Westenbroek, 2012). Research suggests that estrogen enhances dopamine signaling, amplifying the rewarding effects of substances such as cocaine, nicotine, and opioids (Becker & Chartoff, 2019). As a result, women not only experience heightened reinforcement from drug use but may also find it more challenging to resist cravings and avoid relapse (Figure 2).

Hormonal fluctuations further contribute to addiction vulnerability in women. Estrogen and progesterone modulate neurotransmitter activity, influencing mood, stress responses, and drug-seeking behavior (Carroll & Anker, 2010). During periods of high estrogen levels, such as the follicular phase of the menstrual cycle, women exhibit increased sensitivity to stimulants like cocaine and amphetamines (Bobzean, DeNobrega, & Perrotti, 2014). Conversely, during the luteal phase, when progesterone levels rise, women may experience heightened withdrawal symptoms and increased stress responses, making abstinence more difficult (Anker & Carroll, 2011). These hormonal variations mean that women may require more personalized treatment strategies that consider menstrual cycle phases when designing intervention programs.

In addition to hormonal influences, structural differences in the brain contribute to the way addiction manifests in men and women. Imaging studies have shown that women have greater gray matter volume in brain regions associated with emotion regulation, such as the prefrontal cortex and amygdala (Goldstein et al., 2019; Demirakca et al., 2011). This structural difference may explain why women are more likely to develop addiction as a means of coping with emotional distress rather than sensation-seeking, which is more common in men (Hudson & Stamp, 2011). The prefrontal cortex, responsible for impulse control and decision-making, exhibits sex-specific activity in response to drug-related cues, with women showing greater activation and emotional reactivity to cravings (Fattore & Melis, 2016). This heightened response may make women more susceptible to relapse, especially in stressful or emotionally charged situations.

Stress-related neurobiological mechanisms also play a critical role in addiction, with women displaying a more pronounced hypothalamic-pituitary-adrenal (HPA) axis response to stress (Becker et al., 2012). The HPA axis governs the body's stress response, and its dysregulation is strongly linked to addiction risk and relapse susceptibility. Women are more likely to use drugs as a coping mechanism for stress, anxiety, and trauma, reinforcing the cycle of addiction (Mechtcheriakov et al., 2007). Furthermore, stress-induced cravings are often more intense in women, increasing the likelihood of relapse even after extended periods of sobriety (Fox et al., 2007). Given these findings, addiction treatments tailored for women must incorporate stress management techniques, such as mindfulness-based therapy and cognitive behavioral interventions, to enhance recovery success.

Another important neurobiological difference is the way in which withdrawal symptoms manifest in men and women. Women tend to experience more severe withdrawal symptoms, particularly for substances like nicotine, alcohol, and opioids (Hudson & Stamp, 2011; Sawyer et al., 2016). This is partly due to the influence of hormonal fluctuations, but also because women metabolize certain drugs differently than men. For example, women have lower levels of the enzyme alcohol dehydrogenase, which results in higher blood alcohol concentrations even when consuming the same amount as men (Greenfield, Back, & Brady, 2010). These differences necessitate gender-specific approaches to managing withdrawal, including more intensive medical supervision and pharmacological interventions tailored to women's metabolic processes.

While these neurobiological distinctions highlight the unique challenges women face in addiction and recovery, they also present opportunities for more effective treatment strategies. Research suggests that medications targeting dopamine function, such as bupropion and varenicline for smoking cessation, may be particularly effective for women due to their heightened dopamine response (Rossetti et al., 2021). Similarly, hormone-based treatments, such as progesterone supplementation, have shown promise in reducing drug cravings and withdrawal symptoms in women (Carroll & Anker, 2010). However, despite these promising findings, addiction treatment programs remain largely based on male-centric models, underscoring the need for more research and investment in gender-responsive addiction care.

The neurobiological differences in addiction between men and women stem from variations in dopamine signaling, hormonal influences, brain structure, stress responses, and withdrawal severity. Women's heightened sensitivity to drug reinforcement, coupled with their increased stress-induced cravings and more severe withdrawal symptoms, makes addiction particularly challenging to overcome. Recognizing these distinctions is crucial for designing more effective, gender-sensitive treatment interventions that cater to women's unique neurobiological needs. Future research should continue exploring sex-specific mechanisms in addiction to develop targeted therapies that improve treatment outcomes and reduce relapse rates in women.

6.Social Influences on Addiction in Women

Addiction does not occur in isolation; it is profoundly shaped by social contexts, relationships, and societal expectations. For women, social factors play a crucial role in both the development and progression of substance use disorders (SUDs). Gendered norms, stigma, family roles, economic dependence, and exposure to intimate partner violence all contribute to how addiction manifests and is treated in women. Unlike men, who often engage in substance use in social settings for recreational purposes, women are more likely to use drugs as a coping mechanism for stress, trauma, or interpersonal conflicts (Collins et al., 2019). The intersection of addiction with these social pressures makes treatment more complex for women, necessitating a more holistic and gender-sensitive approach.

One of the most significant social influences on addiction in women is societal stigma. Women with SUDs face far greater judgment and discrimination than men, particularly if they are mothers or caregivers (Covington, 2008; Earnshaw et al., 2013). Addiction in women is often framed as a moral failing rather than a medical condition, reinforcing shame and self-blame. This stigma discourages women from seeking treatment for fear of social ostracization or losing custody of their children (Van Olphen et al., 2009; EMCDDA, 2017). Research indicates that women are more likely to seek help only when their addiction reaches a crisis point, such as legal issues or severe health consequences (Grella & Greenwell, 2004). In contrast, men are more likely to engage with treatment earlier in their addiction trajectory due to less societal pressure and stigma. Addressing these biases requires structural changes, including public health campaigns that normalize addiction recovery and gender-responsive policies that protect women seeking help from punitive social consequences (Shimu et al., 2024).

Family and caregiving responsibilities also shape women's addiction experiences. Women are more likely than men to be the primary caregivers for children, elderly parents, or other family members, which adds layers of stress and limits their ability to access treatment (World Health Organization & UNODC, 2020). Many women with SUDs report that childcare obligations prevent them from attending residential rehabilitation programs, which often lack family accommodations (Grella, 2008). Furthermore, mothers with addiction issues are more likely to experience severe legal repercussions, including losing parental rights, further discouraging them from seeking professional help (Van Olphen et al., 2009). These barriers highlight the need for more family-friendly treatment options, such as outpatient programs with childcare support and residential facilities that allow mothers to bring their children.

Economic factors also contribute to gendered differences in addiction experiences. Women are more likely to experience financial instability and economic dependence on partners or family members, which can create barriers to accessing treatment and escaping environments that reinforce substance use (Najavits et al., 2007; Plaza Hernández et al., 2022). Women who rely on partners for financial support may be trapped in cycles of addiction due to fear of losing housing, economic security, or access to their children. Additionally, women are disproportionately represented in low-wage and unstable employment, limiting their ability to afford high-quality addiction treatment. Economic empowerment programs, such as vocational training and financial assistance for women in recovery, could help address these barriers and support long-term sobriety.

Intimate partner violence (IPV) is another major social factor influencing addiction in women. Studies have found a strong correlation between substance abuse and experiences of domestic violence, with many women using drugs or alcohol as a means of coping with trauma and abuse (Kilpatrick et al., 2003). Women in abusive relationships are also at greater risk of being coerced into substance use by their partners, reinforcing patterns of addiction and dependency (El-Bassel et al., 2005). Furthermore, women who seek treatment for addiction often face retaliation or threats from abusive partners, making it difficult to leave dangerous environments. This underscores the importance of integrating domestic violence services with addiction treatment, ensuring that women have access to safe housing, legal advocacy, and trauma-informed care (UNODC, 2018).

Peer and social networks further influence women's addiction trajectories. While men often initiate drug use in male-dominated peer groups, women are more likely to be introduced to substances through close relationships, including romantic partners (Bobzean et al., 2014). This difference means that women are more likely to become dependent on substances within intimate relationships, making it harder to break free from addiction without severing personal ties (Fattore & Melis, 2016). Women are also more likely than men to use drugs in private settings, which can delay intervention and limit access to social support systems (Grella,

2008). Encouraging community-based interventions that provide women with supportive, non-judgmental recovery networks is essential in addressing these social dynamics.

Cultural expectations and gender roles also shape addiction patterns in women. In many societies, women are expected to prioritize family and caregiving responsibilities over personal well-being, making it difficult for them to prioritize their recovery (Covington, 2008). Women from conservative or religious backgrounds may face additional pressure to conceal their substance use due to the fear of bringing shame to their families (Zohala, 2016). These cultural barriers necessitate more culturally sensitive treatment approaches that acknowledge the unique challenges faced by women from different backgrounds.

The social influences on women's addiction are deeply interconnected, creating a complex web of barriers to recovery. Unlike men, whose addiction experiences are often shaped by peer dynamics and sensation-seeking behaviors, women's substance use is more frequently linked to trauma, caregiving responsibilities, economic dependence, and intimate relationships (Fonseca et al., 2021). Addressing these issues requires a multi-faceted approach that goes beyond conventional addiction treatment models. Gender-responsive interventions must integrate childcare support, economic empowerment, trauma-informed care, and domestic violence resources to effectively meet the needs of women with SUDs.

Furthermore, shifting societal perceptions of addiction in women is essential for reducing stigma and encouraging more women to seek help. Public awareness campaigns should emphasize addiction as a medical condition rather than a moral failing, and policies must be restructured to provide legal protections for mothers seeking treatment. Without these structural changes, women will continue to face disproportionate barriers in accessing care and achieving long-term recovery (Afifi et al., 2010).

Addiction in women is not merely a biological phenomenon but is profoundly shaped by social influences. Stigma, family responsibilities, economic challenges, intimate partner violence, and cultural expectations all contribute to the ways in which women experience and recover from addiction. Recognizing and addressing these factors through gender-sensitive treatment models is crucial in improving addiction outcomes for women (Allen et al., 2010). Future research should focus on developing and evaluating social interventions that support women in overcoming substance use disorders while addressing the unique challenges they face in society (Andersen & Teicher, 2000).

7.Psychological Factors in Women's Addiction

Addiction in women is not only influenced by biological and social factors but also deeply rooted in psychological mechanisms. Women's mental health, coping strategies, past trauma, and emotional regulation all play critical roles in the development, maintenance, and treatment of substance use disorders (SUDs). Compared to men, women are more likely to experience co-occurring mental health disorders, use substances as a means of self-medication, and struggle with emotional dysregulation (Polak et al., 2015). Understanding these psychological dimensions is crucial for designing effective, gender-specific addiction interventions that address the root causes of substance dependence.

One of the most significant psychological factors contributing to addiction in women is the high prevalence of co-occurring mental health disorders. Studies indicate that women with SUDs are significantly more likely than men to have comorbid anxiety, depression, post-traumatic stress disorder (PTSD), and eating disorders (Cohen & Hien, 2006). These conditions not only increase the risk of substance abuse but also complicate the recovery process. Women with depression, for instance, may turn to alcohol or sedatives to alleviate symptoms of sadness, loneliness, or worthlessness, reinforcing a cycle of dependence. Similarly, those with PTSD, particularly survivors of sexual or physical abuse, may use drugs to numb distressing memories and emotions. This underscores the importance of integrated treatment programs that simultaneously address addiction and underlying psychological conditions rather than treating them in isolation.

Another major psychological factor in women's addiction is the tendency to use substances as a maladaptive coping mechanism. Women are more likely than men to use drugs or alcohol as a way to manage stress, emotional pain, or interpersonal difficulties (Najavits et al., 2007). Unlike men, who often engage in substance use for thrill-seeking or social bonding, women typically turn to substances as a means of self-soothing (Grella & Greenwell, 2004). This is particularly true for women experiencing high levels of emotional distress due to factors such as relationship conflicts, financial instability, or caregiving burdens (Covington, 2008). Because these stressors are often chronic, women may develop a long-term reliance on substances to regulate their emotions, increasing the risk of addiction. Addressing this issue requires therapies that teach women healthier coping mechanisms, such as cognitive-behavioral therapy (CBT) and mindfulness-based stress reduction (Molina et al., 2020).

Emotional dysregulation is another psychological vulnerability that contributes to addiction in women. Research suggests that women with SUDs exhibit higher levels of emotional sensitivity and impulsivity compared to men, making them more susceptible to addictive behaviors (Bobzean et al., 2014). Women are also more likely to experience intense emotional fluctuations, particularly during hormonal changes such as menstruation, pregnancy, and menopause, which can exacerbate substance cravings (Fattore & Melis, 2016). Emotional dysregulation not only makes it harder for

women to resist drug use but also contributes to relapse after periods of abstinence (Weiss et al., 2010). This highlights the need for addiction treatment programs that focus on emotional regulation strategies, such as dialectical behavior therapy (DBT), which has been shown to be particularly effective for women with substance use and emotional instability.

Trauma and adverse childhood experiences (ACEs) also play a crucial role in the development of addiction in women. Research has consistently shown that women with substance use disorders have higher rates of childhood abuse, neglect, and sexual trauma compared to their male counterparts (Kilpatrick et al., 2003). Early-life trauma alters the brain's stress response system, making individuals more vulnerable to addiction as a means of coping with unresolved psychological pain (El-Bassel et al., 2005). Women who have experienced trauma are also more likely to develop attachment issues and struggle with self-worth, further increasing their susceptibility to substance dependence (Najavits et al., 2007). Given these factors, trauma-informed care is essential in addiction treatment for women.

Traditional rehabilitation programs that focus solely on detoxification and behavioral change may be ineffective if they fail to address the deep-rooted emotional wounds that drive addiction (Cohen & Hien, 2006).

Additionally, gender differences in self-esteem and body image can contribute to substance use behaviors in women. Many women with addiction histories report struggling with low self-worth, perfectionism, and a fear of failure, which may drive them to use substances as a form of escape (Meyers et al., 2022). Eating disorders, which are more prevalent in women than men, often co-occur with substance use disorders, particularly stimulant abuse. Women who use drugs like cocaine or methamphetamine may initially do so to suppress appetite and achieve weight loss, but over time, they develop dependence due to the reinforcing effects of these substances (Fattore & Melis, 2016). Addressing these issues in addiction treatment requires body-positive interventions and therapy models that build self-esteem and self-acceptance.

Shame and guilt also play a significant role in women's addiction patterns. Due to societal expectations, women often feel a heightened sense of shame about their substance use, particularly if they are mothers or caregivers (Van Olphen et al., 2009). This internalized stigma can lead to self-destructive behaviors and prevent women from seeking help. Women with addiction issues may engage in self-sabotage, believing they are unworthy of recovery, or they may isolate themselves from social support systems due to fear of judgment (Covington, 2008). To counteract these negative psychological patterns, addiction treatment programs must incorporate self-compassion practices, peer support groups, and therapy approaches that reframe addiction as a treatable condition rather than a moral failing (Molina et al., 2022).

The psychological factors influencing addiction in women are complex and multifaceted. Co-occurring mental health disorders, maladaptive coping mechanisms, emotional dysregulation, trauma histories, self-esteem issues, and internalized shame all contribute to the unique addiction patterns seen in women. Unlike men, who may use substances for social or recreational purposes, women often turn to drugs and alcohol as a means of emotional regulation and trauma coping. This highlights the importance of gender-sensitive addiction treatment programs that address these psychological factors holistically. Moving forward, research should focus on developing and implementing evidence-based therapies that cater to the unique psychological needs of women struggling with substance use disorders (Polak et al., 2015).

8.Gender-Specific Neurobiological Pathways in Addiction

Addiction is driven by complex neurobiological processes involving the brain's reward system, stress pathways, and hormonal influences. While both men and women experience addiction through similar neurological mechanisms, gender-specific differences in brain chemistry, hormonal fluctuations, and neural plasticity significantly influence how addiction manifests and progresses. Women's unique neurobiology makes them more vulnerable to rapid addiction onset, stronger drug cravings, and greater relapse risk (). Understanding these differences is critical for designing targeted treatment approaches that address the unique neurobiological vulnerabilities of women in addiction.

One of the most significant neurobiological differences in addiction between men and women is related to the dopamine system, which governs pleasure, motivation, and reinforcement. Studies show that women tend to have a more reactive dopamine system, meaning they experience greater pleasure and reinforcement from drug use compared to men (Becker, Perry, & Westenbroek, 2012). This heightened dopamine response leads to a faster progression from initial substance use to dependence, often referred to as "telescoping" (Lynch et al., 2002). For instance, women who start using cocaine, opioids, or alcohol tend to develop addiction at a much faster rate than men, even when consuming lower amounts of the substance (Bobzean, DeNobrega, & Perrotti, 2014). The enhanced dopaminergic sensitivity in women may explain why they report more intense cravings and a stronger desire to continue using despite negative consequences.

Beyond dopamine, sex hormones such as estrogen and progesterone play a critical role in addiction vulnerability. Estrogen has been found to amplify the rewarding effects of drugs, increasing dopamine release in the brain's reward pathway (Becker, 2016). This effect is particularly evident in premenopausal women, whose fluctuating estrogen levels can influence drug sensitivity and cravings. Research suggests that during periods of high estrogen—such as ovulation—women experience heightened drug

reinforcement and are more likely to engage in substance use (Becker & Hu, 2008). Conversely, during phases of low estrogen, such as menstruation, women may experience withdrawal symptoms more intensely, leading to an increased risk of relapse (Fattore & Melis, 2016). These hormonal fluctuations make addiction treatment more complex for women, as their cravings and withdrawal experiences can vary significantly across the menstrual cycle.

Progesterone, on the other hand, appears to have a protective effect against addiction. Studies suggest that increased progesterone levels can reduce drug cravings and blunt the euphoric effects of substances like cocaine and nicotine (Evans & Foltin, 2006). This may explain why some women find it easier to abstain from drug use during pregnancy, when progesterone levels are elevated (Mendrek & Mancini-Marïe, 2016). However, after childbirth, a sharp decline in progesterone can lead to increased vulnerability to relapse, especially in women with a history of substance use disorder The role of progesterone in addiction highlights the importance of considering hormonal fluctuations in developing gender-sensitive treatment interventions.Another key neurobiological difference in addiction between men and women involves stress and the hypothalamic-pituitary-adrenal (HPA) axis. Women have a more reactive HPA axis, which regulates stress response and cortisol release (Weiss et al., 2010). This heightened stress sensitivity makes women more likely to engage in substance use as a means of coping with emotional distress (Fox & Sinha, 2009). Research shows that stress-related drug cravings are more pronounced in women than in men, increasing their risk of relapse even after long periods of abstinence (Sinha, 2008). Moreover, childhood trauma and early-life adversity, which are more common among women with addiction, can dysregulate the HPA axis and further increase substance use vulnerability (El-Bassel et al., 2005). These findings suggest that stress-reduction strategies, such as mindfulness-based relapse prevention and trauma-informed care, should be integral components of addiction treatment for women.

In addition to stress regulation, brain connectivity and neural plasticity differ between men and women, affecting addiction-related behaviors. Neuroimaging studies suggest that women have stronger functional connectivity between the prefrontal cortex and limbic system, which governs emotion and impulse control (Goldstein et al., 2012). While this connectivity may help women resist drug use under normal circumstances, prolonged substance abuse weakens prefrontal control, making it harder for women to regulate their cravings once addiction has developed (Li et al., 2015). This loss of control may explain why women who relapse often return to heavy substance use more quickly than men (Lynch et al., 2002). Treatments that focus on strengthening cognitive control, such as cognitive-behavioral therapy (CBT) and neurofeedback training, could help women regain self-regulation over their addictive behaviors.Opioid addiction, in particular, highlights the gender-specific neurobiological pathways involved in substance dependence. Women who use opioids are more likely than men to develop chronic pain conditions, which increases their risk of prescription opioid misuse (Nielsen et al., 2011). Additionally, research suggests that women experience greater opioid-induced analgesia due to differences in the brain's mu-opioid receptor system This heightened sensitivity to opioids can lead to faster addiction development and more severe withdrawal symptoms in women compared to men. Furthermore, women metabolize opioids differently, often requiring lower doses for the same pain relief but experiencing more intense withdrawal symptoms when they stop using (Roe et al., 2018). These findings underscore the need for gender-specific opioid treatment programs that consider both pain management and withdrawal mitigation strategies.

Nicotine addiction also demonstrates gender-related neurobiological differences. While men are more likely to smoke for the reinforcing effects of nicotine, women tend to smoke for mood regulation and stress relief (Perkins, 2001). This distinction is reflected in brain imaging studies showing that women's nicotine addiction is more influenced by emotional and sensory cues rather than pure nicotine reinforcement (Cosgrove et al., 2014). As a result, nicotine replacement therapies, such as patches or gum, may be less effective for women compared to behavioral interventions that address stress and emotional triggers. Understanding these gender differences is essential for developing more effective smoking cessation programs tailored to women's specific needs.Neurobiological differences play a critical role in shaping addiction in women, from heightened dopamine sensitivity and hormonal influences to stress regulation and neural connectivity. These distinctions explain why women often progress more rapidly into addiction, experience stronger cravings, and face greater challenges in relapse prevention compared to men. Recognizing these factors is essential for developing personalized treatment strategies that align with the unique neurobiological vulnerabilities of women. Future research should focus on integrating hormone-based therapies, stress-reduction techniques, and neuroplasticity-enhancing treatments to improve addiction outcomes for women.

9.Gender-Sensitive Treatment Approaches for Addiction Recovery

Gender-sensitive addiction treatment acknowledges the biological, psychological, and social differences in substance use disorders between men and women. Traditional treatment models were largely designed based on male populations, but research has demonstrated the necessity of approaches tailored to women's unique experiences (Arostegui Santamaría & Martinez-Redondo, 2018). Women face distinct challenges in addiction recovery,

including heightened cravings, a faster progression to dependence, greater trauma exposure, and higher relapse rates due to stress and emotional triggers (Lotzin et al., 2019). To enhance recovery outcomes, treatment programs must integrate gender-specific strategies that address hormonal fluctuations, trauma histories, family responsibilities, and social stigma.

One of the most critical aspects of gender-sensitive treatment is recognizing how hormonal changes influence addiction and recovery. As discussed earlier, fluctuations in estrogen and progesterone can affect cravings, withdrawal symptoms, and relapse risk (Benoit & Jauffret-Roustide, 2016). Personalized treatment plans should consider these hormonal variations. For example, research suggests that during high-estrogen phases, women may respond better to behavioral interventions, while low-estrogen phases may necessitate additional pharmacological support. Future advancements in addiction medicine could explore hormone-based therapies to mitigate withdrawal symptoms and prevent relapse (Molina-Fernández, 2023).

Pharmacotherapy remains an essential component of addiction treatment, but gender differences in drug metabolism, pain sensitivity, and withdrawal severity require tailored medication approaches (Bobes et al., 2007). For instance, opioid replacement therapies like methadone and buprenorphine have been effective for both men and women, but women may require lower doses due to differences in opioid receptor sensitivity. Additionally, research indicates that nicotine replacement therapies, such as nicotine patches, are less effective for women compared to men due to their stronger dependence on sensory and emotional triggers rather than pure nicotine reinforcement (Cosgrove et al., 2014). Gender-specific pharmacotherapy must account for these physiological distinctions to improve treatment efficacy.

Beyond medical interventions, behavioral therapies must also be adapted to address women's unique psychological and social experiences with addiction. Cognitive-behavioral therapy (CBT) is widely used in addiction treatment, but women may benefit more from emotion-focused variations of CBT that emphasize coping with stress, trauma, and interpersonal conflicts (Najavits et al., 1998). Dialectical behavior therapy (DBT) is another effective approach for women, particularly those with co-occurring borderline personality disorder or a history of self-harm. DBT teaches distress tolerance, emotion regulation, and interpersonal effectiveness, which can help women navigate addiction recovery while managing emotional challenges (Linehan et al., 1999).

Trauma-informed care is essential for women's addiction treatment, as many women with substance use disorders have experienced physical, emotional, or sexual abuse (El-Bassel et al., 2005). Trauma histories can contribute to substance use as a coping mechanism, making traditional confrontational treatment models counterproductive for women (Covington, 2008). Instead, trauma-informed approaches prioritize safety, empowerment, and emotional healing (Council of Europe, 2011). Programs such as Seeking Safety, which integrate trauma treatment with addiction recovery, have shown promising results for women with post-traumatic stress disorder (PTSD) and substance use disorders (Najavits et al., 2002).

Social support networks play a significant role in addiction recovery, and women often face unique challenges related to caregiving responsibilities and stigma. Many women with substance use disorders are mothers, and concerns about losing custody of their children can deter them from seeking treatment (Jessup et al., 2003). Gender-sensitive treatment programs must provide family-friendly options, such as residential facilities that allow mothers to stay with their children or offer childcare services during outpatient sessions (Folch et al., 2020). Programs that integrate parenting support and skills training can also help women rebuild their lives while maintaining their roles as caregivers (Grella, 2008).

Peer support groups tailored for women can enhance long-term recovery by fostering a sense of belonging and shared experience. While traditional 12-step programs like Alcoholics Anonymous (AA) and Narcotics Anonymous (NA) can be beneficial, women often prefer women-only support groups where they can openly discuss gender-specific challenges without fear of judgment or harassment (Kaskutas, 1994). Women-for-Sobriety (WFS) is one such program that emphasizes emotional and spiritual healing while addressing the unique recovery needs of women (Kirkpatrick, 1986). Expanding access to gender-specific support networks can improve treatment retention and relapse prevention (Altell, 2011).

Another crucial component of gender-sensitive treatment is addressing the economic and structural barriers that prevent women from accessing care. Women with substance use disorders are more likely than men to experience financial instability, housing insecurity, and a lack of transportation (Greenfield et al., 2007). Integrating addiction treatment with social services, such as housing assistance, job training, and financial counseling, can help women achieve long-term recovery by addressing the socioeconomic factors that contribute to substance use (Martínez-Redondo & Arostegui Santamaría, 2021).

Relapse prevention strategies for women must also consider the role of stress and emotional regulation in addiction recovery. Since women are more likely than men to relapse due to stress and negative emotions rather than environmental cues (Sinha, 2008), stress-management techniques should be incorporated into treatment programs. Mindfulness-based relapse prevention (MBRP), which combines mindfulness meditation with cognitive-behavioral strategies, has been shown to reduce stress-induced cravings and improve emotional resilience in women with

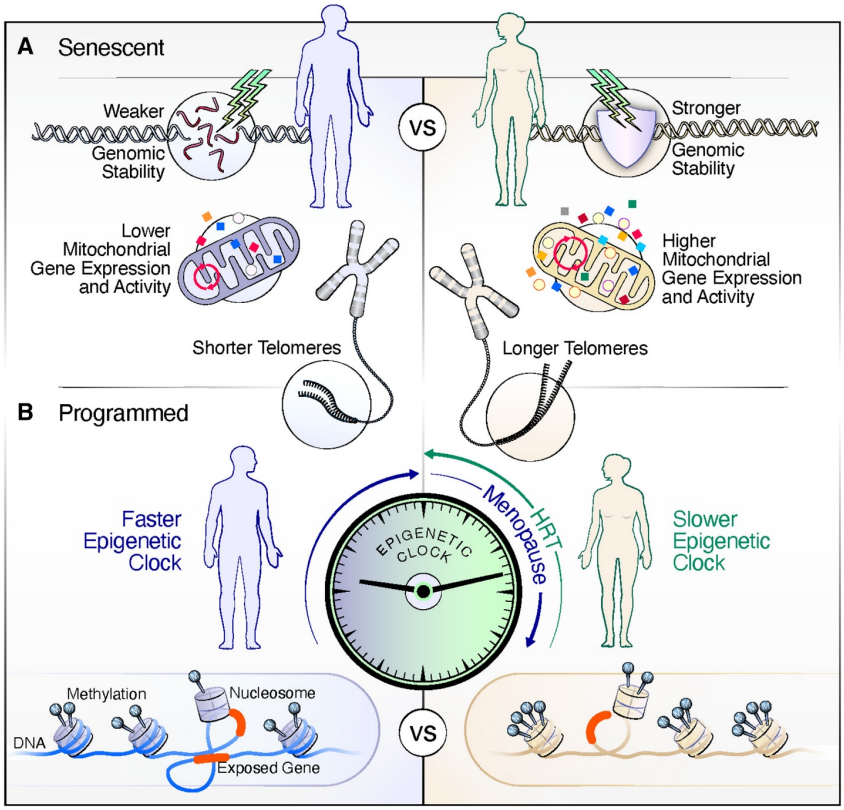

Figure 1. Sex and Gender Differences in Neurodegenerative Diseases. (A) Senescent aging results from accumulated cellular damage. Higher estrogen levels in women protect against genomic instability, enhancing mitochondrial gene expression and activity. (B) Programmed aging follows a genetically and epigenetically regulated process. Sex-specific differences in DNA methylation influence aging, with men showing a higher "epigenetic age." Menopause accelerates epigenetic aging in women, though HRT may slow this effect. Telomere shortening limits cell divisions, serving as a biological clock in both aging theories. (Lopez-Lee, Chloe et al., 2024).

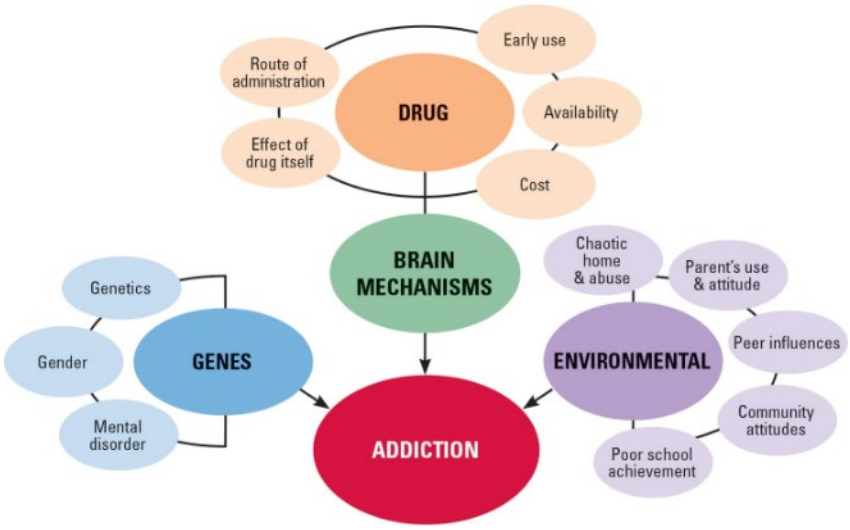

Figure 2. Factor influencing the addiction. Drug of abuse testing and therapeutic drug monitoring. Courtesy of image from Medical Laboratory Observer accessed at https://www.mlo-online.com/diagnostics/article/21287259/drug-of-abuse-testing-and-therapeutic-drug-monitoring)

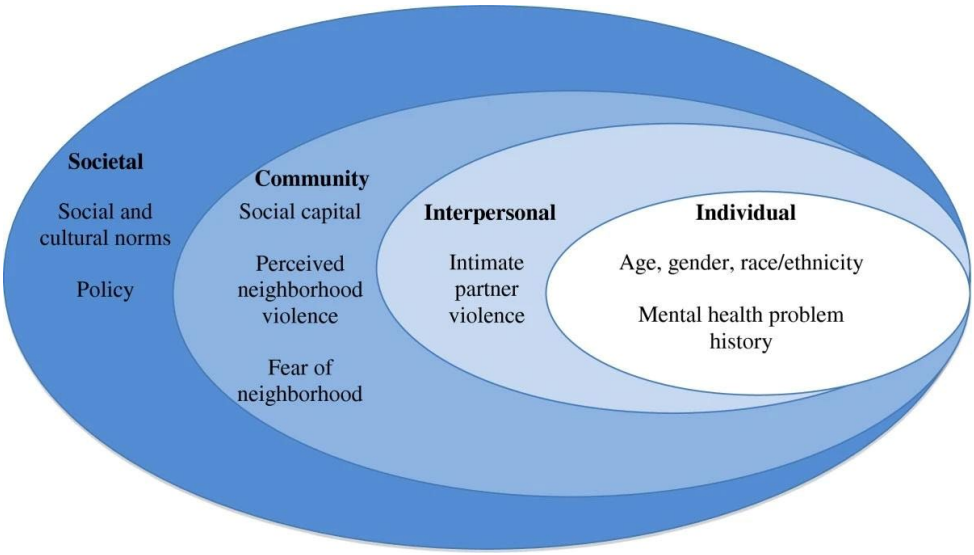

Figure 3. Drug addiction effects from individual level to societal level. (Dembo et al., 1986).

Table 1. Neurobiological Differences in Drug Addiction Between Genders

Aspect	Women	Men	References
Dopaminergic response	Faster dopamine release and higher sensitivity to drug rewards	Slower dopamine response often requiring higher dose for the same effect	Fattore & Melis, 2016
Hormonal influence	Estrogen and progesterone enhance drug cravings and relapse risk.	Testosterone influences impulsivity and risk taking behaviour	Fattore & Melis, 2016; Folch et al., 2020
Metabolism and drug processing	Metabolize drugs differently often leading to prolonged effects	Faster drug metabolism often requiring higher doses.	Grant et al., 2017
Brain structure	Greater change in the prefrontal cortex and limbic system increasing emotional involvement in addiction	More significant structural changes in reward related pathways.	Goldstein et al., 2019; Demirakca et al., 2011
Stress response	Higher stress induced cravings due to cortisol fluctuations	Less stress related craving but higher impulsivity driven relapse.	Degenhardt et al., 2018

Table 2. Social And Psychological Differences In Drug Addiction Between Genders

Factor	Women	Men	References
Stigma	Face greater societal stigma which can hinder seeking treatment	Less stigma,more likely to receive social support for addiction	Volkow & McLellan, 2016
Family and caregiving role	More likely to be primary caregivers,creating barriers to seeking treatment	Less likely to face caregiving responsibility that impact treatment access	Zilberman et al., 2003
Trauma and abuse	Higher likelihood of addiction due to trauma	Addiction often linked to peer pressure and risk taking behaviour	Andersen & Teicher, 2000
Mental health comorbidities	More likely to suffer from anxiety,depression and PTSD alongside addiction	Higher rates of antisocial personality disorder and aggression.	Allen et al., 2010
Treatment seeking behaviour	more likely to seek treatment but face barriers	Less likely to seek treatment but benefit more from traditional rehab programmes	Afifi et al., 2010

substance use disorders (Bowen et al., 2009). Other holistic approaches, such as yoga, art therapy, and equine therapy, may also enhance recovery by providing alternative coping mechanisms that promote emotional well-being (Molina Fernández et al., 2021).

Finally, policy changes are necessary to promote gender-sensitive addiction treatment at a systemic level. Many addiction treatment centers still operate under male-centered models, and funding for women-specific programs remains limited (Council of Europe, 2011). Increased investment in women-focused treatment facilities, research on gender differences in addiction, and public awareness campaigns can help create a more inclusive and effective approach to substance use disorder treatment (Sultana et al., 2023). Policymakers should also work to reduce legal and institutional barriers that discourage women from seeking help, such as punitive policies that criminalize substance use during pregnancy (Terplan et al., 2018).

7. Conclusion

Gender differences in drug addiction necessitate tailored interventions that address the distinct neurobiological, psychological, and social factors affecting women. Women progress more rapidly to dependence, experience stronger cravings, and face higher relapse rates due to hormonal fluctuations, brain structure differences, and sociocultural pressures. Ignoring these distinctions can lead to ineffective treatment approaches.

Neurobiologically, estrogen and progesterone influence addiction vulnerability and relapse patterns, underscoring the need for gender-specific pharmacological and behavioral therapies. Adjusting opioid and nicotine replacement therapies while incorporating emotion-focused cognitive-behavioral therapy, dialectical behavior therapy, and trauma-informed care can significantly enhance treatment outcomes for women.Socially, stigma, caregiving responsibilities, and financial constraints often prevent women from seeking help. Developing gender-sensitive programs that offer childcare, housing assistance, and financial support can improve accessibility and encourage recovery. Additionally, female-centered peer support and therapy models can foster resilience and empowerment.

To advance addiction treatment for women, policymakers and healthcare professionals must prioritize gender-responsive research, funding, and systemic reforms. A holistic, inclusive approach that integrates biological, psychological, and social perspectives will not only improve recovery outcomes but also contribute to broader public health advancements in substance use disorder treatment.

Author contributions

S.J.S. conceptualized the study, designed the methodology, and wrote the initial draft. S.I. contributed to data collection, analysis, and manuscript revision. Both authors reviewed and approved the final version of the manuscript.

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Competing financial interests

The authors have no conflict of interest.

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