A SIMPLE APPROACH TO MONITORING FEMALE ATHLETE PERFORMANCE

BREAKING BARRIERS: INEQUITIES IN FEMALE ATHLETE SPORTS INJURY RESEARCH AND TREATMENT IN THE U.S.

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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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General research problem

How can gender disparities around fitness in the United States be improved?

When thinking of influential figures in earlier American bodybuilding, one may think of several trademark names including Arnold Schwarzenegger, Ronnie Coleman, or Lou Ferrigno. During this era, the fitness industry was undeniably male-dominated, and the prevailing belief was that women engaging in intense physical activities, such as weightlifting, would compromise their femininity. It was believed that a woman should not put her body through too much physical stress from exercise and that muscle hypertrophy was reserved for men only. The emergence of the women's rights movement in the 1970s and 80s challenged these stereotypes, leading to a shift in societal expectations.

The evolving landscape of women's participation in sports and exercise is evident in recent data, illustrating a gradual increase in female engagement over the years (Fig. 1). Despite these positive trends, however, a closer examination from other research reveals a concerning pattern: lower physical activity levels in women from childhood to adulthood compared to their male counterparts (Craft et al., 2014). This discrepancy has far-

Figure 1: U.S. average population percentage engaging in daily physical activity, 2010-2022 (author; data from Gough, 2023).

reaching implications in women's health, contributing to heightened risks of cardiovascular disease and type 2 diabetes (Edwards and Sackett, 2016). On top of this, women have less access and availability to healthcare and injury treatments in comparison to men as women have been historically under researched. Furthermore, the fitness industry continues to have more male leaders than female. Unequal representation in fitness and the view that muscles on a woman are
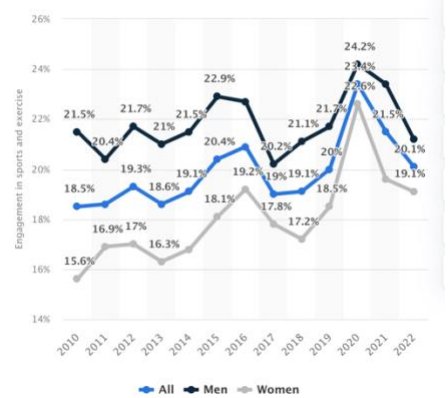
unfeminine needs to be dispelled for the mental and physical health of women in American society. To address this challenge effectively, it is crucial to explore innovative strategies, both technically and sociotechnically, that promote gender inclusivity in fitness-related endeavors and healthcare practices. Overcoming the gender disparities around fitness in the U.S. will allow for a more equitable society where views on fitness are not limited by one's gender.

Reducing female-related sports injuries among female athletes

How can female-related sports injuries be prevented?

Wearable Biomedical Sensors to Monitor Female Athlete Performance

This independent project focuses on the creation of a preventative plan for sports injuries in females. Women's health care and research have been historically overlooked due to lack of inclusion, biases, and large underfunding, so it is important to understand and be more proactive when it comes to female injuries. Biologically, women are different from men in anatomy and physiology. These differences in anatomy cause women to be more prone to certain injuries than others including anterior cruciate ligament (ACL) tears, stress fractures, tendonitis, shin splints, ankle sprains, and joint pain due to hypermobility in exercising women. For example, ACL injuries are more common in females compared to males because female athletes tend to jump and land in an upright position and knees pointing inward. This adds extra stress, as well as the fact that women use mainly the quadriceps (instead of also the hip and glute muscles) for a jump (TRIA. n.d.). In terms of hormones, lower levels of oestrogen increase the risk of osteoporosis which reduces 10% of bone mass five years after menopause (BetterHealthChannel, 2023). The menstrual cycle alone can lead to lower performance with its monthly side effects of muscle weakness, blood loss, and cramps from the production of more progesterone (Carmichael et al.,

2021). So how do we overcome the biological differences between men and women in exercise with a biomedical sensor?

Establishment of three main goals will help determine success of an advanced monitoring system measuring a female athlete's movements. First, this system will contribute to reduction in female-related sports injuries using biomedical sensors as wearable accessories such as a smart watch. These sensors will collect real-time data on the athletes' movements and vital signs for early detection of injury risks and preventive measures. Over time, the collected data can help diminish the injuries females are more prone to and increase overall athletic success through the second goal, which is creating a personalized injury-prevention plan. This plan will use the collected data from the smart watch and update to an app in real-time. The data will be analyzed by AI to detect any irregular movements or patterns from the athlete in real-time and provide feedback on what the data may indicate for coaches and athletes to review. The focus will be on addressing specific vulnerabilities to the athlete to optimize training. The third goal involves improving on existing advanced technological sensors to provide a system that offers a holistic approach to sports training and injury prevention. There are several types of biomedical sensors on the market including biological and chemical sensing, electrocardiogram (ECG) and electroencephalogram (EEG)-based neural sensing platforms (Seshadri et al., 2019).

Unusual constraints to address would involve the sensors' integration into the athletic apparel and data collection. Sensors need to be integrated in such a way that they are comfortable for athletes to wear during prolonged periods of physical activity without hindering performance. Furthermore, the sensors must be robust enough, so they are not negatively affected by environmental factors such as water, heat, cold or physical impact such as tackles or an accidental fall depending on the sport. Lastly, implementing privacy measures to protect athletes'

sensitive health and performance data is vital to ensure compliance with legal regulations and ethical guidelines. Today, sports teams hire 'sports scientists' who handle athlete data, but the design will have numerous safety measures to reduce possible data leaks and allow for easier accessibility for coaches and athletes.

Other technologies that exist to determine athlete's performance are time-motion analysis systems that use videos to track and measure movements. There are biological and chemical sensor types being the more cost-effective alternative to other platform types. What sets this sensor design approach apart from other products and designs, however, is the creation of a clear personalized injury prevention plan for female athletes based on collected and formerly integrated data from past research. Current systems provide feedback to users, but it is up to the user to interpret such data and look up the meaning behind most of it. By making a system that addresses the measured parameters and creates a plan specific to females while also explaining it with the help of AI, athletes and coaches will have a better understanding of injury-prevention and realistic goal setting which can be adjusted in the app, such as increasing an athlete's strength or endurance. Many existing systems do not fully utilize the potential of advanced data analysis techniques such as machine learning and predictive modeling to anticipate injury risks accurately.

For this study, conducting a review of existing literature and technologies is important to incorporate into the machine learning portion of the project. Based on this prior research (which will be updated yearly), AI can accurately provide a treatment and training plan specific for the athlete. Experimental studies would need to be conducted where female athletes wear a prototype wearable sensor system as they do various physical activities. Studies would need to be separated based on the sport being played as movements and other metrics vary. Heart rate, body

temperature, oxygen levels, and movement patterns will be measured, and machine learning algorithms will analyze the data compared to existing models and locate any patterns that may occur. This can, but is not limited to, helping predict performance levels, detecting fatigue, and optimizing training routines. Lastly, interviews, surveys and collaboration with athletes, coaches, sports professionals, and scientists for qualitative data is important to determine comfort level of wearing the accessory and how data is presented on the user-friendly interface and application.

The project's success will be determined by pinpointing vulnerabilities in female athlete movements, advancing and providing more data to women's health research in sports, and ultimately reducing the gender gap in fitness. With the help of AI, the research aims to create an app accessible to coaches and athletes that offers insights to prevent injuries during training based on data measured from the wearable biomedical sensors. Tailored adjustments and clear suggestions to enhance athletic performance will be provided.

Breaking Barriers: Inequities in Female Athlete Research in the United States
In the U.S., how are women's health advocates, researchers, and medical professionals striving to reduce disparities in research related to female athletes' health and treatment?

The differences in women's treatment concerning sports-related injuries compared to men's creates a large gap that needs to be better addressed and reduced. This issue is relevant as it impacts the overall well-being and performance of female athletes, affecting their participation in sports and their physical and mental health. Inclusion of more females in research studies to determine better treatment options are essential determinants of athletes' recovery and future athletic endeavors. Recently, the exploration of inequities between male and female athletes in sports medicine research was conducted and found that studies focused more on male athletes at

5

70.7% and on what are considered male-dominant sports such as baseball, soccer, American football, basketball, and rugby. In comparison, only 8.8% included females which frequently looked at softball and volleyball (Paul et al., 2022). In another study, an "imbalance of female-specific sports science and sports medicine (SSSM) research" was evident with only 39% women contributing to the participant pool of explored papers and journals (Smith et al., 2022). It is known that women are biologically more prone to specific injuries than men, but a paper exploring why ACL injuries are more common in females highlights the importance of looking at "gendered societal and environmental decisions," and that they can be due to "a significant disparity in training, coaching and competitive resources in female sports." Silvers-Granell, 2021. From the current research, the gender gap in female athletics results from women is clearly under researched and underrepresented in studies and particular sports. It is important to increase inclusivity to prevent avoidable injuries in women's athletics.

Today, several major participants are pushing to understand and diminish the female athlete disparities, including women's health advocates programs, researchers, and medical professionals. The following groups are vital in pushing for females athletes' access to accommodating health and treatment through research. Prevention and treatment of clinical issues and injuries for female athletes has been examined with the help of the Female Athlete Program, a 501(c)(3) nonprofit group established in 2013, with a mission to "close the disparity in research and treatment of female athletes" recognizing that "females differ from males in many aspects of general health, sport performance, training, and management for sport-related injuries." (Female Athlete Conference, 2023) They have a Biennial International Female Athlete Conference that brings medical professionals and athletes together to discuss research topics including bone health, nutrition, energy deficiency and low energy availability, and sports injury

research (Farnsworth et al., 2021). Similarly, the Women's Sports Foundation (WSF), founded in 1974, has a goal to "create new inroads for all genders, inside and outside of sports" and "inspire generations of female athletes and cultivate paths for women to realize their full potential in life, through sport." They achieve this through research funding, advocacy, education, and leadership. They have partnered with over 1,000 champion athletes across the country to help with their mission (Women's Sports Foundation, 2023). A new research program from 2023 by Stanford called Female Athlete Science and Translational Research (FASTR) (Zimmerman, 2023) has similar goals to innovate "ways to improve the health of female athletes of all abilities through athletic participation and performance." They are "committed to addressing the gender gap in sports science research" while focusing on "early identification and intervention of injury" for female athletes (FASTR, 2023). By working with athletes, coaches, and practitioners, these programs are able to research and educate female athletes on their health.

References

BetterHealthChannel. (2023). Menopause and osteoporosis. *Reproductive system – female*. https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/menopause-and-osteoporosis.

Carmichael, M. A., Thomson, R. L., Moran, L. J., & Wycherley, T. P. (2021). The Impact of Menstrual Cycle Phase on Athletes' Performance: A Narrative Review. *International journal of environmental research and public health*, *18*(4), 1667. https://doi.org/10.3390/ijerph18041667

Craft, B. B., Carroll, H. A., & Lustyk, M. K. (2014). Gender Differences in Exercise Habits and Quality of Life Reports: Assessing the Moderating Effects of Reasons for Exercise. *International journal of liberal arts and social science*, *2*(5), 65–76.

Edwards, E. S., & Sackett, S. C. (2016). Psychosocial Variables Related to Why Women are Less Active than Men and Related Health Implications. *Clinical medicine insights. Women's health*, *9*(Suppl 1), 47–56. https://doi.org/10.4137/CMWH.S34668

Farnsworth, N., Holtzman, B., McCall, L., Whitney, K. E., Keating, M., Moretti, L., ... Ackerman, K. E. (2021, October 1). The 2019 Biennial International Female Athlete Conference Proceedings. Women In Sport & Physical Activity Journal, 29(2), 163 - 173.

FASTR. (2023). Stanford Female Athlete Science and Translational Research Program. *Stanford University*. https://fastr.stanford.edu/

Female Athlete Conference. (2023). The Female Athlete Conference 2023. https://www.femaleathleteconference.com/about

Figure 1. Percentage of U.S. population engaged in sports and exercise per day 2010-2022. Note. Source: Adapted from "Average percentage of the population engaged in sports, exercise, and recreation per day in the United States from 2010 to 2022" by Gough, Christina, 2023, Statista.

Paul R.W., Sonnier J.H., Johnson E.E., et al. Inequalities in the Evaluation of Male Versus Female Athletes in Sports Medicine Research: A Systematic Review. The American Journal of Sports Medicine. 2023;51(12):3335-3342. doi:10.1177/03635465221131281

Seshadri, D.R., Li, R.T., Voos, J.E. *et al.* Wearable sensors for monitoring the physiological and biochemical profile of the athlete. *npj Digit. Med.* **2**, 72 (2019). https://doi.org/10.1038/s41746-019-0150-9

Silvers-Granell, H. (2021, August 1). Why Female Athletes Injure Their ACL's More Frequently? What can we do to mitigate their risk?. International Journal of Sports Physical Therapy, 16(4), 971 - 977.

Smith, E. S., McKay, A. K.A., Ackerman, K. E., Harris, R., Elliott-Sale, K. J., Stellingwerff, T., & Burke, L. M. (2022, March 1). Methodology Review: A Protocol to Audit the Representation of Female Athletes in Sports Science and Sports Medicine Research. International Journal of Sport Nutrition & Exercise Metabolism, 32(2), 114 - 127.

TRIA. (n.d.). Why are female athletes more prone to certain injuries? *Women's sports medicine,* https://www.healthpartners.com/blog/active-women-are-more-prone-to-certain-injuries-than-men/.

Women's Sports Foundation. (2023). Women's Sports Foundation. https://www.womenssportsfoundation.org/who-we-are/#:~:text=The%20Women's%20Sports%20Foundation%20(WSF,inside%20and%20outside%20of%20sports

Zimmerman. (2023). A New Program Aims to close the Gender Gap in Sports Science Research. *Training & Performance*, Outside. https://www.outsideonline.com/health/training-performance/stanford-fastr-female-athlete-research/