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Not Small Men: The Lack, the Need and the Implementation of Female Input in Sport Engineering, with an Emphasis on the Cycling Industry

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Abstract

'If Manny is for a male mannequin, then is there a Wo-Manny for females?' A rather whimsical, yet relatively insightful question that arose on completion and presentation of my Master's thesis 'Optimising Bicycle Fitting for Aerodynamic Performance'. The question forms the basis of this paper, which highlights the absence of female physical and computational models within sports engineering with an emphasis on the cycling industry. This paper discusses the implication of male assumption on female athletes, and how inclusion can improve the future of research and development. The research was performed by surveying prominent sports engineering researchers, particularly those involved with creation of 3D models for CFD analysis, as well as physiologists and female athletes. Current literature and personal insight have been included to further highlight the research. A thematic analysis showed that there is a need to challenge, not just the cycling industry, but the sports engineering industry as a whole when it comes to the inclusion of female input. This paper serves as a call to action for the cause.

Keywords

women in cycling; sports engineering

1 Introduction

The adage 'women are not small men' crops up in a multitude of ways within the sports industry. In physiological capabilities, training styles, nutrition, and now, with the rise of computational modeling and 3D scanned figures, sports engineering.

There has been an exponential growth in female cyclists. From 2012 to 2020, an 85% increase in female professional teams and an 80% increase in female cyclists has been seen (Van Erp, 2019). However, this is not apparent in research and testing, where reference to elite male participants, and model imagery is dominant (Chowdhury, Alam, & Mainwaring, 2011; Schaffarczyk, Koehn, Oggiano, & Schaffarczyk, 2022; (Defrayeye, Blocken, Koninckx, & Hespel, 2010) (Figure 1). While still a minority group (1/4 of Irish cyclists being female) (Carroll, Brazil, Morando, & Denny, 2020), there is a significant existence of female cyclists, amateur and professional, that requires sufficient study. There exists a multitude of barriers, from the inception of female cycling, which possibly impacts the existence of female-based analysis.

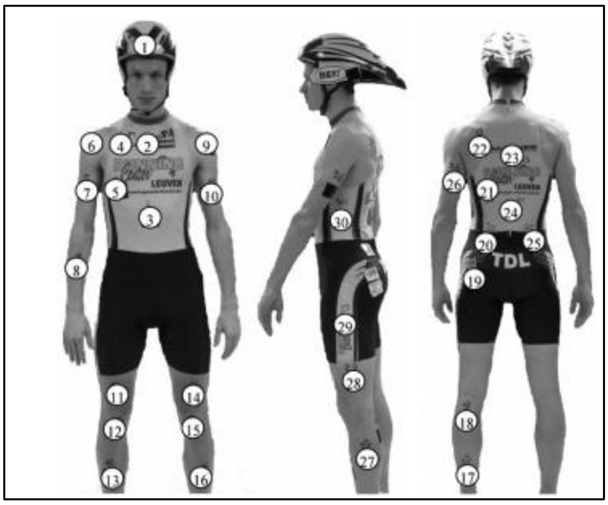

Figure 1. The common references for cycling research and CFD – male, elite (Defrayeye, Blocken, Koninckx, & Hespel, 2010)

1.1 History of Female Cycling

Cycling officially began as a sport in 1868 (Abt, 2025). However, women's professional cycling was not recognized as a sport until the 1990s, with Kitty Knox becoming the first woman accepted into the League of American Wheelman (bikeleague, 2013). 1955 saw an emergence of the 'equivalent' Tour de France races for women, (Heine, 2022) with the inaugural Tour de Femmes established in 2022. In comparison, the official Tour De France began in 1903, 50 years previously. This year, 2025, saw the resurgence of the female Milan San Remo, after its discontinuation in 2006 due to lack of spectator interest and athlete participation.

The staggered reception of female cycling has impacted developments in the infrastructure available to female cyclists. Since the first bicycle engineered in 1817, there was never a 'male specific' model required. It appears that the bicycle was indeed 'made for men'. Following the invention of the Rover Safety Bicycle in 1855 (Watson, 2017), there began a focus on engineering female specific bicycles.

Seeing as there has been significant advancements in the engineering of bicycles, the physical construction, specific aerodynamic advantages to positions to riders, and training and physiologic methods within cycling, it would be remiss to exclude female input from these developments (Blocken, 2014; Crouch, Burton, LaBry, & Blair, 2017; Lukes, Cin, & Haake, 2005).

1.2 Female Specific Requirements

Understanding the societal as well as physical differences and requirements of female cyclists compared to men is an important consideration to make when we think of constructing a piece of equipment – a bike – that requires very specific human contact, and synthesis with human anatomy.

On average, men are taller, with longer limbs, so female specific bike frame setup is required i.e. longer and shorter top tubes respectively. Women also have more flexible lower bodies, greater knee valgus, and hip adductor strength. During cycling, they have increased anterior pelvic tilt in drop position and increased pelvic motion (LIV Bikes, 2021). Weisshaar & Ploeg (2008) composed a study on the influence of gender on pelvic motion and observed substantial pelvic motion in women and suggested that their research, along with an evaluation of pressure distribution, can aid in a better understanding of designing bicycles and components for women.

UCI, and now Ironman, have banned the use of chest fairings due to their aerodynamic advantage. Following Gustav Iden's win at the 2022 Ironman World Championship, where the pro was spotted with a water bottle inserted in the front of his tri suit, Ironman's rules state: *"…additional equipment that has the effect of reducing wind resistance is prohibited during the bike segment of the Race (whether such equipment is worn under the athlete's clothing, over the athlete's clothing, or is otherwise attached to the athlete's body or the athlete's bike)."*, with the following amendment being subsequently added for the 2024 season *"This includes, but is not limited to, (i) any bottles/hydration or any other insert located in the front of an athlete's race suit and (ii) any insert in an athlete's calf sleeves"* (Lacke, 2024).

The addition of a chest fairing in cycling has already been known to reduce drag, which has been further studied in the recent paper on 'CFD analysis of chest fairings in time trial cycling' (Blocken, Malizia, & van Druenen, 2024). The study looks at a full-scale manikin of a male person of 177 cm and 65 kg in time trial position on a time trial bicycle, with the addition of 3 variations of chest fairing. Significant drag reductions were found, with a time gain up to 19.5 seconds over a 25 km time trial being estimated. It comes down to tenths and thousandths of seconds to determine the winners of cycling races, so these gains are not insignificant.

It could be considered that female athletes have natural chest fairings. Rabino (2018) conducted a CFD analysis on the human wake of a fictional model (Figure 2), comparing a buxom, and reduced breast size model (Normal and Flat). It is shown that the Normal model demonstrates similar characteristics of drag reduction and vortex generation that is seen with the addition of chest fairings. There is a useful application to sports performance engineering seen in this study, although further research is required. The models are analysed in standing upright position, there are additional accessories included in the study which are worn by the model in media, and the hair is represented as a solid body. The Normal model is quite exaggerated being a fictional character, which again, calls for the necessity for the use of real-life female athletes in computational analysis to fully understand the aerodynamic performance in a more realistic and applicable simulation.

Figure 2. Physical and aerodynamic analysis of Miss. Kobayashi – is this the best we can do regarding female computational modelling? (Rabino, 2018)

The menstrual cycle is a defining characteristic of female identifying athletes and has been shown to affect athletic performance through each phase (Findlay, et al., 2020). Strength, mood and susception to injury are all factors that must be acknowledged during the various menstrual phases. One cannot apply a 'one size fits all' male training program to compliment a female athlete due to these factors.

It is noted, however, that there are very few articles available discussing the power outputs and cycling performances of female athletes. It's found that much of the research is ongoing or recommends larger sample sizes (Emslie, Viljoen, Beyers, Lamberts, & Noordhof, 2024). This may demonstrate the need for further and in-depth research in this area, if we are to create an inclusive program for female teams and riders, as well as databases for general female riders.

LIV, the sister brand of Giant, is the only comprehensive bicycle brand dedicated to female cyclists. Further developments of female specific bicycles include Canyon's WMN series, and TREK's smaller and lighter iterations of its range of road bikes. LIV utilizes research studies from the Global Body Dimension Database by its design team, highlighting Body Dimensions, Muscular Activity, and Strength Patterns of women to create accurate fitting and engineering as it relates to female anatomy (LIV Bikes, 2021).

1.3 Current Female Model Studies

Regarding female models available in computational studies, particularly for cycling, unless unavailable due to Non-Disclosure Acts, there appears to be very few commercial female models to begin with. The following study by Wang and Kabala (2022) although based on swimming, pertains to the differences of aerodynamic performance of male and female anatomy, and the implications of making assumptions when it comes to CFD analysis. It was determined that the male body shape has a lower drag coefficient to women by 10.1% and 2.8% from top and side views respectively, as demonstrated in Table 1. An influence in up to 12.2% increase of drag due to chest size was also seen. There is a clear difference in shape and surface shown in Figure 2 – wider hips and chest.

Blocken's paper on Numerical-physical modelling of the long jump flight of female athletes: Impact of jump style, hairstyle and clothing produced a very in-depth computational study on long hair, which to a degree, could be determined as a more female characteristic when it comes to elite athletics. The models used were of female anatomy.

Table 1. Aerodynamics of male and female anatomy

	Average Pressure Drag Coefficient	Average Drag Coefficient
Male Side View	0.1399	0.2140
Female Side View	0.1471	0.2207
Male Top View	0.1306	0.1849
Female Top View	0.1529	0.2051

Anatomy, as shown, has a strong impact of aerodynamic performance, where drag variations were seen specifically due to female morphology i.e. larger hips, torso and chest. It would be remiss to then assume that applying results from male model scanning and CFD analysis to female case studies would produce accurate aerodynamic results, in bike fitting, positions, and manufactured bicycles and components.

A direct investigation into frequently referenced papers on cycling aerodynamics reveals the absence of female models. The 2024 paper on 'A Generic Cyclist Model for aerodynamic investigation', outline the process of modeling 14 male elite cyclists (Terra, et al., 2024). Papers on 'Optimal cycling time trial positions' (Fintelman, Sterling, Hemida, & Li, 2014) and 'Evaluation of aerodynamic drag of a full-scale cyclist model' (Terra, Sciacchitano, and Shah, 2019) utilize physical and modelled male figures, where, previously established, biomechanics and physiological capabilities differentiate between men and women. There is a recurring theme of the recommendation being made that female models must need to be considered. But when?

2 Material and Methods

For this research, interviews were conducted with 6 experts across various areas of the sports industry. Amongst the selected cohort, included CFD researchers within the cycling and sports engineering industry as well as female athlete specific physiologists, and interviews were carried out by the author. Using a purposive sampling method, interviewees were selected based on their experience and contribution to the field. Interviews lasted between 30 and 45 minutes over video call. The results were quantified using a thematic analysis to highlight the recurring patterns seen regarding the lack of female modelling. Ethical approval was obtained ahead of the interviews, with consent forms being provided and signed.

To complement the interviews, further reviews of current research and literature into the topics mentioned in the following paragraphs were used.

2.1 Areas of Analysis

2.1.1 Computational Modelling

This source would apply to CFD analysis, biomechanical modeling, and aerodynamic analysis of components to go into manufacture. Although part of the consideration to engineering, this area would cover predictive models such as for CFD simulations, bike fitting, power output models and calculations.

2.1.2 Engineering

How have current models and brands of bicycles utilize 3D modelling, databases, and if applicable, gendered models to create high performance bicycles.

2.1.3 Physiology

As previously mentioned, the anatomy and physical output that females possess compared to men is a key consideration to be made, across a range of sports. How do factors such as pregnancy, menstrual cycle, flexibility, cardiovascular and musculoskeletal affect assumptions made onto their performance from a male perspective.

2.1.4 Performance

What does the current research cover in female specific performance whether that is from ground level development to elite. How does current literature affect female athletes through assumption, poor representation, and support of female athlete development.

3 Results

The research began with a sole focus into the cycling and sports engineering industry which then reveals itself as a much more complex and multi-faceted issue presented within the entirety of the sports industry. It is clear from the supporting research, and interviewee input, that there exists a lack and need of female insight and consideration within these industries.

A recent study emerged on the impact of handlebar width to female cyclist performance (Lin, Tsa, & Chen, 2025). This serves as a breakthrough study in the direct correlation of ill-fitted bikes, lack of consideration of female anatomy i.e. narrow shoulders and smaller frames, and the negative results that can occur due the application of a male frame assumption onto a female athlete. These include higher injury rates, suppressed power output and general discomfort when cycling. These problems can all be avoided if we apply a study like this within cycling engineering.

4 Discussion

The findings have been divided into areas that are failing our female athletes. Following a brief discussion, possible solutions and outputs are highlighted. These headers lean towards the cycling engineering industry; however, the considerations are applicable to other sports and industries that lack female input and inclusion.

4.1 Commercial

Accurate commercial models of female cyclists for computational use, overall, are difficult to find within the industry. Using personal anthropomorphic body scans and performance outputs are protected by professional teams and are not disclosed to public. The need for these models exists particularly for aerodynamic analysis and for the construction of female specific bicycle models. 3D scanning of female athletes is done in the exact same fashion as males, yet we are still waiting to see these models appear in literature. They can contribute greatly to in-depth aerodynamic analysis, as well as general manufacturing, as seen in the literature review.

Reverting to the initial conversation on computational inclusion, we must make use of the athletes we have for analysis and study these resources. It is not enough to assume that women have the same aerodynamics with insufficient study, nor can we begin to create a gender-neutral generic model if that is still based on male assumption. Beyond fluid dynamics, by integrating female input into other platforms – predictive models for nutrition, online training platforms, health trackers – we can improve and diversify these complements to sports performance and everyday life. It can provide information to coaches dealing with different gender groups, the average population on what is suitable for their anatomy and physiology, provide information to athletes on certain factors that influence their lives and how to best navigate challenges such as injury, nutritional requirements and health markers.

The need is there as comments made on the male model testing in the 2025 paper (Maddocks & Walker, 2025) '*They concluded that coefficient of drag (Cd) can depend as much on athlete shape as position. This is unsurprising when considering shape matters,'* and on female inclusion *'However, exceptions may occur when the body characteristics (height, weight, shoulder width) have large differences and the lack of consideration of female athletes is a limitation of the current study;* An accurate model that encompasses female anatomy, average height, weight and limb lengths, and flexibility is key to future testing and manufacturing of bicycles for both professionals and the public.

4.2 Specification

The current literature and research on, not just computational modeling, but within nutrition and physiological practice, is based on male athletes and their needs (McNulty, 2021). If we are to develop systems of modelling and engineering, we need to be extremely specific to the needs of women. In terms of cycling, these include:

- Anatomy and physiology: both smaller and wider frames in comparison to men, higher degrees of flexibility, considerations to body changes during and after pregnancy, pelvic floor differences, older female athlete needs in perimenopause and menopause.
- Performance: lower average speed computational analysis, proper apparel manufacture for larger breasts, hips and sweat requirements, female specific fitting to equipment i.e bike fitting, specific strength and conditioning for female high performance.
- Sports nutrition: caloric and macro-nutrient requirements, exercise intensities, and capabilities, training loads during the menstrual cycle as it pertains to female identifying athletes. Relative Energy Deficiency Syndrome (RED-S) is a hugely problematic issue within female athlete, and while also applies to men, females are much more susceptible. Within our professional teams, and of course to a degree, casual and amateur riders, we need to consider individualized programs and base nutritional and exercise knowledge off female specific research. It is

imperative that female nutrition and training loads are managed specifically to the female to prevent serious health issues and impact to performance (Grabia, Perkowski, Socha, & Markiewicz Zukowska, 2024).

4.3 Access to Resources

At a grass roots and developmental level, there is significant lack in this area for girls. It can be speculated that it is partially due to gender minority within most sports, and in this instance, cycling. From a younger age, the barriers women face can often lead to discontinuation of sport or not even beginning in the first place. These include:

- Lack of girls' teams.
- Male coaches unable to understand female needs
- Significant lack of funding: in professional athletes, to fund team support (kit, equipment etc.).
- Sexism.
- Lack of support and disinterest to promote women's sport: no playing times, no opportunities to race, no support during races (San Remo Femmes discontinuation), no media outlets and coverage.
- Lack of access: poor uptake of strength and conditioning, male dominated area from grass roots to professional stages, facilities ill-suited to females i.e. adequate changing areas.
- Social stigma: sometimes we ae our own worst enemy and it can seem 'not cool' to be dedicated to sport as a female.
- Lack of research: as this paper discusses, the lack of research that can improve the experience of females within their sports and boost the awareness of female needs feeds into a poor upkeep of female athletes. Using males as an indication to female needs leads to overuse, overtraining, injury and loss of enjoyment and inclusion.

5 Practical Applications

The findings from the research uncover a much larger issue that affects a greater span of athletic performance and sports engineering. Exclusion of female reference, input and consideration appears to be rife amongst many subcategories of these industries and thus presents a significant call to change. This is not just an industry issue but a societal one, and until we can change the mindsets of the greater public towards female sport, we are stuck.

Where do we start? How do we approach this chicken and egg situation. Figure 4 demonstrates a cyclical procedure where each part of the cycle can be independently contributed to, to uphold and improve the approach.

It is up to academic institutions to provide resources and opportunities to aspiring female athletes and professionals to support their career developments. To industry leaders to begin considering the female voice, anatomy and input into product design and modelling, and to hire and nurture those interested in the field. To connect female professionals with suitable teams, to demonstrate their specific needs and provide them with specific information. National Governing Bodies (NGBs) are called to support their female sports development to fund the teams, to make athletes available for researchers, and to allow access to facilities that can allow continuous growth and improvement of both team and academic.

The industry and research improvements can go hand in hand and complement each other. Female athletes must be actively sought for in inclusion to sports studies. For general studies, there is no reason why female athletes cannot be identified and included at the same time as men. That unfortunately falls back onto the lack of female team and athletes. For female specific studies, research must tap into NGBs and can demonstrate the need, and relevancy of female athlete input into making future studies more inclusive. Women require the exact same opportunities into these studies as men.

It is easy to say that we are bound by cost, difficulty of research, time restrictions and, again, lack of public interest and female participation. But that is not and should not be the case. We have female athletes deprived of resources, and female sport engineers and researchers looking for participants. We are tackling both ends of the problem, inputs and outputs simultaneously, but it is clear that this needs to be done. We need to start somewhere and cease ignoring 50% of our population, and, in future hopes, 50% of our athlete population.

We need to start asking ourselves hard questions – about how we work, how we collect resources, how we communicate and collaborate with the world within sports, engineering and sports engineering. A great example of how this can be carried out systematically comes from (Okholm Kryger, et al., 2022) on questioning the technology used in women's elite football. A surveillance such as this helps to highlight problems areas for female specific challenges (kits, sport bras, menstrual tracking devices) as well as other inclusive considerations such as hijab design for sport. and bring to the surface what solutions can be put in place. We must challenge ourselves to be better and more inclusive, actively put measures in place to create inclusive and progressive industries, and quantify what we are doing works. If it doesn't work, we will change it again. Because good enough isn't good enough anymore.

In succeeding this, we complete the circle. We can inspire younger generations, with the promise of support and access, to begin a career in sport. We can continuously improve the work environment for these individuals by including and recognizing their inputs and their needs as we develop and fund support systems. We can connect specific professionals to teams and individuals, grow networks of support and development, and increase our knowledge bases over a variety of specific topics. We can create EDI measures within industry, research, and sports, to build more inclusive and nurturing environments. We can create successful role models in athletes and engineering, demonstrating professional skills in inclusive and thriving environments and begin the cycle again.

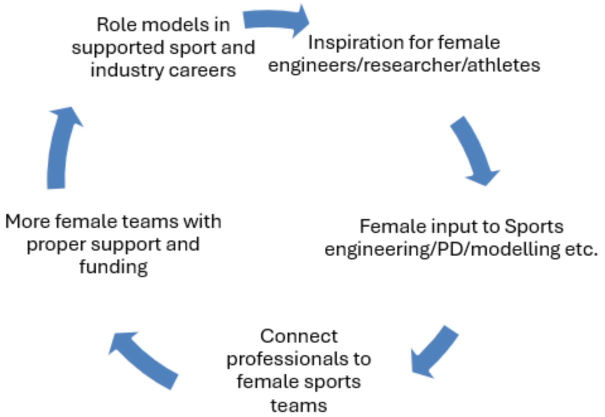

Figure 3. The cyclical approach to nurture female athletic and professional involvement in the sports engineering industry.

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