Mathematical Modeling of Muscle Cramps (Technical Project)

The Effect of Attitudes Towards Pregnancy on Women's Health Outcomes Across Cultures (STS Project)

A Thesis Prospectus
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Pregnancy and women's health have been severely underfunded when it comes to researching their diseases (Mirin, 2021). Pregnancy continues to be an understudied subject due to the necessity of extremely thorough research required to make claims and provide medicinal therapies, specifically because any research done on a pregnant individual has the risk of harming the fetus. Pregnancy conditions such as preeclampsia, placenta previa, and preterm labor are examples of just some of the ailments pregnant women may face but do not get studied because of the complexity and difficulty in recreating them to develop treatments. The lack of research in women's health leaves symptoms and outcomes of pregnancy enigmatic in their causes, while pregnancy continues to be treated more poorly than men's health studies.

My technical project will work to advance research done on symptoms of pregnancy. I will be analyzing the different components of muscle and their roles in contraction. Each component either gives or receives signals from the central nervous system, and therefore has a contribution in the formation and relaxation of muscle cramps. Currently, no model has been created that considers the behavior of each element. My technical project will be to create a model that can mimic a muscle cramp and test hypotheses on its complete cycle, from cramp onset to ease of the muscle. The model will be used to confirm or deny current treatment advice on how to stop cramps from forming and provide a baseline for future research on this topic.

My STS project will work to understand how pregnancy is treated in other cultures and countries. Complications, symptoms, and outcomes of pregnancy differ greatly among countries that are "developed" vs. those that are "developing". Differences between the two sets of countries include practices of medicine and societal norms surrounding gender roles. Both could be contributors to the statistics we see, but a deeper dive is necessary to analyze the cause of

these outcomes. To research this problem, I will be holding interviews with professors from the departments of South Asian and African studies and conducting thorough literature searches to find evidence on the differences between women's pregnancy experiences based on country. The result of this project will provide a more informed background for future studies in women's health, emphasizing the need to be more cognizant about attitudes towards pregnancy and the various contributors to these perspectives in different cultural and societal contexts.

Technical Topic

A muscle cramp is defined as a sudden, unexpected tightening of one or more muscles which can be present from seconds to possibly hours. Nocturnal leg cramps are a type of cramp that occur at night and often in the calves. During pregnancy, nocturnal leg cramps affect about fifty percent of women and increase in frequency as the gestation period progresses (Bordoni et al., 2023).

Muscle cramps are a common occurrence in adults, with estimates of over sixty percent experiencing these from time to time (MUSC Health, n.d.). Common remedies prescribed by clinical websites include stretching, massaging, increasing water intake, adding vitamin intake, and applying a heat or cold compress (Mayo Clinic, 2023). This advice encompasses the widest range of treatments that have no evidence for their efficacy (Miller et al., 2021). Behind these remedies are anecdotal evidence that work for some but not others. Pregnant women complain of these insufferable cramps on forums and in obstetrics clinics, but the main remedies continue to be an array of stretches, prescriptions of magnesium, and multiple medications.

Nocturnal leg cramps are poorly studied and there are lists of diseases with which these cramps are linked (Mayo Clinic, 2023). The underlying cause of all muscle cramps are similarly

understudied, even though there is research on parts of muscles. Specifically, it is known how motor neurons innervate different muscle groups and how a contraction is formed (Hunt & Kuffler, 1954). Scientists in the sixties and seventies characterized sensory organs within muscle bodies. These sensory organs consist of muscle spindles and Golgi tendon organs (Nielson & Sinkjaer, 2002). Each of these parts detect properties of the muscle at a given point in time, including length, velocity of contraction, and tension. Sensory neurons innervate these organs and will send signals to the central nervous system that respond to changes in muscle length, tension, or velocity. Based on these signals, the central nervous system will send efferent potentials to the muscle fibers to either contract or relax.

There are multiple hypotheses in literature that postulate the formation and relaxation of cramping. These range from electrolyte imbalances near the muscle fibers to the lack of an inhibitory signal from the central nervous system to stop contraction (Giuriato et al., 2018). These hypotheses are difficult to reliably test in people, as cramps are unexpected and sudden. Instead, there are studies that induce cramps in cats using electrical stimulation of muscle and analyze the electrical signal received from the activated muscle as well (Bentley, 2012). The formation, sustained contraction, and relaxation stages of cramps have neither been modeled nor studied and is the focus of my technical portion.

My technical project will be to model the three stages of a muscle cramp using viscoelastic and mathematical representations of the main components that are proposed to control cramping. Specifically, a muscle activation factor, a contractile element, a muscle spindle component, and a Golgi tendon organ piece all work together in a closed feedback mechanism to avoid the damage of muscle fibers by over-shortening or over-lengthening. I will do this by searching physiological and biomechanical literature for the responses of each component of the

model to an electrical stimulation. I will then mathematically model each component using physical elements such as springs, dashpots, and masses. Each of these components will fit together in a combined feedback loop that will take inputs of muscle properties at the given instance and output contractile force. By doing this, we will be able to test the hypotheses found in literature and make predictions on cramp formation. Finally, we will be able to apply the model and examine whether nocturnal cramps felt by pregnant women differ from cramps induced by acute exercise. Along with my STS project, my goal is to advance research in women's health as well as give insight and context to ailments of pregnancy.

STS Topic

Complications and outcomes of pregnancy as well as advancements in women's health research differ between the US or European countries and India or African countries. The US and countries in Europe are developed countries, as classified by the United Nations, while India and countries in Africa remain developing (United Nations, 2014). Pregnancy complications refer to symptoms and conditions that can occur before, during, or after pregnancy such as anemia, gestational diabetes, and hypertension (Centers for Disease Control and Prevention, 2023). Adverse birth outcomes here refer to stillbirth, abortion, or low birthweight that are the leading cause of infant mortality (Van Dinter & Graves, 2012).

Developing countries experience significantly poorer conditions and outcomes of pregnancy. Infant mortality rates of South Asian (2-10%) and African countries (1-8%) are significantly higher than rates in North American (0.2-1%) and European (0.1-2%) countries (Central Intelligence Agency, n.d.). Truly, statistics surrounding the death, disease, and injury in developing countries has not been fully established, since the countries that have the highest

infant and maternal mortality rates are also countries that have the lowest registration of infant births and neonatal mortalities. Additionally, about ninety-nine percent of maternal deaths occur in developing countries, where one in four women undergo sudden or long-term disabilities related to pregnancy and where the frequency of hemorrhage, sepsis, and unsafe abortion are higher (Bale et al., 2003, p. 8). It is vital to study the underlying cause of such data to close disparities in birth outcomes.

The medicalization of pregnancy also differs between the sets of countries and is a contributing factor of these outcomes. Developing regions such as India and African countries commonly use traditional practices of medicine, which are defined as knowledge and skills based on theories indigenous to different cultures used in the maintenance of health (Che et al., 2024). On the other hand, developed countries such as those in Europe and North America use western medicinal practices, which focus on using scientifically proven methods for diagnosing and treating illness. The two approaches towards medicine that these sets of countries use are both an outcome and contributor to the lifestyle and thinking of these countries' populations. Studies have shown that when women from developing countries immigrate to countries that follow western medicine, they experience challenges adapting to the healthcare system and way of delivering (Hill et al., 2011).

On a broader scale, approaches to gender roles and women's health are also treated differently in these regions, with developing countries treating women's health as taboo. In India, there has always been rhetoric explicitly condemning the birth of female children into families. Over seventy percent of abortions in one area were due to the sex of the fetus being female. For this reason, India banned prenatal sex discernment (Imam, 1994). Compared to the US, India experiences more negative outcomes of gender inequality (Dhar et al., 2018). In Africa,

menstruation shame is rooted in cultural traditions often originating in patriarchal and discriminatory norms about a woman's "place" in society (Africa Health Organization, 2020). The attitudes on women's health and gender roles, as well as the approaches to medicine in these sets of countries, demonstrate the larger backdrop on which pregnancy outcomes lie. To analyze the cause for these outcomes, more research must be done on the way pregnancy itself is treated in each area.

To further investigate the effects of institutions such as medicine and societal norms such as gender bias on women's health, I will utilize the Actor Network Theory (ANT). This framework analyzes both human and nonhuman elements and traces the associations between heterogeneous actors (Cressman, 2018). Both human and non-human actants hold an equal contribution in creating a network, and ANT's most fundamental concept is that the world is filled with assemblages, or actor-networks. Due to the interplay between policymakers, medical practices through surgeries and tools, and individuals holding certain attitudes such as pregnant women and their loved ones, my STS topic will be most thoroughly studied through this framework.

Research Question and Methods

My research question that I will be exploring is: how do attitudes surrounding pregnancy differ between North American/ European (developed) countries and African/South Asian (developing) countries? To answer this, I will be doing a thorough literature search to analyze the experiences and results of pregnancies in the two sets of countries. The sources I find will likely be anecdotal or long-term systematic research done on pregnancy outcomes, so I will constrain my search to the last 30 years to find reliable studies. Additionally, I will broaden my focus to

examine the cultural differences between pregnancy practices within each region. I hope to interview at least 4 professors from the departments of South Asian and African studies in a semi-structured way to gain an insight on societal and historical factors that could contribute to these views on pregnancy. I will also be interviewing US and European studies professors that will be able to give an insight on the cultural factors contributing to pregnancy care in these countries.

Conclusion

My technical project will result in a mathematical model of muscle cramps that will be publicly available for future researchers to use. The outcome of my STS project will be a greater understanding on the attitudes towards pregnancy in different cultures and societal contexts, and how these attitudes affect pregnancy experienced by the women of those societies. I hope that the technical portion will be used further in women's health studies to test ways of treating cramps. Researchers will be able implement new parameters into the model to see if a contraction will be sustained under different conditions. Through my STS portion, I hope that governments and researchers in different countries will recognize how their approaches to pregnancy contribute to disparate health outcomes for women. Combined, my projects will serve to increase the importance that is placed on women's health research.

Word count: 1,940

References

Bale, J. R., Stoll, B. J., & Lucas, A. O. (2003). *Improving Birth Outcomes: Meeting the Challenge in the Developing World*. National Academies Press.

Bentley, S. (1996). Exercise-Induced Muscle Cramp. *Sports Medicine*, *21*(6), 409–420. https://doi.org/10.2165/00007256-199621060-00003

Bordoni, B., Sugumar, K., & Varacallo, M. (2023). Muscle Cramps. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK499895/

Che, C.-T., George, V., Ijinu, T. P., Pushpangadan, P., & Andrae-Marobela, K. (2024). Chapter 2—Traditional medicine. In S. B. McCreath & Y. N. Clement (Eds.), *Pharmacognosy (Second Edition)* (pp. 11–28). Academic Press. https://doi.org/10.1016/B978-0-443-18657-8.00037-2

Cressman, D. (2018). *Actor-Network Theory*. 1–2. https://doi.org/10.1002/9781405165518.wbeosa009.pub2

Dhar, R., Prakash, V., & Singh, B. (2018). Gender Inequality: A Comparison of India and USA. In NILERD (Ed.), *Reflecting on India's Development: Employment, Skill and Health* (pp. 251–269). Springer. https://doi.org/10.1007/978-981-13-1414-8_12

Dinter, M. C. V., & Graves, L. (2012). Managing Adverse Birth Outcomes: Helping Parents and Families Cope. *American Family Physician*, *85*(9), 900–904.

Giuriato, G., Pedrinolla, A., Schena, F., & Venturelli, M. (2018). Muscle cramps: A comparison of the two-leading hypothesis. *Journal of Electromyography and Kinesiology*, *41*, 89–95. https://doi.org/10.1016/j.jelekin.2018.05.006

Hill, N., Hunt, E., & Hyrkäs, K. (2012). Somali Immigrant Women's Health Care Experiences and Beliefs Regarding Pregnancy and Birth in the United States. *Journal of Transcultural Nursing*, *23*(1), 72–81. https://doi.org/10.1177/1043659611423828

Hunt, C. C., & Kuffler, S. W. (1954). Motor innervation of skeletal muscle: Multiple innervation of individual muscle fibres and motor unit function. *The Journal of Physiology, 126*(2), 293–303. https://doi.org/10.1113%2Fjphysiol.1954.sp005210

Imam, Z. (1994). India bans female feticide. *BMJ (Clinical Research Ed.), 309*(6952), 428. https://doi.org/10.1136/bmj.309.6952.428

Infant mortality rate. (n.d.). The World Factbook. Retrieved October 27, 2023, from https://www.cia.gov/the-world-factbook/field/infant-mortality-rate/country-comparison/

Maughan, R. J., & Shirreffs, S. M. (2019). Muscle Cramping During Exercise: Causes, Solutions, and Questions Remaining. *Sports Medicine, 49*(S2), 115–124. https://doi.org/10.1007/s40279-019-01162-1

Miller, K. C., McDermott, B. P., Yeargin, S. W., Fiol, A., & Schwellnus, M. P. (2021). An Evidence-Based Review of the Pathophysiology, Treatment, and Prevention of Exercise-Associated Muscle Cramps. *Journal of Athletic Training, 57*(1), 5–15. https://doi.org/10.4085/1062-6050-0696.20

Mirin, A. A. (2021). Gender Disparity in the Funding of Diseases by the U.S. National Institutes of Health. *Journal of Women's Health*. https://doi.org/10.1089/jwh.2020.8682

Muscle Cramps & Spasms. (n.d.). Medical University of South Carolina Health. Retrieved October 27, 2023, from https://muschealth.org/medical-services/geriatrics-and-aging/healthy-aging/cramps-and-spasms

Nielsen, J. B., & Sinkjaer, T. (2002). Afferent feedback in the control of human gait. *Journal of Electromyography and Kinesiology, 12*(3), 213–217. https://doi.org/10.1016/S1050-6411(02)00023-8

Pregnancy Complication. (2023, February 8). Centers for Disease Control and Prevention. Retrieved October 27, 2023, from https://www.cdc.gov/reproductivehealth/maternalinfanthealth/pregnancy-complications.html