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Fair Enough?—Scientific and Historic Perspectives on Sex Controversies at the Paris 2024 Olympics

Tin Hang Hung * **and Po-Hsun Chen**

1. Introduction

Imane Khelif and Lin Yu-ting—two names that probably received more media attention than any others—at the Paris 2024 Olympics. On 31 July 2024, the International Boxing Association (IBA) made a public statement about their disqualification from the previous year's Women's World Boxing Championships in New Delhi because they had failed "to meet the eligibility criteria for participating in the women's competition" (International Boxing Association 2024). One day later, the International Olympic Committee defended the two athletes as "the victims of a sudden and arbitrary decision by the IBA […] disqualified without any due process" and confirmed their eligibility for the Paris 2024 Olympics (International Olympic Committee 2024).

> "There is nothing new under the sun".[1]

From the earliest Greek Olympic Games, where athletes participated naked, through to the uproar of suspicion over women's participation in athletic competitions from the 1930s to the 1960s, it was widely accepted that men simply had a physical advantage over women in sport (Rupert 2011). Reeser even coined the term "sex fraud", to describe where men "in disguise" were punished for entering women's events (Reeser 2005).

The Grenoble Winter Olympics of 1968 were seen as a time of scientification and innovation for the Games, with the introduction of in-competition anti-doping and gender tests. The IOC trialed a chromosome test known as the "Barr body test". Females typically have two X chromosomes, of which one at random is rendered inactive inside the cell. This silenced X chromosome forms a clump that is easily observed under a microscope and thus presents a straightforward method for sex testing. Ewa Kłobukowska, a Polish sprinter, was the first woman subsequently to be disqualified after failing a Barr body test. Although the test continued to be used and modified over the years, considerable criticism from the scientific community finally led to its abolition for the 1996 Atlanta Games (Ritchie et al. 2008).

> "There is nothing new under the sun".

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[1]Ecclesiastes 1:9

2. Is it Fair Enough? Perspectives of STS and the History of Biology

There is already an extensive body of social science research addressing the many issues linking sport and sex; however, this article mainly focuses on that of sex testing. The above-mentioned controversies are rooted in the assumption of a level playing field. In order to ensure and maintain fairness in competitions, people have chosen a seemingly impartial and objective tool—scientific technology—as a referee (Cooky and Dworkin 2013; Henne 2014). We need to ask, however, whether this kind of referee is, in fact, sufficiently fair? From the perspective of Science and Technology Studies (STS), such seemingly scientific controversies often reflect unfairnesses in political and gender discrimination. And scientific uncertainties over sex-testing technologies also trigger controversial issues such as competition fairness and human rights (Heggie 2010).

With the development of biological knowledge and technologies, it seems sufficiently objective enough to verify the binary sex of athletes using sex tests. However, in recent decades the work of STS and research into the history of biology have underscored how the uncertainties of science are intertwined with cultural, social, and political factors in the public sphere. Many commentators in gender studies already agree that scientific knowledge can serve as a tool for the expansion of Euro-centrism and imperial power. In the well-known case study of the inhumane display of an African woman, the "Hottentot Venus", in the nineteenth century, scientists shaped knowledge of non-Western women through the lens of empire and disguised racial prejudice in scientific descriptions (Fausto-Sterling 1995; Qureshi 2004).

These controversies over science, verification, fairness, and human rights are also rooted in a historical aspect of biological knowledge: differentiation. Differentiation has been a fundamental research focus, from the various disciplines of natural history through to experiment-based modern biology, while the evidence for differentiation also ranges from outward appearances down to the molecular level. Yet scientific methods of establishing differentiation are usually intertwined with social and moral imaginaries. Londa Schiebinger's 1996 study, for example, convincingly demonstrated how Carl Linnaeus (1707–1778) based the class "Mammalia (breastfeeding)" in his taxonomical system not only on a species' females' characteristics but also by projecting the eighteenth-century moral initiative of the rearing of off-spring by the birth mother rather than by wet nurses (Schiebinger 1996). Another STS study on testosterone (the primary male sex hormone) insightfully indicates that, although testing for testosterone provided twentieth-century sports competitions with more objective fairness and certainty over an athlete's sex, this single biochemical molecule nevertheless reduces the diversity within gender and reinforces the fixation on the sexual binary. What is worse, this sole and emphatic yardstick also forces women with naturally high levels of testosterone to become unhealthy, abnormal, and even unqualified female athletes (Jordan-Young and Karkazis 2019).

STS scholars also point out the hidden politics in technology. Langdon Winner's renowned fable of the Long Island Bridge cautions us about the discrimination designed into artifacts (Winner 1980). With this in mind, the geopolitical context of sex testing in sports is significant. Lindsay Parks Pieper (2016), a historian

trained in women's history and sports humanities, clearly underscores how the rise of molecular biology in sex testing can be traced to the Cold War, and how the interpretation of results came to be intermixed with nationalism and geopolitical tensions. In other words, seemingly objective sex testing, ranging from morphology to molecular biology, is more ambiguous and impure than its artifacts would have it appear.

Given that the Paris 2024 controversy has given rise to so much public discussion and dispute, instead of simply reiterating the criticism heard from social science quarters this article aims to open up the black box of sex-testing technology and challenge the binary classification constructed by molecular biology. The first part briefly introduces the knowledge, application, and limitations (or uncertainties) of sex differentiation from a biological perspective. The second part challenges problematic binary sexual classification based on belief in the objectivity of science and the fallacy thereof.

3. Sex (Un-)Differentiation in Humans

The canonical development and differentiation of sex in humans begins in the embryo, which is bipotential—that is capable of developing into either a "male" or a "female"—but programmed to be "female" by default. The first question is: how does an embryo decide to "stay female", or to "turn male"?

Most people would think chromosomes hold the answer— specifically, that only the Y chromosome matters in most cases. The Y chromosome contains a gene called the "sex-determining region Y" (SRY). Like most genes, it is first "transcribed" into messenger RNA, which is then "translated" into a protein. This process is known as "gene expression". The SRY protein also has a special function that makes it a "transcription factor" which can bind to other genes to turn them on or off and control their expression, in what might roughly be imagined as a kind of domino effect.

The SRY protein regulates the level of many other sex-related proteins, many of which finally turn the undifferentiated, bipotential gonads into testes. The testes produce two hormones—testosterone and anti-Müllerian hormone,—which travel through the bloodstream to reach receptors on cells and to be duly "understood". Testosterone continues to stimulate the testes development (a positive feedback mechanism), while the anti-Müllerian hormone inhibits the development of Müllerian ducts (which would otherwise grow into female reproductive organs). Thus, nearly every part of the canonical male and female reproductive systems shares the same anatomical origin (they are "homologous"): the penis, for example, equates to the clitoris, the testes equate to the ovaries, and the scrotum equates to the labia majora. However, *non*-canonical development can occur at all levels of chromosomes, hormones, and genitalia.

3.1. Chromosomes

A Y chromosome contains approximately 55 genes, along with so-called "junk DNA" that appears to be non-functional , in stark contrast to an X chromosome, which contains some 900 genes that control various aspects of functions related and unrelated to sex. If errors occur on the relatively unimportant Y chromosome

during cell replication, the embryo is more likely to survive and develop compared to when errors appear on the X. Swyer syndrome, for example, results in female reproductive organs in XY individuals when the SRY gene is missing or non-functional. By contrast, the SRY gene can be misincorporated into the X chromosome, and de la Chapelle syndrome results in male reproductive organs in XX individuals.

3.2. Hormones

Hormones, particularly testosterone, are commonly seen as key to qualification in elite athletics. A hormone is essentially a form of biological communication, and here the two sides matter: both the production and the reception of information. Hormone production is controlled by gene expression, which is not a binary state of "on" or "off" (although this is commonly used for simplicity), but regulated by numerous factors such as promoters, enhancers, and epigenetics. It is more accurate to say that gene expression is a scale, and that a gene can produce more or less in the way of hormones. The receipt of information, too, depends on hormone receptors, which again are regulated by gene expression. Both hypogonadism (diminished production of sex hormones) and androgen insensitivity syndrome (AIS) can lead to a person with male chromosomal sex developing female reproductive organs.

Unlike chromosomes, which remain relatively stable throughout life, an athlete's hormone levels can change significantly depending on lifestyle, training regimen, and disease. A 2014 study revealed that 16.5% of "male" elite athletes have lower testosterone than normal, while 13.7% of "female" have higher than normal. There turns out to be a significant overlap between the two "sexes" (Sönksen et al. 2018). "Female" elite athletes are also more likely to have polycystic ovary syndrome (PCOS), which leads to higher testosterone levels in their bodies and stronger muscles (Hirschberg 2020).

3.3. Genitalia

It already goes without saying, then, that genitalia can disagree with chromosomes and hormones. But even if we ignore those chromosomes and hormones and simply use genitalia to classify sex, ambiguous genitalia do occur, with as many as 2% of the population born with such an ambiguity and doctors performing "corrective" genital surgery for 0.1–0.2% of live births (Blackless et al. 2000).

3.4. How (Biologically) Sexually Dimorphic Are We?

In medical terms, all these non-canonical sexual developments are referred to as "disorders of sexual development" (DSD), as defined in the 2006 Chicago Consensus, which classifies atypicality in chromosomal, gonadal, and anatomical sex (Lee et al. 2006). However, clinical classification can be problematic because of very similar appearances (phenotypes) and multiple etiologies. It is estimated that 1 in

around 5,000 newborns could have a form of DSD, a figure, which could rise 1 in 2–300 if types of anomalies are considered (García-Acero et al. 2020).[2]

The idea of non-canonical sexual development is evidenced from the 1960s, when Keith L. Moore in 1968 first proposed the "nine sexes", taking into account external genital appearance, internal reproductive organs, structure of the gonads, endocrinological sex, genetic sex, nuclear sex, chromosomal sex, psychological sex, and social sex. The first seven became commonly thought of as "biological sex" (Fausto-Sterling 1993), and Anne Fausto-Sterling (1993) simplified the nine sexes down to five, taking into account chromosomes, hormones, gonads, genitalia, and secondary sexual characteristics.

Moore and Fausto-Sterling caused controversy at the time, but since then it has become clear that biological sex is a complicated, multidirectional construct. In a 2018 statement, more than 2,000 scientists (including 9 Nobel laureates) openly opposed the Trump administration's proposal for an unchangeable, binary definition of gender determined at birth (Not-Binary.org 2018):

> The relationship between sex chromosomes, genitalia, and gender identity is complex, and not fully understood. There are no genetic tests that can unambiguously determine gender, or even sex. Furthermore, even if such tests existed, it would be unconscionable to use the pretext of science to enact policies that overrule the lived experience of people's own gender identities.

4. Perspectives of "Binary"—a "No True Scotsman" Argument

Many argue that human sexes are "binary" because there are only two forms of gamete—the smaller, mobile sperm and the bigger, immobile ovum—as a result of sexual dimorphism and evolutionary history. They commonly refuse to accept "intersex" as the counterexample against a binary framework by way of an argument from exceptions, which is of course invalid, since, as mentioned above, 1 in roughly 5,000 might have a form of DSD. They call for proof of a "third gamete" to show that sex is non-binary (Goymann et al. 2023), and indeed a third gamete has never been found in humans.

A common argument used to support the assertion that sex is binary and that intersex cannot be used as a rebuttal of this is broadly that presented by Rehman (2023):

1. We should begin with "well-known" scientific investigations [Assumption 1].
2. We should define "intersex" in light of "well-known" human sex(es) [Assumption 2].
3. Since "intersex" is the subject of inquiry, it is not currently "well-known" [From (1) and (2)].
4. So, male and female sex must be defined in order to understand what "intersex" means [From (1) to (3)].

[2]Note that genital ambiguities (~2%) are not entirely synonymous with DSDs (up to 0.5%), as some cases of genital ambiguities at birth may be temporary.

5. If sex is defined by gamete production, sex in human beings is exclusively male and female [Disjunctive syllogism].
6. Sex is defined by gamete production [Antecedent].
7. (C1) Sex in human beings is exclusively male and female [From (6)].
8. (C2) "Intersex" does not refute the sex binary [From (1) to (8)].

First, Assumption 2 assumes that "intersex" should be defined based on "well-known" human sexes, which already imply male and female, proposing a binary sex framework from the outset. This leads to circular reasoning where the conclusion is predetermined by the premises and not by logical derivation. The argument also begs a question by assuming that "sex is defined by gamete production" (Premise 6), without justifying why gamete production should be the sole criterion for defining sex.

Broadly, these arguments concerning gametes are something of a "No True Scotsman" argument, where one starts with a generalization or definition of a term (here "sex'") that is not well-defined in the first place, even in a biological sense. Scientists have never clearly agreed that the term "sex" should be restricted to the ability or potential to produce certain types of gametes. And if there *were* a "sex" schema that could be called "well-known", we would not be having this conversation today. When evidence of sex ambiguity is presented as a counterexample (for example, people with a DSD) to challenge such a generalization, we need discussion to refine the original definition, not the arbitrary exclusion of the counterexample.

5. The Many Nightmares of Biological Criteria

Beyond gender, there are various other factors where biological metrics play a significant role. Each of these introduces its own complexities and ambiguities in the "pursuit" of "fairness" in competitive sports.

Age determines eligibility and competition in many disciplines. Youth sports, for example, categorize athletes by age group and often set ambiguous age limits. However, the biological development of young athletes varies significantly, and differences in growth rates and maturation can create differential advantages for players with a greater relative age (Engebretsen et al. 2010).

Body composition and weight are crucial in combat sports such as wrestling, boxing, and weightlifting. Athletes often specifically manipulate weight through extreme dieting or dehydration, resulting in health risks and inconsistent performance. In the meantime, athletes in the same weight class but with different body compositions in terms of muscle and fat will have different performance advantages (Franchini et al. 2012).

The Paralympic Games were founded to offer fair and inclusive opportunities in competitive sports for athletes with a range of disabilities. The wide range of impairments and their sheer variability, though, raises challenges in establishing consistent eligibility criteria (Stalin and Dalton 2021). In addition, the use of assistive technoscience such as prosthetic limbs in Paralympic sports can also be argued to offer unfair competitive advantage (Loland 2021).

6. Conclusion: There is no Fairness in Biology

Biology has never been "fair" to us. If we succumb, and narrow the definition of biological sex to genes, we may have to begin gene testing on all genes unrelated to sex but giving clear biological advantages to athletes. Eero Mäntyranta, a seven-time Olympic medalist, was diagnosed with primary familial and congenital polycythemia, caused by a mutation in the EPOR gene, which can potentially lead to a higher blood-oxygen capacity. Michael Phelps, a 28-time Olympic medalist, has a unique body shape and flexibility that allows faster movement in water. Kenyan and Ethiopian runners, with genetic predispositions and bodily adaptations to high-altitude, low-oxygen environments, have dominated the middle- and long-distance events in athletics since the 1968 Mexico City Olympics (Wilber and Pitsiladis 2012).

The controversy surrounding the Paris 2024 Olympics is nothing new. We have been through similar discussions many times before. In fact, perhaps the more important questions, though less asked, are instead perhaps: Why is the debate constantly being fueled, if the science itself is already irrefutable? Why do we seemingly only celebrate the genetic achievements of "male" athletes but punish the "females"? And is the discourse of binary sex erasing the natural diversity in humans, where a "stronger woman" should be classified as a "man" instead, to re-assert and reinforce the physical power in "men"?

The controversies surrounding sex testing and classification at the Paris Olympics underscore the intricate interplay between science, technology, and society. These practices, rooted in biological and technological frameworks, directly shape notions of fairness and eligibility in sport. While science continues to expose the limitations and challenge the legitimacy of such classifications, these disputes highlight the need to critically examine how knowledge is constructed, deployed, and contested within social-political contexts.

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References

Blackless, Melanie, Anthony Charuvastra, Amanda Derryck, Anne Fausto-Sterling, Karl Lauzanne, and Ellen Lee. 2000. "How Sexually Dimorphic are We? Review and Synthesis." *American Journal of Human Biology: The Official Journal of the Human Biology Council* 12 (2): 151–166. doi:10.1002/(SICI)1520-6300(200003/04)12:2<151::AID-AJHB1>3.0.CO;2-F

Cooky, Cheryl, and Shari L. Dworkin. 2013. "Policing the Boundaries of Sex: A Critical Examination of Gender Verification and the Caster Semenya Controversy." *The Journal of Sex Research* 50 (2): 103–111. doi:10.1080/00224499.2012.725488

Engebretsen, L., K. Steffen, R. Bahr, C. Broderick, J. Dvorak, P.-M. Janarv, A. Johnson, et al. 2010. "The International Olympic Committee Consensus Statement on Age Determination in High-Level Young Athletes." *British Journal of Sports Medicine* 44 (7): 476–484. doi:10.1136/bjsm.2010.073122

Fausto-Sterling, Anne. 1993. "The Five Sexes." *The Sciences* 33 (2): 20–24. doi:10.1002/j.2326-1951.1993.tb03081.x

Fausto-Sterling, Anne. 1995. "Gender, Race, and Nation: The Comparative Anatomy of 'Hottentot' Women in Europe." In *Deviant Bodies: Critical Perspectives on Difference in Science and Popular Culture*, edited by Jennifer Terry, and Jacqueline Urla, 19–48. Bloomington: Indiana University Press.

Franchini, E., C. J. Brito, and G. G. Artioli. 2012. "Weight Loss in Combat Sports: Physiological, Psychological and Performance Effects." *Journal of the International Society of Sports Nutrition* 9 (1). doi:10.1186/1550-2783-9-52

García-Acero, Mary, Olga Moreno, Fernando Suárez, and Adriana Rojas. 2020. "Disorders of Sexual Development: Current Status and Progress in the Diagnostic Approach." *Current Urology* 13 (4): 169–178. doi:10.1159/000499274

Goymann, Wolfgang, Henrik Brumm, and Peter M. Kappeler. 2023. "Biological sex is Binary, Even Though There is a Rainbow of Sex Roles." *BioEssays* 45 (2): e2200173. doi:10.1002/bies.202200173

Heggie, Vanessa. 2010. "Testing Sex and Gender in Sports: Reinventing, Reimagining and Reconstructing Histories." *Endeavour* 34: 157–163. doi:10.1016/j.endeavour.2010.09.005

Henne, Kathryn. 2014. "The 'Science' of Fair Play in Sport: Gender and the Politics of Testing." *Signs: Journal of Women in Culture and Society* 39 (3): 787–812. doi:10.1086/674208

Hirschberg, Angelica Lindén. 2020. "Female Hyperandrogenism and Elite Sport." *Endocrine Connections* 9 (4): R81–R92. doi:10.1530/EC-19-0537

International Boxing Association. 2024. "Statement made by the International Boxing Association regarding Athletes Disqualifications in World Boxing Championships 2023." Accessed 22 September 2024. https://www.iba.sport/news/statement-made-by-the-international-boxing-association-regarding-athletes-disqualifications-in-world-boxing-championships-2023/.

International Olympic Committee. 2024. "Joint Paris 2024 Boxing Unit/IOC Statement." Accessed 22 September 2024. https://olympics.com/ioc/news/joint-paris-2024-boxing-unit-ioc-statement.

Jordan-Young, Rebecca M., and Katrina Karkazis. 2019. *Testosterone: An Unauthorized Biography*. Cambridge, MA: Harvard University Press.

Lee, Peter A., Christopher P. Houk, Faisal Ahmed, Ieuan A. Hughes, and LWPES Consensus Group, & ESPE Consensus Group. 2006. "Consensus Statement on Management of Intersex Disorders." *Archives of Disease in Childhood* 91 (7): 554–563. doi:10.1136/adc.2006.098319.

Loland, S. 2021. "Classification in Sport: A Question of Fairness." *European Journal of Sport Science* 21 (11): 1477–1484. doi:10.1080/17461391.2021.1923816

Not-Binary.org. 2018. "Transgender, Intersex, and Gender Non-Conforming People #WontBeErased by Pseudoscience 2018/10/26." Accessed 22 September 2024. https://not-binary.org/statement/.

Pieper, Lindsay Parks. 2016. *Sex Testing: Gender Policing in Women's Sports*. Illinois: University of Illinois Press.

Qureshi, Sadiah. 2004. "Displaying Sara Baartman, the 'Hottentot Venus'." *History of Science* 42: 233–257. doi:10.1177/007327530404200204

Reeser, J. C. 2005. "Gender Identity and Sport: Is the Playing Field Level?" *British Journal of Sports Medicine* 39 (10): 695–699. doi:10.1136/bjsm.2005.018119

Rehman, Rashad. 2023. "'Intersex' Does not Violate the Sex Binary." *The Linacre Quarterly* 90 (2): 145–154. doi:10.1177/00243639231155313

Ritchie, Robert, John Reynard, and Tom Lewis. 2008. "Intersex and the Olympic Games." *Journal of the Royal Society of Medicine* 101 (8): 395–399. doi:10.1258/jrsm.2008.080086

Rupert, James L. 2011. "Genitals to Genes: The History and Biology of Gender Verification in the Olympics." *Canadian Bulletin of Medical History* 28 (2): 339–365.

Schiebinger, Londa. 1996. "Why Mammals are Called Mammals." In *Feminism and Science*, edited by Evelyn Fox Keller, and Helen Longino, 137–153. Oxford: Oxford University Press.

Sönksen, Peter H., Richard I. G. Holt, Walailuck Böhning, Nishan Guha, David A. Cowan, Christiaan Bartlett, and Dankmar Böhning. 2018. "Why do Endocrine Profiles in Elite Athletes Differ Between Sports?" *Clinical Diabetes and Endocrinology* 4: 3. doi:10.1186/s40842-017-0050-3

Stalin, A., and K. Dalton. 2021. "Exploration of the Minimum Visual Disability Criteria for Para Nordic and Para Alpine Skiing Using Simulated Vision Impairments." *Journal of Sports Sciences* 39: 167–187. doi:10.1080/02640414.2021.1903685

Wilber, R. L., and Y. P. Pitsiladis. 2012. "Kenyan and Ethiopian Distance Runners: What Makes Them so Good?" *International Journal of Sports Physiology and Performance* 7 (2): 92–102. doi:10.1123/ijspp.7.2.92

Winner, L. 1980. "Do Artifacts Have Politics?" *Daedalus* 109 (1): 121–136. https://www.jstor.org/stable/20024652.

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