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The Implications of Tear Gas Use on Endocrine Function

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Abstract

Tear gas is currently used as a riot control agent by the police and federal agents of the government. Though it has been banned in many countries, its use remains legal in the United States. Discussion surrounding the use of tear gas in the United States has increased in the news and social justice discourse throughout 2020 as a result of the Black Lives Matter protests that have swept across the nation. City, state, and federal government officials in multiple cities have attempted to quell protests using tear gas via police and federal agents. Many individuals with ovaries who had contact with tear gas reported disruptions to their menstrual cycles, which only occurred after exposure. The presented research aims to question the link between tear gas and endocrine disruption, using a survey study to understand the perspectives of individuals who experienced physical disruptions to their menstrual cycles — indicating endocrine disruption — post exposure to tear gas. The implications of this survey study show the necessity of a continued exploration of the TRPA1 channel, the channel which tear gas acts upon, in order to understand the relationship between TRPA1 and the endocrine system. This study and the suggested studies it provides is a timely and necessary step in the understanding of tear gas and the protection of Americans experiencing its effects throughout the United States.

Project description

Overview

Tear gas is a pain inducing agent that causes respiratory inflammation, ocular injuries, lacrimation, breathing issues, and intensive stinging to the skin. Tear gas potentially has unchecked effects on the reproductive systems and endocrine systems of those with ovaries. This study proposes to use survey analysis to look for patterns in menstrual cycles post exposure to tear gas, and provides suggestions for future research surrounding the molecular interactions between tear gas and the body. Tear gas is a weapon, first and foremost, but the severity of its effects are widely unknown. This provides enough push to be a necessary and justifiable study to conduct, particularly as a result of the widespread use of tear gas seen in America throughout 2020.

Aims

This work aims to provide the building blocks for a cohesive study on tear gas lacrimators. The survey portion of this study gives researchers the necessary tools to collect data on this topic in any population, while also providing an initial sample to glean patterns from. This study also aims to lead researchers to new study ideas given the large gap in scientific understanding surrounding both TRPA1 and the effect of tear gas on the body.

Background

Brief history of tear gas

Tear gas — a term synonymous with riot control agents, harassing agents, incapacitating agents and lacrimators — is a chemical weapon. Tear gas is used to inflict pain across the body, specifically targeting the ocular and respiratory tracts, in order to debilitate those inhaling it (Tidwell & Wills, 2020). Tear gas was originally developed by chemists Ben Corson and Roger Stoughton at Middlebury College(Corson & Stoughton, 1928). Though accidental, the reaction between carbonyl compounds and malononitrile produced 2-chlorobenzylidene malononitrile — now referred to as CS gas. This discovery paved the way for the utilization of tear gas as it is seen today (Townend, 2020). Three formulations of tear gas are currently produced — OC, CS, CN gasses (Tidwell & Wills, 2020).

Tear gas was widely used during World War I, where it gained its popularity. America used CS throughout the Vietnam war to control crowds (Tidwell & Wills, 2020). Debates in the 1980s about the use of riot control agents as chemical warfare resulted in the 1997 ban of tear gas utilization in war (Dakwar, 2018). Despite this, the decision permitted riot control agents to be used by law enforcement, which has remained controversial. Current exposure to these gasses in the United States is a result of the use of riot control agents by law enforcement (Tidwell & Wills, 2020). Riot control agents as a group also include smoke bombs and pepper spray, which are also used by law enforcement.

Physical effects

Symptom onset after exposure to tear gas occurs between 20 and 60 seconds. The chemicals inflict responses from the ocular and respiratory systems initially — including burning pain, inflammation of the eyes, skin and respiratory tract, and irritation (Meents et al., 2019). This sensation is exacerbated by moisture, which becomes an issue as a result of lacrimation (or tears). Research on the effects of tear gas on the eye has found reactions including lacrimation, conjunctival injection (the enlargement of conjunctival vessels), blepharospasm (the abnormal contraction of the muscles of the eyelid), photophobia (sensitivity to light causing discomfort), conjunctivitis (or pink eye — the inflammation or infection of the membrane of the eyelid), and periorbital edema (puffy eyes). Lack of vision and lacrimation is caused by stimulation of nerves of the lacrimal glands, which produces tears. Ocular injuries can also occur, though these are less common — including hyphema, cataracts, traumatic optic neuropathy and loss of sight. More symptoms may continue to become apparent with continued time, including cough, shortness of breath, headache, chest pain, and dizziness. Distributions of tear gas in areas with poor ventilation can induce more severe symptoms, including bronchospasm, hemoptysis, chemical pneumonitis, pulmonary edema, asphyxia and even death.

Tear gas symptoms are reported to resolve themselves in time. Studies report short term symptoms — burning pain and lacrimation — resolve within 10 to 40 minutes after removal from the source, though this is a variable that is impacted by different metabolisms and differences in personal health (Meents et al., 2019). However, coughing, shortness of breath, and lack of vision generally persist past this time frame. Exposure may result in a runny nose and salivation, which may last up to 12 hours, while headaches may last up to 24 hours. Finally,

erythema of the skin may resolve within an hour, but blistering may occur for up to four days. Some individuals may experience nausea and vomiting, as well, throughout their experience.

Neuroscience of Tear Gas

Tear gas in the environment reaches the nervous system through mucosal membrane exposure and inhalation. Tear gas irritates mucous membranes in the eyes, nose, mouth and lungs — ultimately activating transient receptor potential ankyrin 1 (TRPA1) channels expressed on nociceptors (Schep et al., 2013)(Bessac et al., 2009). There are three formulations of tear gas: OC, CS, and CN gasses, which all activate TRPA1 channels through this process. Each is debilitating, but each causes different responses within the body in comparison to one another. CS gas remains a more potent irritant than OC, but is less incapacitating. CN causes more severe dermal injuries in comparison to CS. OC is absorbed in the gastrointestinal tract, while CS is primarily absorbed via the respiratory tract. Very little is known about the metabolism of CN, though it is suggested that it is converted to an electrophilic metabolite, which eventually influences and disrupts cellular processes. Again, limited data exists surrounding this interaction (Tidwell & Wills, 2020).

Structure and Pathways of the TRPA1 Channel

TRPA1 is a homo or heterotetrameric nonselective cation channel. This ion channel is a sensor for pain, cold, and itch in humans and other mammals. This ion channel also exists as a sensor for irritants in the environment, which results in the physiological responses of cough, tears, and airway resistance (Andersen et al., 2014). These factors suggest that the channel helps

with the detection of body temperature and the mediation of the sensations of cold and pain (Tidwell & Wills, 2020).

TRPA1 channels are expressed all over the body, mainly in small-diameter C or Aδ fibers of sensory ganglia — including the DRG, trigeminal and nodose ganglia. The channels are found in the cells of the inner ear, endothelial cells, colon and enterochromaffin cells, and throughout the respiratory tract.

Physically, each monomer consists of six transmembrane domains, intercellular NH_2 and COOH termini, and a pore forming loop between TM5 and TM6 (Meents et al., 2019). The NH_2 terminus is the largest part of the channel, making up 64% of the entire protein. 16 ankyrin repeat domains exist in the NH_2 terminal portion of the protein. One additional domain exists, which only contains part of the ankyrin consensus motif. These domains consist of 33 amino acid sequences which form an antiparallel helix turn helix structure, followed by a Beta hairpin loop. The site for the activation of TRPA1 has been proposed to be an EF-hand present in the N terminus of the protein (Wang et al., 2008).

Tear gasses are the most potent TRPA1 agonists known to date (Bessac et al., 2009). CS and CN are found to be 10,000 times more potent in interactions with the TRAP1 channel than other natural agonists (Tidwell & Wills, 2020). TRPA1 is ultimately activated by a variety of chemical compounds. Many of these can be found and interacted with in everyday life. These agonists induce a strong burning sensation upon interaction. Agonists of TRPA1 can be categorized into two groups — electrophilic and nonelectrophilic compounds. Thiol-reactive electrophiles covalently modify the channel, while nonelectrolyte compounds noncovalently interact with the channel. Agonists that interact covalently include certain herbs and spices,

including allicin and cinnamaldehyde — which are found in garlic and cinnamon, respectively. Industrial chemicals and volatile irritants also covalently modify the channel. These include hydrogen peroxide, anesthetics, isoflurane, lidocaine, and propofol. Laboratory chemicals like formalin and endogenous activators and components of oxidative stress (nitric oxide, zinc, hydrogen peroxide) also fall into this category. For all agonists that covalently modify the channel when binding, three cysteine residues and one lysine residue seem to be responsible for the effect of all of these agonists on TRPA1 (Bessac et al., 2009). Because of this, and the ability of reactive compounds to covalently modify cysteine residues in the channel, it is suggested that all oxidizing or electrophilic chemicals will affect the function of the channel.

Compounds that are nonelectrophilic in nature make up the second group of TRPA1 agonists, known as nonreactive compounds. These compounds do not covalently modify cysteine residues. Nonelectrophillic agonists include herbal ingredients and plant derivatives, nicotine, menthol, thymol carvacrol, and nonsteroidal anti-inflammatory drugs.

TRPA1 has been shown to interact with TRPV1 as well, which is the ion channel activated by pepper spray. When CS interacts with TRPV1 mucocutaneous sensory nerve receptors it can cause severe facial pain which reflects blepharospasm and lacrimation (Tidwell & Wills, 2020).

It is suggested that extracellular Calcium (Ca^{2+}) is a key regulator in both potentiating and inactivating TRPA1 activity. Calcium plays at least two roles in the regulation of this type of channel. Ca^{2+} may mediate the potentiation of pungent chemicals that activate TRPA1. Activation of this channel by intracellular Ca^{2+} has been observed in lab experiments involving the dialysis of Ca^{2+} into cells or the application of the ion into excised patches, though it is not

clear whether this is the mechanism that allows for the potentiation of Ca^{2+} or, rather, the channel activation of TRPA1 (Wang et al., 2008).

The second effect of extracellular Ca^{2+} is to inactivate TRPA1. TRPA1 currents, which have been activated by pungent chemicals, decay within seconds when extracellular Ca^{2+} is introduced (Wang et al., 2008). The exact mechanism of inactivation is not yet completely understood, but it may involve the binding of Ca^{2+} to the outside of the channel. It may also potentially involve the elevation of intracellular Ca^{2+}, which is associated with desensitization of other TRP channels. These are simply two hypotheses, and many more potential interactions exist. Inactivation of this channel may reflect the obligatory entry of the channel into the inactivated state that occurs following the Ca^{2+} dependent activation of the channel, like that of the inactivation of voltage-gated ion channels (Aldrich et al., 1983).

The implications of understanding further information and qualities of this channel point towards better understanding of treating tear gas effects using potential antagonists to the TRPA1 channel (Bessac et al., 2009). Understanding the reaction by which the central channel opens and the nerve fiber is acted upon by impulses that impact the brain to sense pain, is a key component in determining new ways to mediate pain. Research also allows for the understanding of the diversity and severity of different chemicals that act upon this channel and the differences in pain levels they cause (Farley, 2015). The downstream effects that are a result of the activation of this channel are not yet fully understood beyond the reality that TRPA1 antagonists block the noxious effects of tear gasses (Bessac et al., 2009). These downstream effects include the processes of lacrimation, skin inflammation, and more. Despite a strong understanding of these downstream effects, research suggests that these effects result from the channel's interaction with sensory

neurons (Fernandes et al., 2012). These sensory neurons integrate information from noxious stimuli, hence resulting in the aforementioned physical effects. Understanding more about the receptor may allow neuroscientists to better understand the effects that result from tear gas distribution.

Most side effects of tear gas have become clear as a result of first hand interaction with the substance of tear gas, rather than in ethical, scientific studies. One of these side effects involves influence on the reproductive and menstrual cycle in those with ovaries (Goldberg, 2014). Discussions of this topic are based on observation, not on empirical evidence. However, the results of studies and qualitative research point towards an opening in the literature where studies researching the endocrinological influence of tear gas may help answer many biological and social questions.

Endocrinology of Menstruation

Menstruation is the result of hormonal changes that are cyclical within the bodies of those with ovaries. This occurs across the hypothalamic-pituitary-gonadal neuroendocrine axis and gives the opportunity for an egg to be fertilized (Nelson & Kriegsfeld, 2017). The process of menstruation is the result of the shifts of hormones that result from follicle growth. Most menstruation, decreased levels of estrogen and progesterone result in negative feedback, which decreases levels of gonadotropin-releasing hormone (GnRH) secretion. GnRH release increases, which allows for the gradual increase of follicle-stimulating hormone (FSH) and luteinizing hormone (LH). As follicles mature, estrogen is produced by the follicle which causes a decrease

in GnRH through negative feedback. This influences a decrease in FSH and LH, eventually resulting in programmed cell death in non-mature follicles.

The late follicular phase sees negative feedback switch to a positive feedback loop. Estrogen production from the follicle increases GnRH production, which in turns influences a surge in LH and FSH (Nelson & Kriegsfeld, 2017). This surge causes ovulation, where the ovocyte ruptures out of the mature follicle and ovary, and sees a return to negative feedback. Post ovulation, estrogen levels decrease, while progesterone increases due to its production by the corpus luteum. If the individual is not pregnant the corpus luteum regresses, causing a dramatic decrease in progesterone. This triggers menstruation. After menstruation, estrogen and progesterone levels are low. This causes FSH and LH to gradually build up in the blood, and the cycle begins again.

Environmental stimuli and chemicals can cause reproductive dysregulation, resulting in an influence on the menstrual cycle. These stimuli can include lack of nutrition, stress, and lack of a comfortable or proper environment to live in (Nelson & Kriegsfeld, 2017). Medication, additional hormones taken or prescribed, and endocrine disrupting chemicals — chemicals that mimic the effects of hormones or disrupt hormonal systems — can also cause reproductive dysregulation.

The relationship between the TRPA1 receptor and menstruation has yet to be clearly defined. As referenced in observations post exposure, menstruation seems to be affected by the chemicals within tear gas (Ellis, 2020). The mechanisms by which menstruation may be affected is not known. The reality that tear gas acts on the TRPA1 channel provides a push to understand whether the endocrinological reaction tear gas may enact on the bodies of those with ovaries

comes from a direct influence on the endocrine system or, rather, via another biological avenue. This drives questions surrounding TRPA1's relationship to menstruation.

Description of project

Overview

Little research has been conducted surrounding the endocrinological effects of tear gas on the body, specifically on those with ovaries. Some studies have researched the implications of tear gas on the body, suggesting that it is possible that the chemicals associated with CS gas could create chemicals that may impact hormonal homeostasis when inhaled or ingested (Hout et al., 2010). Even fewer studies have delved deeper into this phenomenon. A 2012 review of tear gas use in Bahrain documented pregnancy loss in the community exposed to tear gas during anti-government protests (PeaceWomen, 2012). Chile suspended the use of tear gas by the police in 2011, reasoning that the potential to cause miscarriages and harm young children was strong enough to ban its use (Hayman, 2011). Chilean toxicology experts noted that there is a probability that the chemical substances present in tear gas can negatively influence reproductive function, damage a fetus in the last trimester of pregnancy, and harm children in their early years of life. However, as previously mentioned, few laboratory studies have worked to understand the validity of this claim and the relationship between endocrine disruption and tear gas.

2020 has seen tear gas popularly used by the American government via police force in response to the thousands of Black Lives Matter protests that have resurged following the killing of George Floyd by Minneapolis police on May 25th. Many protesting individuals have also reported instances of hormonal imbalances resulting in irregularities in menstruation. These

individuals experience debilitating cramps, and the passage of large blood clots after inhaling tear gas. Trans protesters who had been taking testosterone, and therefore stopped menstruating, saw their cycles restart after inhaling tear gas specifically (Ellis, 2020).

Many who have experienced this phenomenon have expressed their belief that their irregular menstruation is a direct result of tear gas exposure, rather than acute stress — which is also present in the protest environment (Nowell, 2020). Other influences in the protest specific environment include shifted bedtimes, an inconsistent diet, as well as intensive sprinting away from danger. Those reporting, however, express that it is only after direct exposure to tear gas that their menstruation occurs irregularly (Ellis, 2020).

Recently, many accounts of the effects of tear gas on menstruation are spread via word of mouth using social media. Those who have experienced tear gas exposure band together on platforms like Twitter to discuss their symptoms and express concern (Smith, 2020). Despite commonalities in situations, it is clear that it is uncertain whether the bodily response seen is a direct result of the gas. Scientists agree that it is not wise to conclude any kind of relationship as causational without evidence, thus it is imperative that a study is conducted surrounding the specific interactions between tear gas and endocrine disruption. The long term effects of tear gas on the body are widely unknown, therefore reproductive safety is potentially at risk. However, many also agree that it is unethical to test tear gas on humans to answer these unknown questions. It is clear that other methods must be employed.

This study aims to delve into the influence of tear gas as it pertains to its effects on those with ovaries. This qualitative research study surveys individuals afflicted by tear gas exposure through protests in Portland, Oregon — where protests have consistently occurred for over 100

nights -- from May 29th 2020 to November 16th 2020 -- and counting. To understand how tear gas influences the nervous system, I propose focusing on 1) the effect of tear gas on the endocrine system and 2) the necessity of research studying interactions between tear gas and TRPA1 channels through the use of a qualitative research study.

Methods

This study is to be conducted following similar methods to the call to action and survey project surrounding endocrine disruption after tear gas exposure conducted by Planned Parenthood (Planned Parenthood North Central States, 2020). 1000 study participants will be gathered digitally. This sample consists of protesters who had attended one or more protests in Portland, Oregon between June 2020 and October 2020. This demographic was chosen because of the prevalence of tear gas that has been utilized in the city throughout the aforementioned time frame. A call for participants would be posted by researchers on Twitter, Facebook, and the researchers main website, asking participants who had been exposed to tear gas and other chemical weapons to share their experiences through a Qualtrics survey. IRB approval would be attained before the start of the study.

Requirements for participation include participants are able to answer yes to the following questions: Participant is...

a. 18 years old or older
b. Had ovaries and a uterus at time of exposure
c. Has faced tear gas or any other chemical agents
d. Is able to give consent, take a survey and/or give an interview.

Survey and interview questions were created using language that could allow them to be applicable to any city or demographic. Therefore, this study acts as a model for testing in other locations. Language was codified to specify between general lacrimators and tear gas, pepper spray, and smoke bombs. Survey questions can be found in Appendix A.

Predicted results

Researchers created a survey calling for reponses surrounding endocrine disruption as a result of tear gas exposure. 1000 responses were recorded. Predicted results were cultivated using the website Mockaroo to randomize 1000 responses to each question, acting as a sample of 1000 respondents. All following data is a reflection of the data gathered through the randomizing site.

All participants were 18 years old or older, had been exposed to tear gas/canisters, smoke bombs/grenades, or pepper spray/ mace, and had a uterus and ovaries at the time of exposure. All participants consented to taking the survey. 672 participants identified as white, 272 as Black, 28 as Asian, and 28 as Indigenous. Four participants identified as transgender men, eight identified as genderqueer, and 976 identifed as cis-women. All participants had experienced their exposure to riot control agents in Portland, Oregon in 2020. 320 participants surveyed were exposed to tear gas at least once in these experiences.

348 participants reported typically regular menstrual cycles before exposure, 337 individuals reported irregular cycles before exposure, and 316 individuals reported that they do not typically experience physical bleeding as a result of their cycles. Those who reported monthly bleeding typically experienced bleeding for an average of five days, and experienced a

median of 28 days in the typical cycle. Survey questions attempted to account for any potential influences on the menstrual cycles, and identify these patterns within the sample accumulated. Many individuals possessed a variety of diagnoses, including polycystic ovary syndrome (n = 86), premenstrual dysphoric disorder (n = 94), endometriosis (n = 80), ovarian insufficiency (n = 77), menopausal symptoms (n = 88), overactive thyroid (hyperthyroidism) or underactive thyroid (hypothyroidism) (n = 109), uterine fibroids (n = 79), or none (n = 387). These questions prepared researchers to potentially understand other factors that may have impacted the delicate system of the menstrual cycle.

Participants had been exposed to chemical agents used by law enforcement a median of three times. This exposure occurred in Portland, Oregon, and was linked mostly to protests. Most individuals were exposed while protesting (n = 271), but many experienced exposure through attendance for other reasons, namely serving as a health responder or medic (n = 94), acting as a legal observer (n = 104), reporting as a journalist (n = 107), or volunteering or providing mutual aid (n = 119). Other experiences that are similar but possible outside of a protest setting as well include being arrested or detained (n = 91), remaining in law enforcement or police custody (n = 99), in one's home or business (n = 115), or none of the listed experiences (n = 107). The participants' most recent exposure reflected this, as participating in demonstrations where chemical agents were used by law enforcement was the primary route of exposure in the sample (n = 650). Exposure occurred through direct inhalation of chemical agents outside (n = 254), direct inhalation of chemical agents within a home or business (n = 251), spraying of chemical agents in the face directly (n = 264), or being sprayed on another part of the skin (n = 231). During exposure, participants were hit with rubber bullets (n = 235), paint rounds or bullets (n =

120), batons or police sticks (n = 122), canisters of tear gas or smoke (n = 124), handles or barrels of firearms (n = 39), other items (n = 2), or nothing (n = 216). Exposure occurred an average of 3.4 times in a given participant's life within the sample. These factors were taken into consideration to recognize potential influences that could cause increased stress.

Post exposure, participants experienced unexpected or early bleeding, late or delayed bleeding (n = 436). Some participants did not experience any unusual disruptions to their menstrual cycle after exposure (n = 64). When surveyed about whether or not participants believed exposure to riot control agents influenced their menstrual cycle, participants widely agreed that they did (n = 899).

Participants were surveyed to understand other influences on menstruation — including birth control and hormone usage. The anonymous nature of the survey prevents specific extrapolation of personal experiences which makes it difficult to understand trends as they pertain to certain aspects of an individual's experience with tear gas and their own hormonal experiences as a human being. A future qualitative, interview-based study could address these questions. Overall, as a result, the data collected shows a personal belief in a relationship between exposure to riot control agents and endocrine disruption, though these individuals may not understand the implications of additional stress on the endocrine system. All results can be found in Appendix B.

Limitations

Limitations to this study include the reality that it is impossible to glean whether or not individuals afflicted by multiple types of chemical agents are possessing any assumed reactions

as a result of tear gas specifically, or a combination of tear gas and other lacrimators, if individuals experienced interactions with multiple chemical agents. Qualitative data can identify correlations and generate hypotheses, but can not conclude causation in this relationship. The ambiguity of lacrimators used during protest by the police increase this inability to correlate reactions to tear gas specifically, and increase the possibility for further laboratory experiments surrounding the influence of a variety of lacrimators on the body and endocrine system.

Furthermore, the sample of respondents who experienced tear gas specifically was roughly one third of respondents (n = 320). This limitation negates the ability to draw any correlations between tear gas on any other effects, due to the small sample available — unless further research was conducted to specifically inquire about the experiences of this smaller sample who had experienced tear gas specifically.

Limitations exist in the demographics that this survey reaches. Portland provides a large sample of individuals who have inhaled or experienced tear gas at some capacity. However, this survey only looks to understand the experiences of these individuals, and therefore it is impossible to know if any patterns extrapolated from this data are applicable to those who are not experiencing tear gas, ultimately leaving room for further research into patterns of menstruation across many demographics and under the influence of a variety of environmental, social, and endocrinological factors. Despite this, this study was designed to be replicated in other cities with other populations of people, making it a strong contribution to this area of research.

Surveys as a method of data collection possess limitations. Surveys are not always representative of the population that they attempt to collect data from, the wording of the survey may affect responses, and the gender or race associated with the survey may influence responses.

Though survey questions were created with these factors in mind, it is possible that these influences may carry through into this study for some participants.

Finally, in this hypothetical study, data was collected and created using a randomizing platform. This provides a limitation, as it is impossible to glean true information from this study as a result. Limitations also exist in the reality that, in using a sample of true individuals and not a randomized generator, individuals may select for more than one response in many of the multiple choice survey questions presented, not simply one answer — which the sample generator does not account for.

Implications for Further Research

Further research can work to address the limitations of this survey study by studying the direct influence of the TRPA1 channel on the endocrine system. Studying this channel and its effects on the body as a whole can help to draw correlations and conclusions between tear gas exposure and the effects that are referenced to in the accounts of those afflicted by it. In order for this to be successful, an animal model must be included in further laboratory research. Animal models provide an avenue for scientific research that pose critical ethical concerns. This study provides a key example of research that would benefit greatly from the use of animal models to attain a critical understanding of the abortifacient nature of tear gas.

Priorities for future research include, firstly, gleaning a greater understanding of the TRPA1 channel and the processes that activate this channel on a molecular level. An understanding of the processes involved in the activation of the TRPA1 channel may point to the influences that may or may not impact the endocrine system. A variety of approaches and

laboratory tools may be used to enact these discoveries, including looking at ion channel interaction in specific cells using tear gas. These studies will also aid in understanding the long term effects of tear gas at a molecular level, which will influence understandings of necessary medical intervention post exposure. Ultimately, no correlation or significant evidence for a relationship between tear gas and endocrine disruption can be concretely defined until TRPA1 is more widely understood, given that this is the mechanism by which tear gas appears to influence and access the neuroendocrine reproductive axis. This fact implies that there is a current need for data in order to address the social and physiological issue of tear gas and endocrine disruption.

Intellectual merit

The United States has seen a great increase in the use of tear gas by police across the country, with the increase of its use as a result of Black Lives Matter protests throughout the nation. The use of tear gas during this time frame has provided a large sample to pull from to see trends in endocrine disruption after tear gas exposure (Baker, 2020). Researchers, scientists, and human rights activists alike all concur that tear gasses have not been well studied, and — as weapons of war — they cannot be condoned to be used on anyone from a medical perspective (Dakwar, 2018). Given the current disposition of the State and its enforcers (namely police officers) it is likely that it will take empirical research conducted in an American context to qualify the need to disband these substances. In other words, scientific research is essential in the movement to curb the United States's use of tear gas. This provides imperative intellectual merit for not only the proposed study, but any study surrounding the use of tear gas.

The politics and effects of tear gas and the discussions that arise from these subjects are ongoing, important, and central to today's discourse about state sanctioned violence. Intellectual and societal merit exists as a result of this research.

Conclusion

Tear gas use is a human rights issue. Profuse evidence cites the bodily harm that occurs as a result of its use, and the implications of these studies only work to further the reality of this harm. Tear gas disproportionately impacts those with ovaries, and BIPoC individuals with ovaries. The lack of research on an issue that directly intersects with the health of BIPoC, transgender, and activist communities is not suprising, as reserach and science has promoted the interests of white cis-men for the majority of time. Broader implications of this study shine light on the lack of emphasis put on studies that focus on marginalized individuals and modes of marginalization inflicted by the power-elite, such as the use of tear gas by law enforcement. Broader implications also stem from considering the unknown effects of tear gas as an environmental pollutant, as well as on sensitive groups and those suffering or interacting with COVID-19.

The broader impacts of this study also relate to the deep necessity for change in regard to the use of tear gas. Public knowledge of the aversive effects of tear gas are continuing to rise. The current accessibility to knowledge via the internet and social media has given individuals a platform to rally around the knowledge of the harm tear gas inflicts. For example, the Black Lives Matter movement has shaped thousands of protests, governmental action, and social media posts in such a way that community has grown in support of human rights. One of the aspects

that this community is shaped by is the use of tear gas. Those afflicted by tear gas use social media to question the reactions that they have experienced and find solidarity with others. This especially relates to the symptoms of endocrine disruption seen.

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Appendix A

1. Are you 18 years or older?
2. Have you ever been exposed to chemical agents used by law enforcement such as tear gas/canisters, smoke bomb/grenades, or pepper spray/ mace
3. Do you have ovaries or did you have ovaries at the time of exposure to chemical agents?
4. Do you consent to the completion of this brief survey?

5. What is your gender identity?
    a. female/cis woman
    b. male/cis-man
    c. Genderqueer/nonbinary
    d. Transgender female
    e. Transgender male
    f. Other
6. What is your racial identity (select all that are applicable)
    a. Black
    b. White
    c. Indigenous
    d. Asian
    e. Native Hawaiian or Pacific Islander
    f. Other

7. What is the highest level of education you have received
    a. Less than high school
    b. High school diploma or GED
    c. Associate degree
    d. Bachelor's degree
    e. Master's degree
    f. Doctorate
    g. Professional degree (MD, JD, DDS, ect)
    h. Other
8. What best describes your daily activities or responsibilities
    a. Full time work
    b. Part time work
    c. Unemployed
    d. Looking for work
    e. Taking care of household
    f. Raising children or taking care of dependents full time
    g. Taking care of household and raising children or taking care of dependents full time
    h. Retired

9. When was the first day of your last bleeding cycle? Estimations are appreciated if you are not sure.

10. Select the best descriptor for your bleeding cycle
    a. Regular - around once a month
    b. Irregular — less than once a month
    c. Not applicable/does not happen to me
11. If regular, how many days do you usually experience bleeding
12. How many days are in your typical bleeding cycle — in other words, how many days from start of first bleeding until the start of your next bleeding
13. Have you ever experienced a diagnosis of
    a. Polycystic ovary syndrome
    b. Endometriosis
    c. Premenstrual dysphoric disorder
    d. Ovarian insufficiency
    e. Menopausal symptoms
    f. Overactive or underactive thyroid
    g. Uterine fibroids
14. How many times in your life have you been exposed to riot control chemical agents (i.e. tear gas/smoke bombs/mace).
15. What state and/or city were you in when you experienced these agents.
16. What activities were you engaged in when you were most recently exposed?
    a. Exercising my right to protest and publicly demonstrate
    b. Serving as a health responder or medic
    c. Acting as a legal observer

d. Reporting as a journalist
e. Volunteering/providing mutual aid
f. In my home or business
g. Being arrested or detained
h. In law enforcement or in police custody **or** as law enforcement
i. None of the above
j. Other

17. What chemical agent or agents do you believe you were exposed to in your most recent exposure? Select all that apply.
    a. Tear gas
    b. Smoke bomb/grenade
    c. Pepper spray/mace
18. When were you most recently exposed to this or these chemical agents
19. How were you most recently exposed to these chemical agents
    a. (participating in demonstrations where chemical agents were used by law enforcement, living in a neighborhood or area where chemical agents were used by law enforcement/police, forced entry in a home or business by law enforcement/police who used chemical agents, while in custody or under arrest by law enforcement who used these agents)
20. How was your body exposed to these chemical agents?
    a. Directly inhaled chemical agents

b. Inhaled chemical agents that entered my home or business

c. Directly sprayed in the face

d. Sprayed on other parts of my skin

21. Were you physically hit by any of the following while in the presence of chemical agents

a. Rubber bullets

b. Paint rounds/bullets

c. Batons or police sticks

d. Police or riot shields

e. Tear gas canisters or smoke

f. Handles or barrels of firearms

g. Other

h. No, I was not physically hit with anything

22. Did you experience any of the following during or after your exposure to the aforementioned chemical agents?

a. Unexpected or early bleeding

b. Late or delayed bleeding

c. I thought or knew i was pregnant

d. I did not experience disruptions

23. Did you experience any of the following effects after your exposure?

a. Uterine cramping

b. Constipation or diarrhea

c. Breast tenderness

d. Headache

e. Fatigue

f. Joint or muscle pain

g. Abdominal bloating

h. Acne-flare up

i. Other

j. None of the above

24. Do you think that being exposed to these chemicals have had an effect on your bleeding since your exposure?

25. Have you experienced any other symptoms after your exposure?

a. Breathing problems

b. Body aches

c. Eye irritation

d. Mental health problems

26. During your most recent exposure, were you using any birth control?

a. Birth control pill

b. Birth control ring

c. Birth control patch

d. Hormonal intrauterine device

e. Non Hormonal intrauterine device

f. Contraceptive implant

g. Other

27. During your most recent exposure, were you taking any hormones?

a. No

b. Progesterone

c. Testosterone

d. Estrogen

e. Other

Appendix B

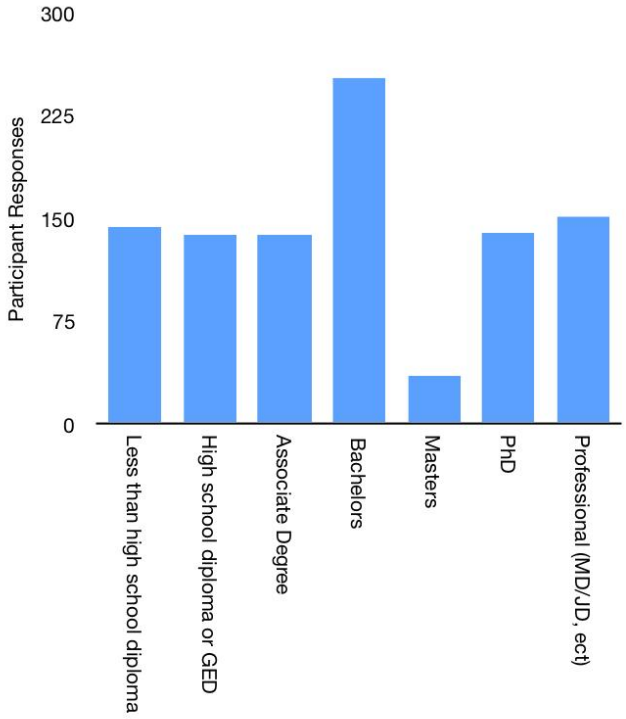

Figure 1. Highest level of education reached by respondents (n=1000).

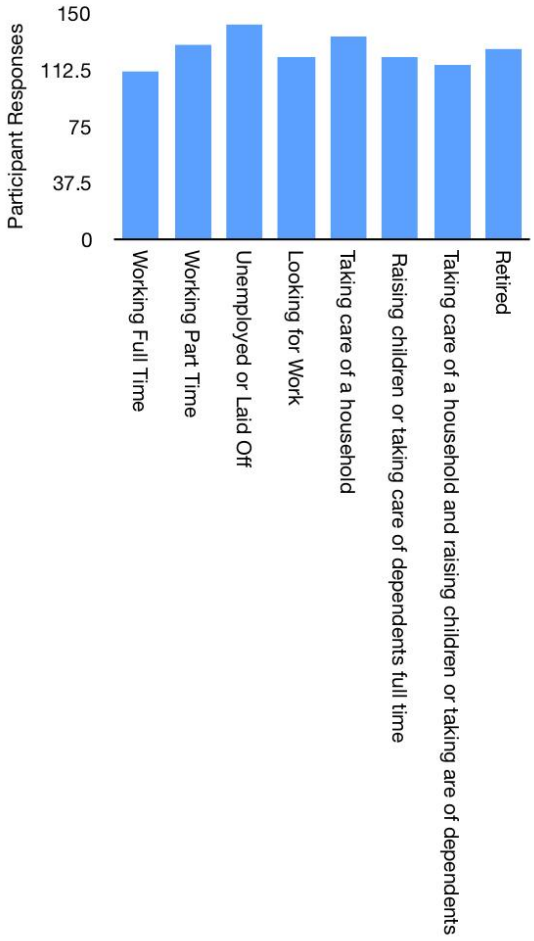

Figure 2. Current employment of participants (n=1000).

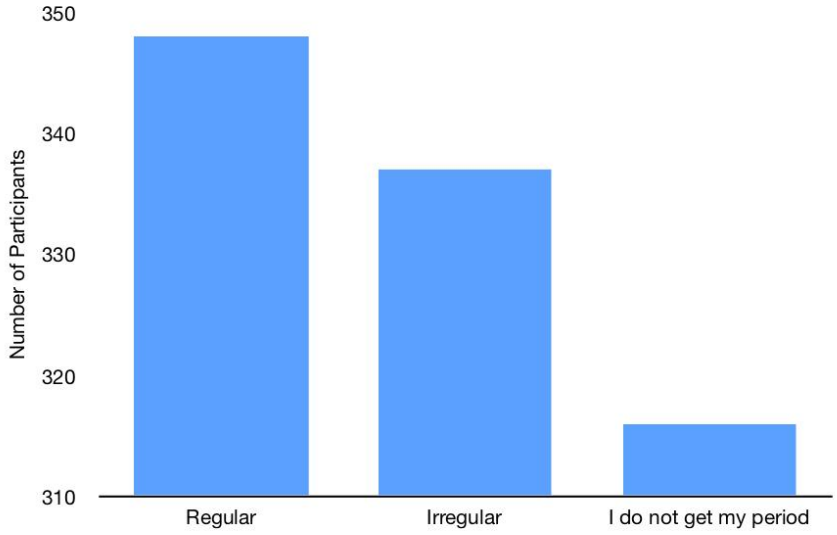

Figure 3a. Regularity of menstrual cycle in participants (n = 1000).

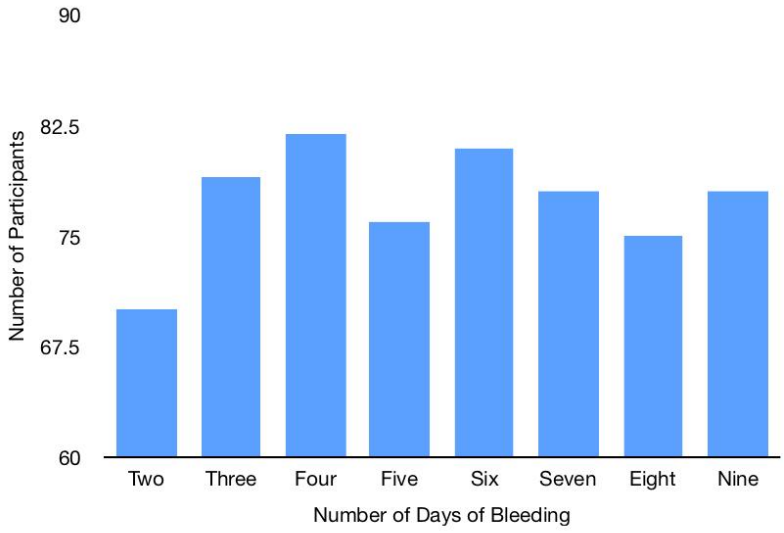

Figure 3b. Participants average days of bleeding, if regular or irregular menstural cycle reported (n = 685).

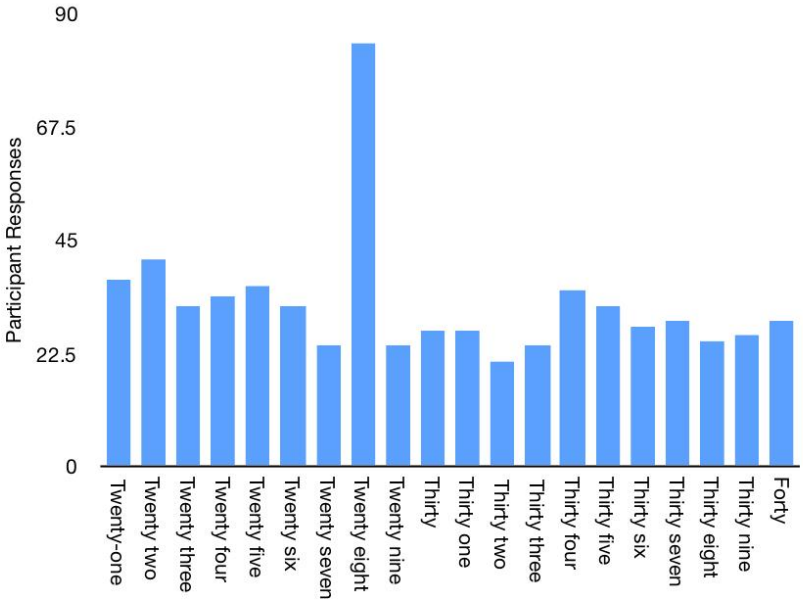

Figure 3c. Average days in typical cycle, if regular or irregular menstrual cycle reported (n = 685).

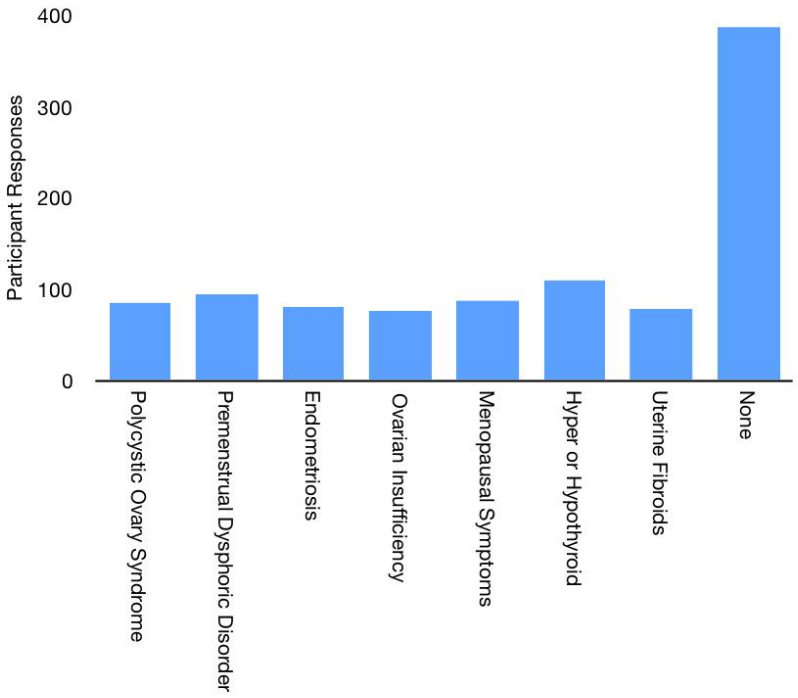

Figure 4. Diagnoses of polycystic ovary syndrome premenstrual dysphoric disorder, endometriosis, ovarian insuffieicney, menopausal symptoms, hyper or hypothydroid, uterine fibroids, or no diagnoses within the population (n = 1000).

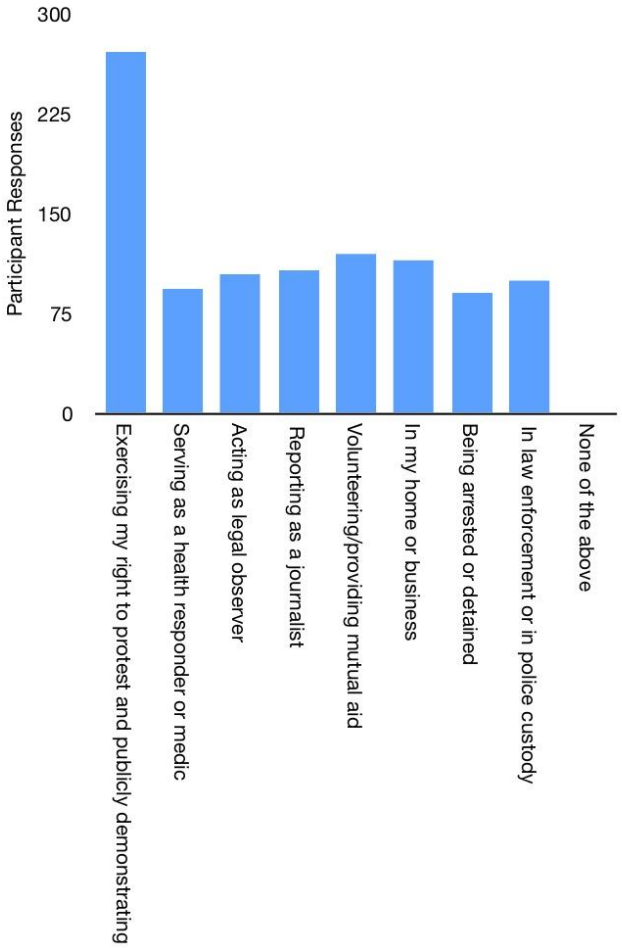

Figure 5. Activity engaged by participants when exposed to tear gas (n=1000).

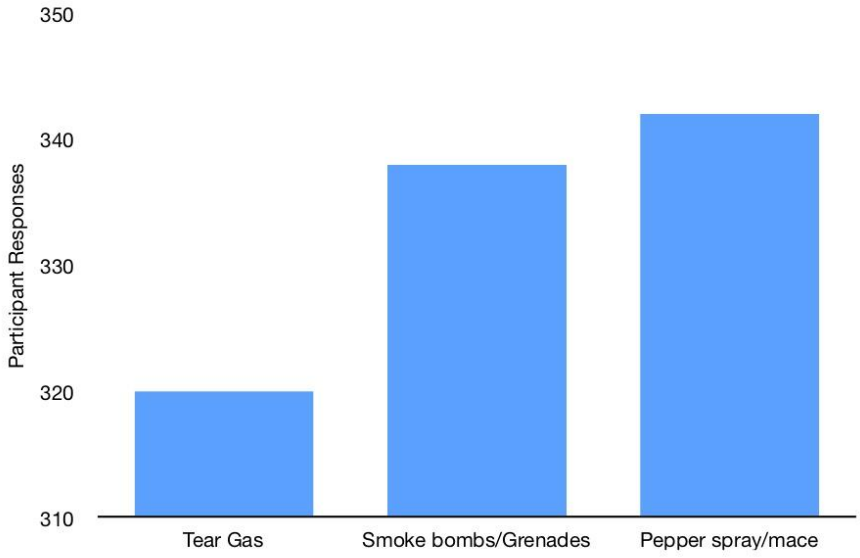

Figure 6. Perceived riot control agent participants were exposed to (n = 1000).

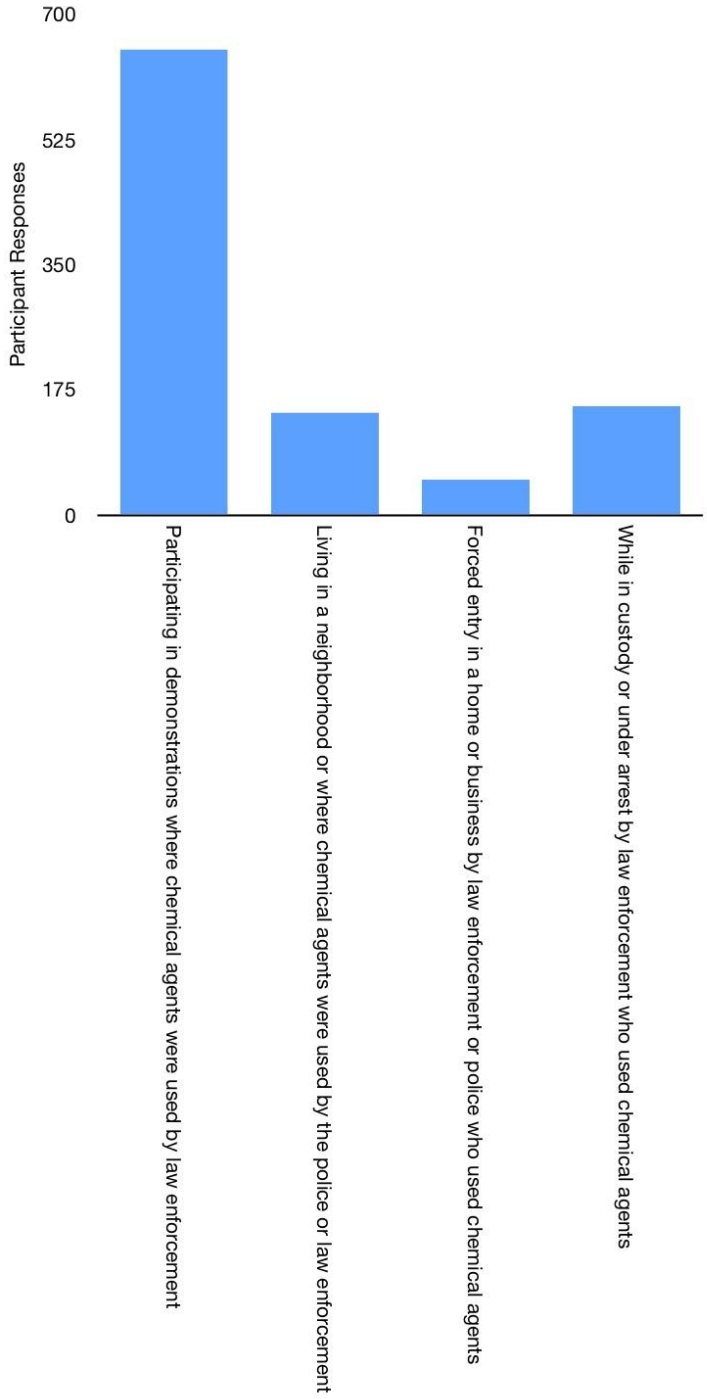

Figure 7. How participant exposure to chemical agents occurred (n = 1000)

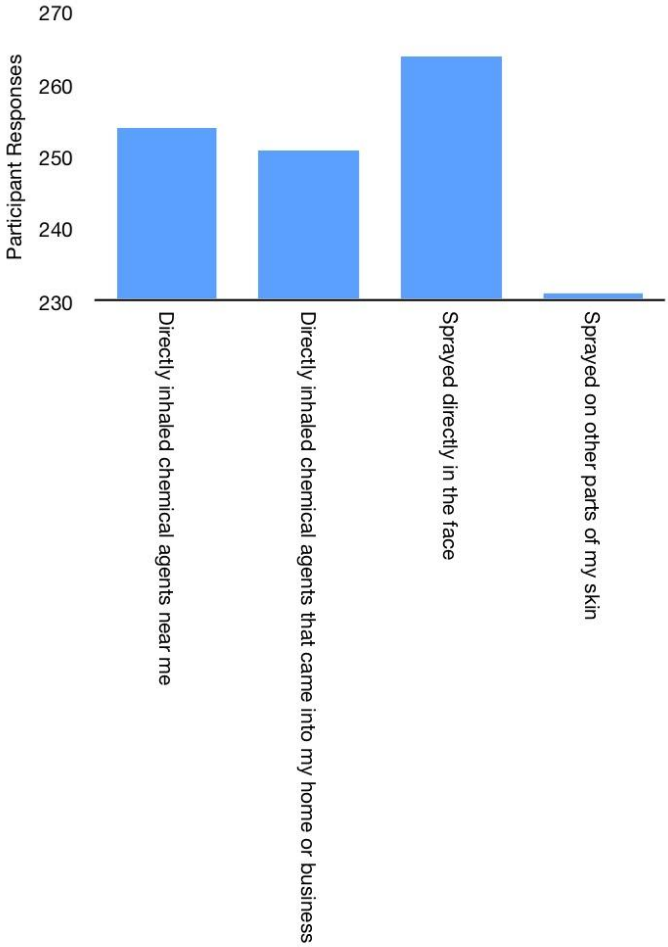

Figure 8. How participant bodies were exposed to chemical agents (n = 1000)

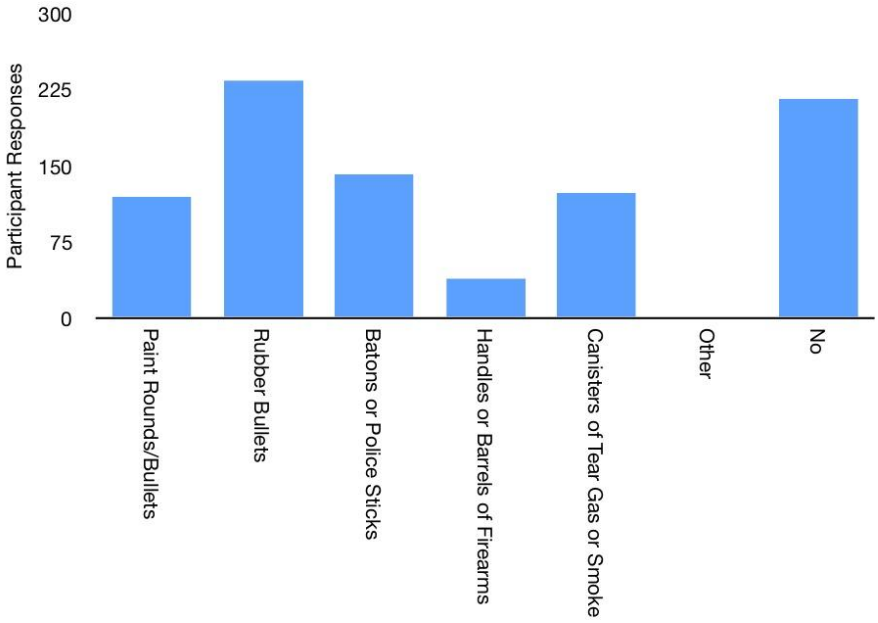

Figure 9. Participants experience with other physical weapons at time of exposure (n = 1000)

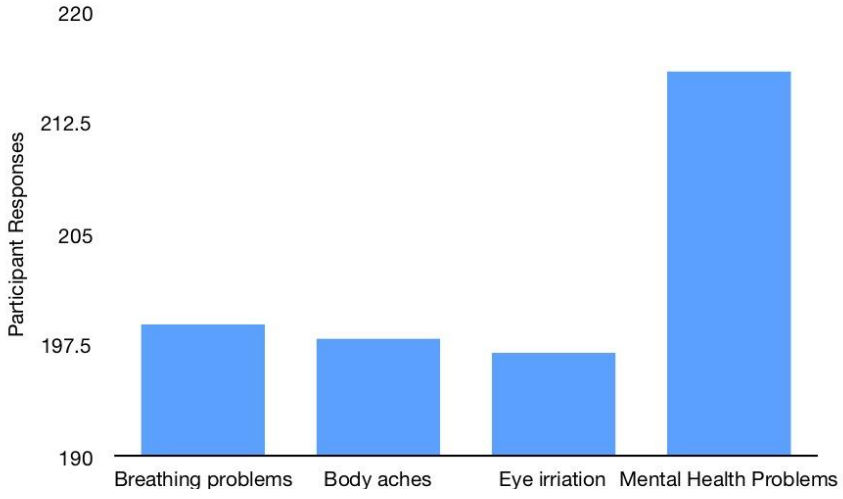

Figure 10. Participants reported symptoms after exposure (n = 1000)

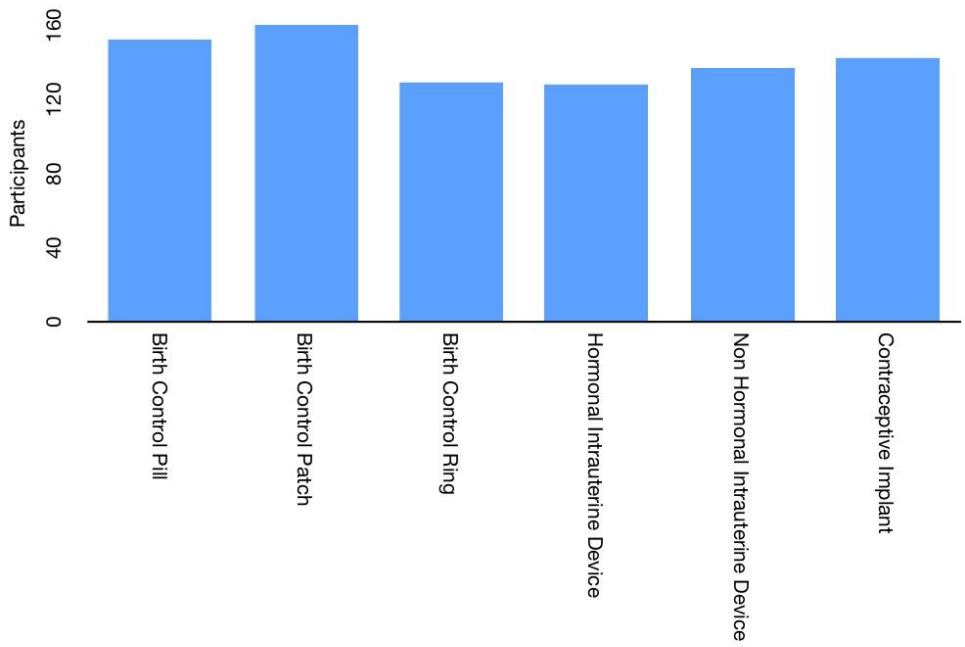

Figure 11. Participants birth control usage at time of exposure (n = 1000)

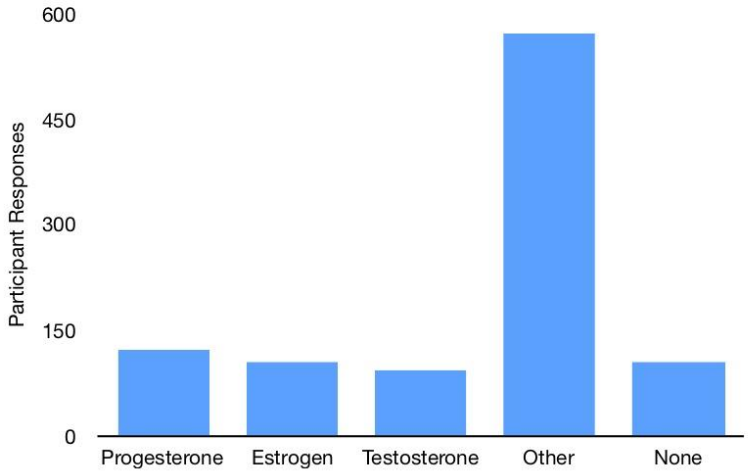

Figure 12. Participants hormone usage at time of exposure (n = 1000)

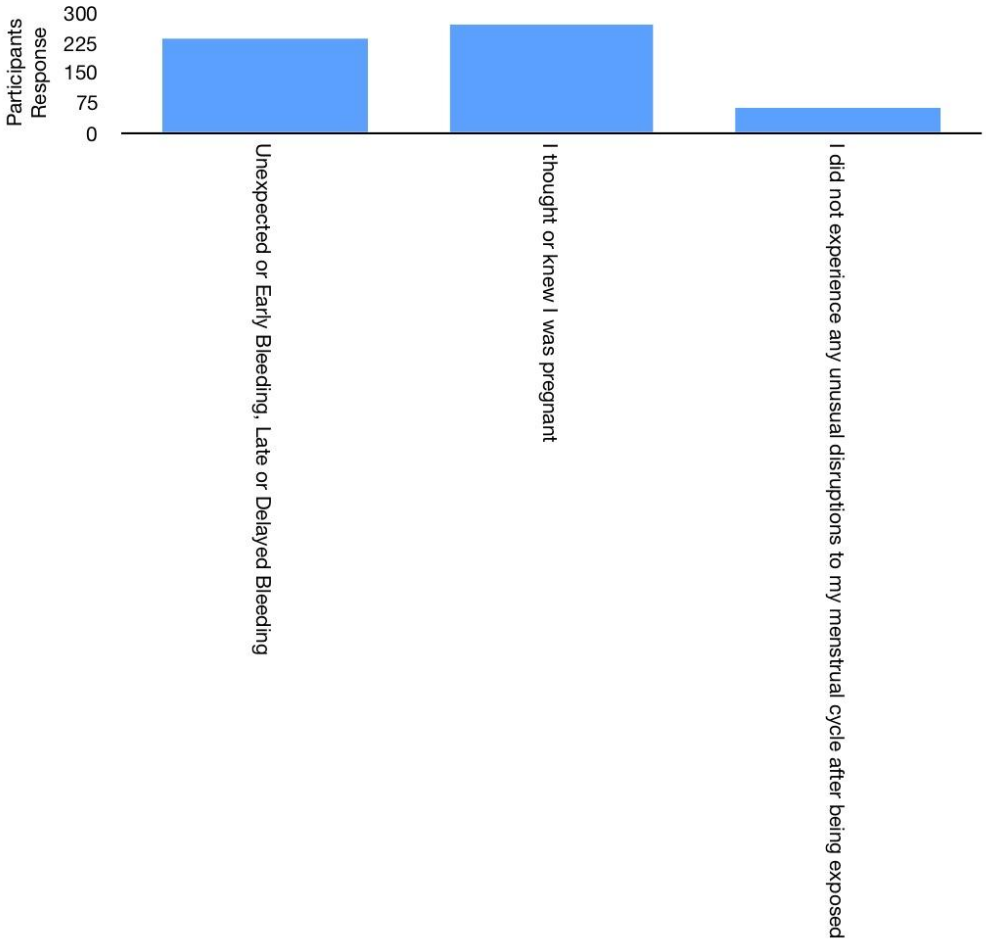

Figure 13. Participants experienced disruption to cycles after exposure (n = 1000)

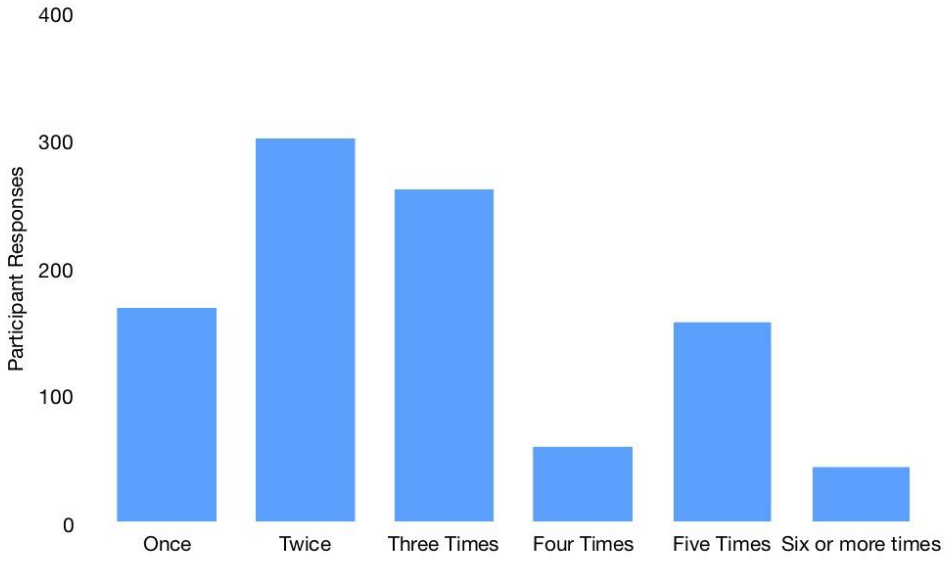

Figure 14. Number of times participants had been exposed to riot control agents (n = 1000).

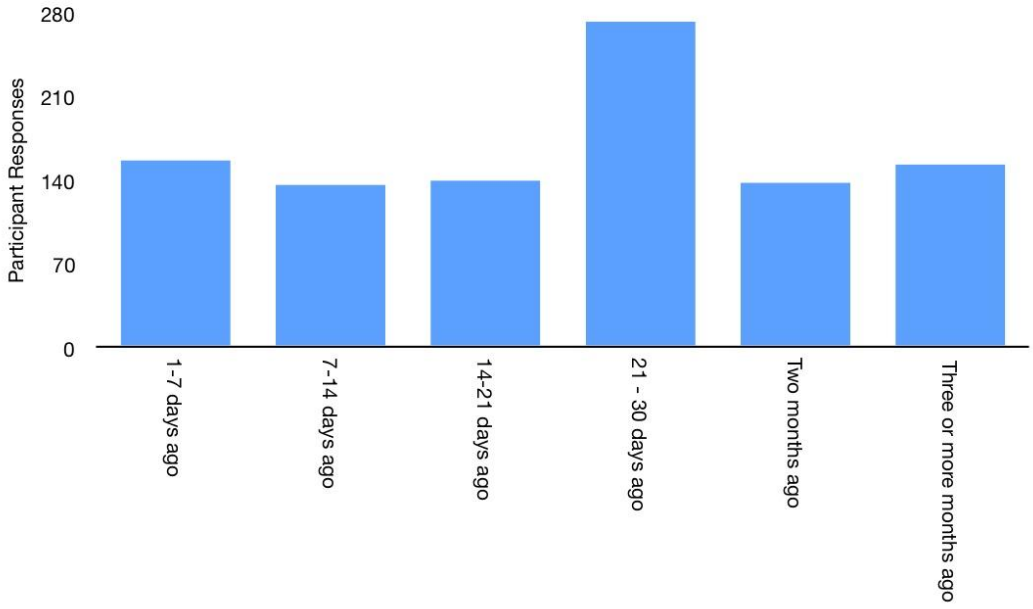

Figure 15. Last recalled exposure to riot control agents (n=1000).

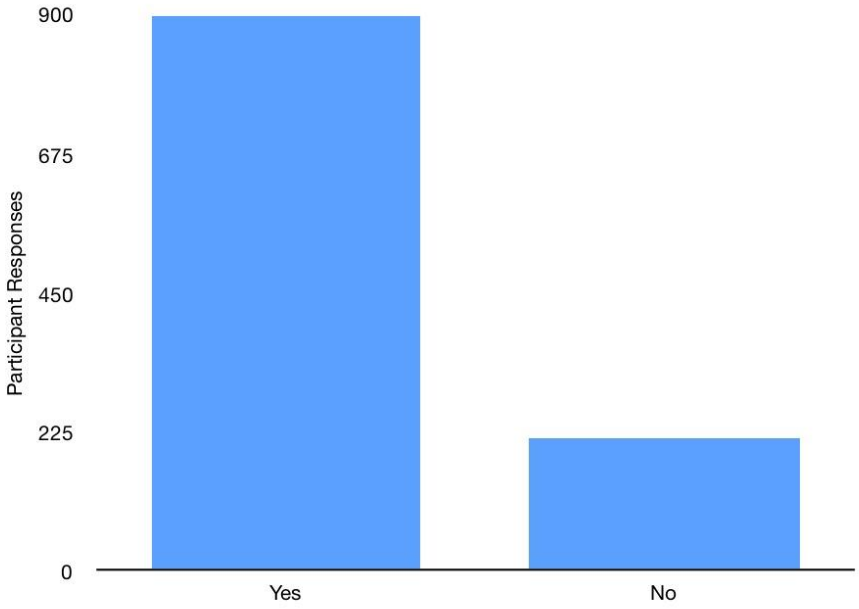

Figure 16. Participants response considering whether or not they believe exposure to riot control agents influenced their menstrual cycle (n = 1000).

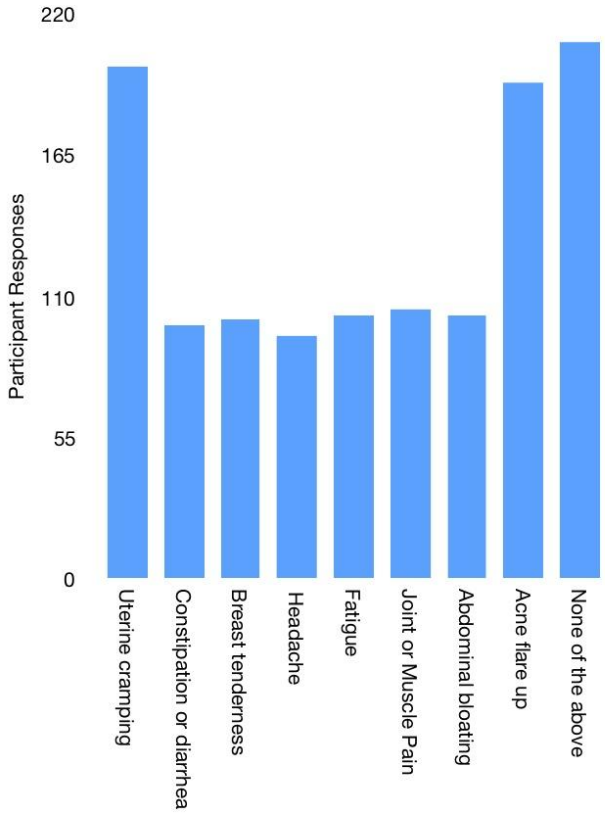

Figure 17. Additional symptoms menstruation/bleeding/period symptoms experienced (n = 1000).