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"Understanding Suicidal Ideation Among Jail Inmates: A Genetic and Environmental Framework"

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Abstract
Suicidal ideation, thoughts about suicide, is a significant public health challenge leading to suicidal deaths in Jail inmates. Different contributors including genes, life adversities, psychopathologies and the easy access of the methods of suicide are the causes of it during incarceration. Conditions like depression, anxiety, and personality disorders consistently elevate the risk of suicide ideation and antisocial delinquencies in jail inmates. Key neurotransmitters involved in mood, such as serotonin, noradrenaline, and dopamine, play a significant role in the contemplation of suicide. This paper explores the genetic factors like polymorphisms in serotonin related genes (SLC6A4), dopamine related genes (SLC6A3), and brain-derived neurotrophic factors(BDNF) which interact with environmental stressors (substance abuse, trauma, social isolation, exposure to violence) in jail environments. It causes impulsive behavior and emotional dysregulation, which induce the development of suicidal behavior. A structured approach has been explained in this paper to understand the gene-environment interaction contributing to suicidal ideation, with the aim of development of specialized screening tools and intervention strategies for jail population. This multifactorial issue requires extensive research and targeted mental health initiatives to reduce suicide rates among jail inmates. Addressing this can enhance their quality of life, support rehabilitation, and promote their successful reintegration into society.
Keywords: Suicide Ideation, Dopamine, Serotonin, Gene-environment Interaction

Introduction
Suicide
Suicide is an intricate and multifaceted occurrence, involving a purposeful engagement in self-harming actions that lead to death. (Lewis *et al*., 2023). It is a difficult and devastating issue that has become a major public health concern globally. Being a major public health challenge, it incorporates mental health conditions, cultural and social factors, genetic and biological factors, ranking as the 17th primary contributor to global mortality (Williams *et al*., 2002). The World Health Organization (WHO) has considered suicide as a leading factor in worldwide mortality, with an estimation of 700,000 deaths every year. According to WHO, the actual figures of suicides are higher than the reported cases, with males being more effected (13.7 per 100,000) than females (4.6 per 100,000) (Ilic & Ilic, 2022). Like many other countries, it is also underreported in Pakistan, so there is a need to implement operative approaches to get the real data, so that this problem can be solved promptly (Shagufta *et al*., 2015). Family and twin studies centered on suicidal ideation also provide support for genetic risk factors related to suicide ideation.

Suicide ideation
Suicide ideation reflects psychological distress through thoughts of self-harm, while antisocial delinquencies involve behaviors deviating from societal norms. Recent research highlights a significant overlap between these behaviors in certain individuals, indicating the possibility of shared underlying mechanisms (Noam *et al*., 2015). The phenomenon of suicide ideation is a complex multilayered subject that spans psychology, criminology, genetics, and public health. These behavioral tendencies have drawn significant scholarly attention due to their profound societal implications and potential for harmful consequences (Patrick, 2022). The complex relationship between suicidal ideation (thoughts of self-harm or death) and delinquent behaviors (such as aggression and rule-breaking) presents a rich opportunity for interdisciplinary research and exploration (Barak, 2009).

Suicide ideation among prisoners
Suicide ideation among prisoners can be up to ten times greater than general population and depends on several factors like country, region and particular prison (Zhang *et al.,* 2010). So, implementation of effective prevention and intervention strategies like substance abuse treatment, suicide risk assessments and comprehensive mental screening is necessary for the prisoners experiencing suicidal ideation (Daniel, 2006). In Europe, one third of all custodial deaths are caused by suicide. According to

the data of United States, it is one of the major causes of deaths reported in prisoners, while it is four times higher in Australia than the general community (Pratt *et al.,* 2006).

The epidemiology of Prisoners in Pakistan is not well documented, and very limited data is available on the prison population. The word prison brief reports that as of August 2021, the prison population rate in Pakistan was 47 per 100,000 populations (Khan *et* al., 2008), which is lower than global average of 144 per 100,000 populations (Herbert *et al.,* 2012). However, Pakistani prisons face numerous challenges, including poor conditions, overcrowding, and limited access to mental and healthcare services leading to mental illness, and data is very limited. But suicide is not uncommon and in recent years several cases of suicide have been reported, in fact actual number of suicides in Pakistan is higher, as many cases go unreported (Anwar *et al.,* 2017).

Exposure to Suicidal Behavior in Jail Environment

i. **Social Isolation and Lack of Social Support:** Feeling socially isolated and experiencing loneliness are major environmental risk factors for suicide ideation. Individuals lacking meaningful social connections may encounter intensified emotional distress and a sense of hopelessness in jails, thereby elevating the probability of experiencing suicidal thoughts. The absence of support systems can exacerbate feelings of isolation in prisoners (Quadt *et al.*, 2020).

ii. **Access to Lethal Means:** Convenient availability of lethal methods, like firearms and medications, drugs, substantially amplifies the risk of suicidal ideation culminating in lethal attempts in prisoners. Limiting access to these means can serve as a preventive measure, potentially saving lives in moments of crisis. Restricting access to these means can act as a preventive measure in jails (Bunney *et al.*, 2002).

iii. **Presence of Suicide Clusters:** Suicide clusters in specific communities or social groups can be a powerful environmental risk factor in prisoners. The imitation of suicidal behaviors within these clusters can lead to a contagious effect, resulting in an increase in suicide ideation among vulnerable individuals (Cheng *et al.*, 2014).

iv. **Stigma Surrounding Mental Health:** Stigmatization of mental health issues and discussions about suicide can discourage individuals from seeking help and support. Social stigma may cause jail inmates to internalize their struggles and avoid reaching out for assistance, exacerbating feelings of isolation and hopelessness (Grady *et al.*,2019).

Factors Contributing to Suicide Ideation among Prisoners

Suicide ideation can be due to the response of social behaviors like violence, abuse and mental illness. External deadly events affect the identities and memories, so, it is concluded that such traumatic experiences can lead to the psychological states which results in desire for suicide and death (JJ Mann, 2003). In some cases, these mental health problems are genetically inherited, and in many cases, these are due to disturbing experiences, caused by sexual, domestic, emotional and physical abuse. Suicidal ideation is a social behavior that is induced by external forces. Once, they are effected enough they become into mental health concerns leading to suicide. (Mehdi & Raouf, 2021).

Risk Factors

In contrast to various medical conditions that rely on specific diagnostic tests, suicidal ideation is identified based on the persistence and regularity of the symptoms mentioned earlier. The prevalence of suicide ideation involves the following risk factors.

1- Biological Aspects: These encompass hormonal and neurobiological systems, which include the functioning of neurotransmitters. Neurons release neurotransmitters, which are chemical messengers that transmit nerve signals by stimulating neighboring neurons and muscle cells. Key neurotransmitters involved in mood, such as serotonin, noradrenaline, and dopamine, play a significant role in the contemplation of suicide (Liu *et al.*, 2018)

i. Serotonin: It is a neurotransmitter that influences mood, emotions, and behavior. Dysregulation of the serotonin system has long been implicated in depression and other mood disorders, which are often connected with suicide ideation. Low levels of serotonin are associated with feelings of hopelessness, sadness, and impulsivity – factors that contribute to the development of suicidal thoughts. Serotonin also regulates the brain's stress response, and disruptions in this regulation may contribute to increased vulnerability to suicide ideation during times of distress (Lotrich *et al.*, 2001).

ii. Dopamine: It is a neurotransmitter that plays a crucial role in regulating mood, reward, motivation, and pleasure. Imbalances in the dopamine pathway have been associated with mood disorders and suicidal behavior. Research suggests that altered dopamine receptor sensitivity and dysfunction in dopaminergic circuits may contribute to a person's vulnerability to suicide ideation. High levels of dopamine activity in certain brain regions have been linked to impulsivity and aggression, both of which are risk factors for suicidal thoughts and behaviors. Imbalances in the dopamine pathway may contribute to the emotional dysregulation observed in individuals with suicide ideation. (Salatino-Oliveira *et al.*, 2018).

iii. Dopamine and serotonin: These pathways are not isolated systems; they interact with each other and with other neurochemical pathways in complex ways. Altered functioning in either or both pathways can disrupt the delicate balance that maintains mental well-being. Dysregulation of these neurotransmitter systems may contribute to cognitive distortions, emotional instability, and impulsive behaviors that are often seen in individuals with suicide ideation. These pathways play significant roles in shaping the neurobiological foundation of suicide ideation. While imbalances in these pathways have been associated with increased vulnerability to suicidal thoughts, they are part of a larger puzzle that encompasses diverse factors. Ongoing research in this area contributes to the understanding of the intricate mechanisms underlying suicide ideation, offering potential insights into the development of effective prevention and intervention strategies. (Manuck *et al.*, 2004).

2. Psychological Risk Factors in Jail Inmates

i. Mental Health Disorders: Conditions like depression, anxiety, and personality disorders consistently elevate the risk of suicide ideation and antisocial delinquencies. The interplay of distorted cognition, negative affect, and impaired coping mechanisms may heighten vulnerability to these behaviors (Siever, 2008).

ii. Impulsivity and Emotional Dysregulation: Heightened impulsivity and emotional dysregulation are contributing factors to both suicide ideation and antisocial behaviors. Difficulties in managing emotions and controlling impulsive reactions may drive individuals towards maladaptive coping strategies (Okado & Bierman, 2015).

iii. Feelings of Hopelessness and Desperation: A sense of hopelessness combined with a lack of perceived alternatives can fuel both suicide ideation and engagement in antisocial activities. The perception that life lack's purpose or positive prospects may increase the inclination towards these behaviors (VandeWalle, 2003).

iv. Mood disorders: Such as depression, bipolar disorder, anxiety disorders stand out as notable risk factors for suicidal ideation. These conditions often lead to emotional distress, hopelessness, and feelings of isolation (Dillon *et al.*, 2018).

v. History of Trauma and Adverse Childhood Experiences (ACEs): Encountering traumatic incidents or adverse experiences during childhood, such as abuse or exposure to violence, could raise the chances of developing thoughts of suicide because of lingering emotional wounds and unresolved trauma (Brockie *et al.*, 2015).

vi. Early Behavioral Problems: Early behavioral problems, like oppositional and aggressive behavior, can predict the onset of antisocial delinquencies later in life. Failure to address these behaviors in childhood can exacerbate the risk (Wasserman, 2003).

3. Environmental Factors

Environmental factors emerge as the most influential contenders in the genesis of suicidal thoughts among prisoners. The precise mechanism through which environmental factors contribute to the emergence of these thoughts is currently being investigated. Certain studies suggest that these factors may disrupt the typical functioning of the nervous system, thereby fostering the emergence of thoughts of suicide (Brummett *et al.*, 2008). Predominant among these environmental factors are age, gender, absence of positive environments, stress resulting from chronic illnesses, socioeconomic disadvantages, and acute life events such as violence or prolonged neglect, and substance misuse. When combined with genetic influences and individual vulnerabilities, these environmental factors present themselves as the most promising risk factors in the development of suicidal ideation (Mirkovic *et al.*, 2016).

Within the scope of risk evaluation and preventive strategies, the environment assumes a central role in influencing individuals' susceptibility to unfavorable outcomes. These external circumstances notably influence diverse facets of human conduct, encompassing mental well-being, delinquent conduct, and the likelihood of experiencing suicidal ideation (Zastrow *et al.*, 2019). Dysfunctional family interactions, marked by inadequate communication, conflicts, and insufficient emotional support, can substantially heighten individuals' proneness to suicidal ideation and delinquent conduct. The absence of a nurturing family environment might contribute to isolation and the adoption of maladaptive coping mechanisms (Liebling, 2012).

The absence of positive peer interactions may lead to feelings of loneliness and the embrace of deviant coping strategies. Succumbing to negative peer norms and pressures can sway individuals towards suicidal ideation and delinquency. The need for belonging and the fear of exclusion might prompt individuals to adopt behaviors that align with the group, even if they are maladaptive (Roebuck, 2014).

Widespread challenges in academics, combined with the pressure of academic performance, have been linked to an increased likelihood of experiencing suicidal ideation and engaging in delinquent behaviors. Persistent academic challenges may lead to lowered self-esteem and feelings of hopelessness (Tam et al., 2007).

Encountering bullying and victimization within the school environment can contribute to the emergence of both suicidal ideation and antisocial behaviors. The emotional toll of bullying can worsen existing vulnerabilities and lead to the adoption of maladaptive coping mechanisms (Troop-Gorden, 2017).

4- Genetic Elements

Suicidal thoughts have a hereditary component, although the precise mechanisms and specific genes contributing to the prevalence of these thoughts remain unclear. Numerous studies have verified that, in addition to hormones and neurotransmitters as vulnerable factors for suicidal ideation, several genes—acting independently or exerting their influence through linked interactions—are substantial risk factors for the prevalence of suicidal thoughts (Mirkovic *et al.*, 2006). Family and twin studies centered on suicidal ideation also provide support for genetic risk factors related to such ideation. It is also important to note that everyone might possess distinct sets of genetic factors that impact their mental well-being and behavior, potentially leading to a diagnosis of suicidal ideation. (Hankin *et al.*, 2015).

Genetic Susceptibility and Behavioral Outcomes among Prisoners

The present understanding of suicide is that subjects with a genetic predisposition are particularly vulnerable to stressful environmental inputs. The biological basis of suicide has been investigated in several studies to better understand its precipitating factors (Orsolini *et al.*, 2020). There have been several biological hypotheses. Recent studies have explored the genetic impact on suicidal behavior through Genome-wide association studies (Tam *et al.*, 2019). However, many GWAS suggested associations that did not reach genome-wide significance, pointing out that there are multiple genomic targets that need further investigations in suicidal behavior. A recent study identified by several genes involved in neural functions such as neurodevelopment (cellular assembly, function, and organization), cell death, survival mechanisms, and immunological/inflammatory mechanisms has been found to link with genetic predisposition and suicide ideation. The use of GWAS has been limited to the investigation of common genetic variants. The associations of early life adversities (ELAs) and

suicide have suggested interaction with genetic liability leading to the stress diathesis model of suicide. Studies on functional genomics have consistently identified brain regions involved in psychiatric disorders and suicide ideation including hippocampus, amygdala, anterior cingulate cortex and the prefrontal cortex (Schmaal *et* al., 2010).

In the synthesis of 5-Hydroxytryptamine (5-HT), a specific enzyme called Tryptophan hydroxylase-2 (TPH2) is the sole participant (Tara & Christian, 2020). The TPH genes have been identified as potential candidates linked to suicidal behavior (López-Narváez *et al.*, 2015). Disrupted enzymatic activity due to gene polymorphism of TPH2 within the brain leads to variations in serotonin (5HT) levels, which in turn influences the release of dopamine in brain tissues. Polymorphisms in TPH occur at multiple sites, including "rs4570625, rs7305115, rs1799913, and rs1800532" (Laksono *et al.*, 2019), and these have a significant correlation with neuropsychiatric disorders like aggression, ADHD, and suicidal behavior have been linked to these conditions (Sheehan *et al.*, 2005; Tao *et al.*, 2018). Notably, the TPH2 SNP rs7305115, which features A/G allele polymorphism, is significantly associated with psychological difficulties, especially suicidal ideation, and behaviors, in individuals diagnosed with major depressive disorder (MDD) (Zhang *et al.*, 2010).

In the development of suicide ideation, numerous genes have been found to have a significant effect. Many genes regulate neurotransmitters like serotonin and dopamine, and these are also found to be related to stress and inflammation (Mariani *et* al., 2021). It's important to highlight that although genetic factors contribute to suicidal thoughts, they are not the sole determining factor (Smith *et al.*, 2012). The interplay between genetic and environmental influences is often intricate. It is vital to recognize that seeking assistance and finding support are critical steps in mitigating the risk of suicide and enhancing mental well-being, irrespective of any genetic predisposition (Hofer & Savell, 2021).

Advancements in genetic research have led to the identification of specific polymorphisms and gene variations associated with neurotransmitter systems, neural pathways, and behavioral traits pertinent to suicide ideation. An illustrative example is the serotonin transporter gene (5HTT), a key player in serotonin regulation (Suchankova Karlsson, 2010). Certain allelic variations in the 5HTT gene have been linked to modified serotonin transport and availability, potentially influencing mood regulation, impulsivity, and aggression – all pivotal factors in both suicide ideation (Lotrich *et al.*, 2001).

Furthermore, the dopaminergic system, renowned for its role in reward processing, motivation, and reinforcement, has garnered significant attention in the investigation of these behaviors. Variants in genes encoding constituents of the dopamine pathway, encompassing dopamine receptors and transporters, have been associated with heightened impulsivity, sensation-seeking, and aggression – traits that could contribute to suicide ideation (Archer *et al.*, 2012).

According to research findings, certain genetic variations in the SLC6A4 and SLC6A3 genes, responsible for regulating serotonin and dopamine transporters, may be associated with an elevated susceptibility to suicidal thoughts. In the case of higher risk of aggression and suicide specific variants of SLC6A4 gene have been seen to have a link with the decrease of serotonin reuptake. Additionally, the medications having the levels of serotonin and dopamine are found to have an impact on suicide ideation (Murphy *et al.*, 2008). In relation to suicidal thoughts, the efficacy of selective serotonin reuptake inhibitors (SSRIs) is found to reduce the risk of suicide in specific populations, which underscores the importance of serotonin regulation (Kenna *et al.*, 2012). Nonetheless, it is crucial to acknowledge that an increased risk of suicide ideation is contributed by neurotransmitter regulation of transporter genes. Suicide ideation typically involves an intricate interplay of genetic and environmental factors. Seeking appropriate treatment and support is paramount in significantly reducing the risk of suicide.

The genes encoding the components of neurotransmitter systems, like the serotonergic and dopaminergic pathways are of particular interest (Murphy *et al.*, 2013). So, the individual's predisposition to suicide ideation and antisocial behaviors are affected by the variations in the genes that have been implicated in altering neurotransmitter levels and receptor functioning. (5HTT), the serotonin transporter gene has been found to be linked with both suicide risk and aggression, emphasizing its role in the interplay between these behavioral tendencies (Devor *et al.*, 2017). Investigations have identified specific genetic variations, known as polymorphisms, in genes related to the serotonin and dopamine neurotransmitter systems that may be associated with suicide ideation (Clayden *et al.*, 2012).

5- Gene-Environment Interactions

With the advancement of genetics, the exploration of gene-environment interactions becomes increasingly significant. Gene-environment interplay encompasses the intricate relationship between genetic predispositions and environmental elements, working together to influence the development of distinct behaviors. The core objective of this research is to comprehend the interaction between genetic components and environmental factors, molding the course of suicidal thoughts and antisocial delinquency (Miller *et al.*, 2022). Recent studies in epigenetic research have underscored the impact of early-life adversity on shaping epigenetic patterns that may contribute to subsequent psychopathological conditions. Adverse childhood experiences, like maltreatment or trauma, can imprint enduring epigenetic signatures on genes implicated in stress response, emotional regulation, and impulsivity. This imprinting process could serve as a molecular conduit linking genetic predispositions to the emergence of suicide ideation and antisocial behaviors (Mill & Petronis, 2007). So according to Diathesis-Stress model suicidal ideation in Jail inmates arises from the interaction between environmental stressors and predisposition vulnerability. Various personality traits of prisoners, in conjunction with genetic and environmental influences, can contribute to the emergence of suicidal thoughts. Among these traits, a primary one is having low self-esteem and self-criticism, coupled with an overwhelming response to unfavorable situations, anxiety, pessimism, fragile social connections, excessive rumination, and disrupted cognitive functioning. It's essential to recognize that the risk factors associated with suicidal ideation, whether stemming from personal susceptibilities, environmental circumstances, or biological factors, aren't fixed throughout an individual's life. Instead, they can transform with experiences and different life phases (Butler, 2018), potentially impacting the psychological processes and serotonin (5-HT) neurotransmitter function. When 5-HT function and processing deviate from the norm, it can disrupt the equilibrium of dopamine levels in synaptic gaps and presynaptic neurons. This disruption has been associated with

the development of various psychological disorders, such as aggression, major depressive disorder, anxiety, and suicidal tendencies (Zhang, 2010).

6-Epigenetics and Behavioral Outcomes among Prisoners

The emerging realm of epigenetics provides a nuanced lens through which to view the interplay between genetic factors and behavioral outcomes is possible among prisoners. Genetic predisposition and environmental stimuli have influence on epigenetic modifications, which pertains to modifications in gene expression that occur without making changes in DNA sequence. Epigenetic markers, including DNA methylation and histone modifications, can act as intermediaries, illustrating how genetic susceptibilities interact with life experiences to mold an individual's vulnerability to suicide ideation (Ludwig & Dwivedi, 2006).

7- Neurological Basis of Suicide among Prisoners

Studying postmortem brain tissue from individuals who died by suicide, along with conducting imaging studies on those who survived suicide attempts, has identified a correlation between these brain regions and observed changes in both their functional and structural characteristics. According to the neurological basis of suicide, neurotransmitter systems within the brain regions are also involved in suicidality (Roy *et al*., 2017). Considering it from a neurochemical perspective, the serotonin neurotransmitter system and the hypothalamic-pituitary-adrenal (HPA) axis are thought to have a crucial involvement in this scenario (Whiteman *et al*, 2019).

In addition to genes directly related to neurotransmission, variations in genes associated with neural plasticity, emotion regulation, and stress response may also contribute to the link between suicide ideations. Epigenetic mechanisms, which modulate gene expression in response to environmental factors, further contribute to the intricacy of this interplay, potentially mediating the effects of early-life experiences (Maccari *et al*., 2014).

Additionally, a study published in Neuropsychobiology in 2018 demonstrated that variations in the DRD2 gene, responsible for encoding the dopamine D2 receptor, an association was found between The utilization of selective serotonin reuptake inhibitors (SSRIs) has been associated with an increased susceptibility to suicidal ideation among individuals diagnosed with major depressive disorder (De Berardis *et al*., 2021). Genetic factors alone do not solely cause suicide ideation or suicidal behavior. Suicide ideation is an intricate phenomenon influenced by a fusion of environmental, genetic and social factors. To understand the role of genetics in suicide ideation, there is a need for comprehensive research (Orsolini *et al*., 2020).

Conclusion

Suicidal ideation, a critical public health and societal issue, is a complex interplay of genetic vulnerabilities and environmental stressors among jail inmates. By understanding all the risk factors contributing to suicidal ideation in prisoners, it can be helpful in the formulation of practical strategies to improve mental health care for jail populations as well as whole society. So, the development of screening programs, like genetic profiling can be helpful in identification of inmates at high risk, especially focusing on markers that strongly interact with stress, which is the cause of suicidal thoughts in jail settings. Genetic testing can be used to find out the genetic predispositions, such as polymorphisms and stress-response genes like BDNF, 5-HTTLPR, TPH2, which interact with unique environmental conditions of incarceration. So, it would be helpful in early risk detection and personalized mental health interventions in the population. The implementation of environmental modifications and incarceration support i.e. calming and clean spaces, opportunities of treatments, sessions of cognitive behavioral therapies and use of antidepressants (mood stabilizers) would be helpful to reduce the risks of suicide rates in the population. These strategies hold profound social implications, which addresses the mental health needs of people and supportive reintegration into society. To break the cycles of trauma, criminal behavior, and stigma around mental health is a crucial step in prioritizing the well-being of incarcerated individuals. So, the integration of genetic insights into public health enhances the quality of care for high-risk populations but also promotes compassionate and safer community.

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