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FEATURES

Exploring the genetic basis of violence: The impact of Y and X chromosomes

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ABSTRACT

Violence is a pressing global concern, causing more than 475 000 deaths annually and disproportionately affecting women and children. While environmental, genetic, and epigenetic factors contribute to violent behavior, this article focuses on the genetic aspect, particularly the roles of the X and Y chromosomes. The monoamino oxidase A (*MAOA*) gene influences neurotransmitter catabolism and is located on the X chromosome. Polymorphisms, such as tandem repeat variants associated with low transcriptional activity, have been linked to aggression, particularly in men, as X chromosome inactivation complicates studies in women. Other *MAOA* variants, including single-nucleotide polymorphisms, have also been associated with violent behavior. Additionally, individuals with fragile X syndrome often exhibit increased aggression patterns. The Y chromosome's sex-determining region Y gene (*SRY*) plays a pivotal role in male sexual development and behavior. Besides directing testicular formation, *SRY* is expressed in other tissues, influencing violence by modulating catecholamine release and inhibiting the monoamio oxidasa A. Evolutionary hypotheses suggest that *SRY* may have adapted to promote male aggression for survival. Despite evidence linking the X and Y chromosomes to violence, conflicting findings highlight the need for further research to fully understand their roles in aggressive behavior. This article focuses on the genetic component, specifically analyzing the bibliographic evidence associating Y and X chromosome genetics to violent behavior.

KEYWORDS Violence, genetics, gender equality

BACKGROUND

Violence has become a critical global concern, with homicides alone accounting for more than 475 000 deaths globally. This figure is particularly alarming considering that violence manifests in various forms beyond homicide, including child maltreatment and sexual violence. The number of victims continues to rise across these categories. Women and children are disproportionately affected by violence, making them vulnerable groups [1]. For example, the United Nations Entity for Gender Equality and the Empowerment of Women stated that in 2023, approximately 51 100 women and girls were killed by their intimate partner or other family members [2].

Despite efforts to raise awareness in several countries and the commitment to fight against gender-based violence by working under the Sustainable Development Goal (SDG) 5 to achieve gender equality and empower all women and girls, the prevalence of violence against women continues to rise [1].

Violent behavior is influenced by environmental, genetic, and epigenetic factors [3]. The present article focuses on the genetic component, specifically analyzing the bibliographic evidence associating Y and X chromosome genetics with violent behavior.

CHROMOSOMES

Chromosomes are structures within the nucleus of body cells. Humans typically have 23 pairs of chromosomes (46 in total). The 23rd pair is the sex chromosomes, which determine an individual's biological sex. Generally, biological females have two X chromosomes, with one of them randomly inactivated, while biological males have one X and one Y chromosome [3].

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MAIN MESSAGES

- Violence is a global problem that primarily affects women and children, with genetic, environmental, and epigenetic factors playing important roles in violent behavior.
- Genetic variants in genes such as *MAOA* or *SRY* have been studied because of their possible association with violence.
- However, while evidence for the influence of the X and Y chromosomes on violent behavior has been found, there are conflicting findings, which emphasizes the need to conduct studies focused on this association.

Notably, the X chromosome contains about 800 protein-coding genes, while the Y chromosome has around 60 [3].

The X chromosome´s association with violent behavior

X-linked polymorphisms, especially in the *MAOA* gene, have been associated with violent behavior. This gene encodes the monoamine oxidase A enzyme, responsible for the catabolism of neurotransmitters such as serotonin and dopamine. Additionally, a variable number of tandem repeats polymorphism within the *MAOA* gene has also been correlated with increased violent tendencies. The variable number of tandem repeats polymorphism consists of 30 base-pair repeat (R) sequence, with alleles ranging from 2R to 6R [4].

Based on their genetic structure, these variants are categorized into high transcriptional activity (*MAOA*-H) alleles (3.5R-4R), which increase *MAOA* expression, and low transcriptional activity (*MAOA*-L) alleles (3R), which, in turn, decrease gene expression. Variants associated with a reduced *MAOA* expression level have been linked to aggression, anger, and violent behavior [4].

Notably, research on the *MAOA* variable number of tandem repeats has primarily identified an association with aggression in men. This is because the random inactivation of one X chromosome in females complicates the identification of such associations.

Other studies have also linked other *MAOA* variants, such as single-nucleotide polymorphisms, to violent behavior. These involve single base change in the DNA sequence. For instance, several single-nucleotide polymorphisms, including rs5906957, rs909525, rs6363, and rs2064070, have been associated with physical aggression in boys or anger in adult men [5].

Chromosomal number abnormalities, such as Jacobs' syndrome (47XYY), have also been associated with aggressive behavior in some studies. However, these studies lacked sufficient statistical evidence, and recent research indicates that there is no significant evidence linking this syndrome to an increased predisposition for violent behavior [6].

Furthermore, the relationship between people with fragile X syndrome and aggressive behavior has been well-documented. For instance, Wheeler A.C. et al. 2015 found that more than 90% of male and female subjects with fragile X syndrome have displayed violent behavior. Notably, in male individuals, 30% of such violent episodes resulted in injuries [7].

The Y chromosome´s association with violent behavior

One of the most important genes located on the Y chromosome is *SRY* (Sex determining region Y). The protein encoded by this gene functions as a transcription factor that binds to specific DNA regulatory regions such as promoters and enhancers [8]. The principal function of *SRY* is to direct embryonic gonads to develop as testes, which will secrete hormones that masculinize other male characteristics, including physiology and behavior [8,9].

Interestingly, *SRY* is also expressed in other tissues, including the heart, lungs, adrenal glands, and brain. This suggests that *SRY* has additional roles beyond sex determination [9]. In the brain, it has been linked to the "fight or flight" response by increasing catecholamine release and inhibiting the monoamino oxidasa A, thereby stimulating aggression. Notably, the authors hypothesize that during early human evolution, when males were hunters competing for resources, *SRY* may have evolved not only to determine sex but also to influence male behavior, fostering aggression to improve survival [9].

However, studies investigating the role of the Y chromosome in aggression have yielded conflicting results, supporting or rejecting its role in violent behavior. Further research is needed to clarify the association between the Y chromosome and aggressive behavior. Moreover, genes and single-nucleotide polymorphisms located on other chromosomes may also be associated with violence. For instance, *IPO13, PCDH7*, and *ST3GAL3* were linked to childhood aggression in genome-wide association studies [10].

Future perspectives

Human behavior is shaped by genetic, epigenetic and environmental factors, making its study inherently complex. This complexity underscores the intricate interplay of biological and external influences on behavioral traits. Genome-wide association studies offer a potential approach to identifying single-nucleotide polymorphisms associated with violent behavior, thereby enhancing our understanding of its genetic basis. Furthermore, genome-wide association studies can be complemented by other genetic analyses, including gene expression studies, next-generation sequencing, and karyotyping, among others. Integrating these approaches could lead to a comprehensive understanding of the genetic component underlying violent behavior.

CONCLUSIONS

This paper has examined the potential roles of the X and Y chromosomes in violent behavior, incorporating findings from genetic and evolutionary perspectives. Evidence suggests that men, who statistically exhibit higher levels of aggression, may partly present this tendency due to genetic influences, such as polymorphisms in the *MAOA* gene on the X chromosome and the behavioral effects of the *SRY* gene on the Y chromosome. These genetic factors interact with environmental and epigenetic influences, which together may amplify aggressive tendencies. While the association between genetic factors and violence is supported by some studies, conflicting evidence highlights the complexity of isolating genetic contributions to aggression. Further research is needed to understand the complex interaction between genetic, environmental, and epigenetic factors influencing violent behavior.

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REFERENCES

1. World Health Organization. Violence Info – A global knowledge platform for preventing violence. https://apps.who.int/violence-info/
2. United Nations Entity for Gender Equality and the Empowerment of Women. Facts and figures: Ending violence against women [Internet]. 25 Nov 2024 [cited 27 Mar 2025]. Available. https://www.unwomen.org/en/articles/facts-and-figures/facts-and-figures-ending-violence-against-women
3. National Human Genome Reearch Institute. X Chromosome. 2013; 352–354. https://doi.org/10.1016/B978-0-12-374984-0.01650-8
4. Castillo-López G, Ostrosky-Shejet F, Camarena-Medellín B, Vélez-García AE. Moderating effect of gender and MAOA genotype on aggression and violence. Revista Médica Del Hospital General De México. 2015;78: 4–12. https://doi.org/10.1016/j.hgmx.2015.03.002
5. Veroude K, Zhang-James Y, Fernàndez-Castillo N, Bakker MJ, Cormand B, Faraone SV. Genetics of aggressive behavior: An overview. Am J Med Genet B Neuropsychiatr Genet. 2016;171B: 3–43. https://doi.org/10.1002/ajmg.b.32364
6. Re L, Birkhoff JM. The 47,XYY syndrome, 50 years of certainties and doubts: A systematic review. Aggress Violent Behav. 2015;22: 9–17. https://doi.org/10.1016/j.avb.2015.02.003
7. Wheeler AC, Raspa M, Bishop E, Bailey DB. Aggression in fragile X syndrome. J Intellect Disabil Res. 2016;60: 113–25. https://doi.org/10.1111/jir.12238
8. Lovell-Badge R. Aggressive behaviour: contributions from genes on the Y chromosome. Novartis Found Symp. 2005;268: 20–33; . https://doi.org/10.1002/0470010703.ch3
9. Lee J, Harley VR. The male fight-flight response: a result of SRY regulation of catecholamines? Bioessays. 2012;34: 454–7. https://doi.org/10.1002/bies.201100159
10. Ip HF, van der Laan CM, Krapohl EML, Brikell I, Sánchez-Mora C, Nolte IM, et al. Genetic association study of childhood aggression across raters, instruments, and age. Transl Psychiatry. 2021;11: 413. https://doi.org/10.1038/s41398-021-01480-x

Explorando las bases genéticas de la violencia: el impacto de los cromosomas X y Y

ABSTRACT

La violencia es un problema mundial acuciante, que causa más de 475.000 muertes al año y afecta de forma desproporcionada a mujeres y niños. Aunque los factores ambientales, genéticos y epigenéticos contribuyen al comportamiento violento, este artículo se centra en el aspecto genético, en particular en el papel de los cromosomas X e Y. El gen MAOA influye en el catabolismo de los neurotransmisores y se localiza en el cromosoma X. Los polimorfismos, como las variantes de número variable de repeticiones en tándem asociadas a una baja actividad transcripcional, se han relacionado con la agresividad, sobre todo en los hombres, ya que la inactivación del cromosoma X complica los estudios en las mujeres. Otras variantes de la MAOA, incluidos polimorfismos específicos de un solo nucleótido, también se han relacionado con el comportamiento violento. Además, los individuos con síndrome del cromosoma X frágil suelen presentar patrones de agresividad aumentados. El gen SRY del cromosoma Y desempeña un papel fundamental en el desarrollo sexual y el comportamiento masculinos. Además de dirigir la formación de los testículos, el SRY se expresa en otros tejidos e influye en la violencia modulando la liberación de catecolaminas e inhibiendo la MAOA. Las hipótesis evolutivas sugieren que el SRY puede haberse adaptado para promover la agresividad masculina en aras de la supervivencia. A pesar de las pruebas que relacionan los cromosomas X e Y con la violencia, los resultados contradictorios ponen de relieve la necesidad de seguir investigando para comprender plenamente su papel en el comportamiento agresivo. Este artículo se centra en el componente genético, analizando específicamente las pruebas bibliográficas que asocian la genética de los cromosomas Y y X con la violencia.