**Optimizing Recovery for Female Endurance Athletes Using Machine Learning and Wearable Technology**
(Technical Project)

**Examining Gender Disparities in Endurance Athlete Research and Recovery Technologies**
(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

Participating in sport, whether at the professional or recreational level, is a demanding endeavor, but have you ever wondered what distinguishes exceptional athletes from the rest? Beyond rigorous training and innate talent, a key differentiator is the ability to recover quickly and smartly after workouts. Endurance athletes are notorious for undertaking large training volumes to enhance adaptations and subsequently improve performance. These high training loads often lead to an imbalance between stress and recovery. Stress is defined as the destabilization or deviation from the norm in a biological and/or psychological system (Braun-Trocchio et al., 2022). Stress can appear in two forms: physical stress, which refers to the physical fatigue induced during training and/or competition, or physiological stress, which occurs when people perceive that the demands from external situations are beyond their coping capacity. Both physical and physiological stress directly impact an endurance athlete's ability to recover (Jeffreys, 2005).

While all endurance athletes must strike a balance between stress and recovery, there is an even more specific and underserved aspect of this equation: the unique recovery needs of female athletes. Historically, the field of endurance athlete recovery, *and* sports science in general, has faced a significant gender gap. Data extracted from 1,382 original sports and exercise medicine research articles, involving a total of 6,076,580 participants, found that the average percentage of female participants per article ranged from 35% to 37% (Costello et al., 2014). Females are significantly under-represented in sports research and technology development because past efforts have predominantly focused on male athletes.

The existing bias in sports research and technology development is not simply a matter of equity. It impacts the health and performance of female athletes, who have unique physiological characteristics that significantly influence their training, recovery, and overall well-being. One of

the key factors contributing to these differences is the hormonal fluctuations that occur due to the menstrual cycle. There is a need for further research to quantify the impact of the menstrual cycle on perceived and physical performance outcomes, ultimately affecting recovery needs, in female athletes (Carmichael et al., 2021).

My thesis portfolio focuses on the historical lack of female-specific research and technology development in the field of endurance athlete recovery through both a technical and STS topic. The technical aspect of my prospectus outlines a project aimed at developing a specialized mobile application that integrates wearable device data and employs machine learning to provide personalized recovery recommendations for female endurance athletes. My STS topic will examine the impact that the historic gender gap has had on the performance and well-being of female athletes and determine what can be done to bridge it.

**Technical Topic**

Sports science professionals aim to apply evidence-informed approaches to optimize athlete performance and well-being. However, practices such as training and recovery protocols, nutritional strategies, and injury prevention interventions in female sports are often underpinned by research conducted on male athletes. This bias can be attributed to the limited representation of female athletes in the sports performance literature (Emmonds et al., 2019).

In recent years, there has been an exponential rise in the professionalism and profile of female sports. The gender bias in sports science research is finally receiving the attention it deserves, with an increasing realization of the significant impact that the menstrual cycle has on female athletes' physical performance. Researchers have highlighted the menstrual cycle as a crucial factor in women's sport, leading to a growing need for further research and gender-specific considerations in sports science research (Carmichael et al., 2021).

One existing technology in the field of athlete monitoring is the WHOOP wearable fitness tracker. The WHOOP strap is a popular device that tracks various physiological metrics like heart rate, sleep, and recovery to improve an athlete's training and fitness. It is designed to calculate the exertion you put on your body to measure both cardiovascular and muscular load. However, it is not gender-specific, and its algorithms are primarily based on data from male athletes, which can lead to less accurate insights for female athletes (Lundstrom, 2020).

My technical project is aimed at addressing this issue by developing a specialized mobile application that integrates wearable device data and employs machine learning to provide personalized recovery recommendations tailored to female endurance athletes. I will build off past methods of training monitoring that assess both external (an objective measure of the work that an athlete completes during training or competition) and internal loads (the biological stress imposed by the training session) (Kellmann et al., 2018). However, I will focus on understanding the impact of the menstrual cycle on female athletes to design effective and personalized recovery strategies. For example, certain phases of the menstrual cycle are associated with higher injury risks, increased susceptibility to fatigue, and altered responses to training loads. Neglecting these nuances can lead to inadequate recovery practices, decreased performance, and potential health issues for female athletes (Temm et al., 2022).

Machine learning offers a promising method for analyzing extensive datasets and personalizing recommendations based on individual athlete data, with wearable technology allowing for real-time data collection and monitoring. However, it will be crucial to gather substantial and diverse data from female athletes, ensure the accuracy and effectiveness of the machine learning algorithms, and develop a user-friendly mobile application.

**STS Topic**

Gender equity is a fundamental issue. The are countless instances of women facing gender bias in their careers, education, relationships, and athletic opportunities. The purpose of my STS project is to examine the history of gender inequity in sport, how it has contributed to the under-representation of women in sports exercise science, and its impact on female endurance athletes in terms of performance and recovery. It is important to understand that sports research and technologies have predominantly focused on male athletes, often assuming that findings could be universally applied to both men and women.

Women were historically excluded from significant sporting events like the ancient Greek Olympics, setting a precedent for gender disparities in sports. In the United States, progress towards women's involvement in sports did not gain substantial traction until the late 19th and early 20th centuries, albeit gradually. However, opportunities for women remained limited, with minimal recognition and support. These inequities extended to funding and resources, with women's sports programs often receiving fewer resources than their male counterparts. Media coverage and public attention predominantly favored men's sports, perpetuating the notion that men's athletic endeavors were more significant. These disparities were reinforced by gender stereotypes that portrayed women as less competitive, capable, or interested in sports (Chalabaev et al., 2013).

This historical backdrop has directly translated into inequities in sports research and technology, affecting women's performance and well-being. The limited representation of female athletes in sports science research and technology development has meant that many scientific advances have not benefited female athletes to the same extent as their male counterparts. This is

particularly evident in endurance sports, where the “one-size-fits-all” training, nutrition, and recovery guidelines developed have been based on research conducted on men.

A prime example of the adverse effects of this gender bias can be observed in ultrarunning. A prevalent practice among ultramarathon runners, both male and female, involves endurance training in a fasted or low carbohydrate availability state, aiming to improve the body's ability to oxidize fat, spare muscle glycogen, and delay fatigue. Research based primarily on male athletes has shown potential benefits to this practice. When applied to female athletes, however, this approach can have undesirable health consequences. Research has revealed that within-day energy deficits, as experienced in practices like fasted training, can lead to clinical markers of metabolic and menstrual disturbances in female endurance athletes (Kelly, 2023). This underscores the importance of developing gender-specific strategies that consider the unique physiological characteristics of female athletes.

Additionally, the language and culture of sports science itself have been tailored predominantly to male athletes, creating a hostile environment for female participation that often neglects women's experiences. The recruitment language in sport science is often very masculine and aggressive, which can undermine a woman’s confidence in their ability to be an active participant. When the research findings among women differ from those of men, as demonstrated in a study on carbohydrate and fat oxidation, the consequences of gender bias are clear. For instance, a female participant encountered a situation where the results of her participating in an experiment were different than those of her male counterparts. Instead of considering the impact that a test subject’s gender might have, these disparities were attributed to her inadequately executing the experiment. This ultimately led to the dismissal of her results in the overall data recordings (Bowen et al., 2009). This action perpetuates a cycle of neglect, reinforcing the

tendency to overlook the distinctive requirements and responses of female athletes. These instances further illustrate the impact of the gender gap in sports science on the well-being and performance of female athletes.

**Research Question & Method**

The question I will set out to answer is: How does the historical lack of female-specific research and technology development in the field of endurance athlete recovery impact the performance and well-being of female athletes? To answer this, I will start by reviewing existing research in the Springer Sports Medicine Journal to identify gaps in knowledge and gender disparities in sports science and technology. I will also examine historical data in literature reviews to assess how female athletes have been considered compared to males in research and technology development, as well as evaluate existing recovery technologies and their applicability to female athletes. I will then gather data through interviews with female endurance athletes at UVA, coaches, and experts to understand their experiences and needs with recovery-specific technology. Ideally, I will take all this information to create recommendations to promote gender equity in sports research and technology development.

I will utilize STS concepts from feminist science studies, such as those exploring gendered technology, to further understand how gender bias can permeate technological developments in sports science (Åsberg, & Lykke, 2010). These concepts will guide my examination of how technology in sports has often been designed with a male-centric approach, excluding the specific needs and experiences of female athletes. My research approach will also take inspiration from sociotechnical systems studies, which analyze the interplay between technology, society, and individuals. These concepts help frame the discussion of how gender

bias in sports science is not just a matter of individual prejudices, but is deeply embedded in the systems and structures of the field.

**Conclusion**

The anticipated deliverable of my technical project is a specialized mobile application that integrates wearable device data and utilizes machine learning to provide personalized recovery recommendations tailored to female endurance athletes. In conjunction, my STS research seeks to improve our understanding of gender bias in sports science, contributing to a more equitable representation of women in research and technology development. Successful implementation of these topics could help address the historical lack of female-specific research and technology, potentially enhancing the performance and well-being of female athletes. By challenging these established biases, I hope to provide female endurance athletes with tailored strategies to optimize their training and recovery, ultimately fostering gender equity in sports science and improving the overall experiences and outcomes for women in sports.

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