UK Parliament POST

POSTNOTE

Number 682 October 2022

Performance, Inclusion and Elite Sports - Athletes with Differences in Sex Development

There is debate about restrictions on the participation of female athletes with Differences in Sex Development (DSD) in elite sport. This POSTnote discusses policies by some sporting bodies that require some female athletes with DSDs to suppress the level of the hormone testosterone, to mediate fairness between competitors. It also highlights stakeholder perspectives on balancing fairness and inclusion.

Overview

- Testosterone is the established key factor for sex differences in sports performance.
- Some female athletes with Differences in Sex Development (DSDs) may have naturally high levels of testosterone.
- There is little research on the extent to which female athletes with DSDs have a performance advantage over female athletes without DSDs.
- Sporting bodies have different policies on participation in the female category. Some impose a testosterone limit, but this approach is contested.
- Stakeholder views on regulations vary: they are seen as discriminatory and lacking in evidence or seen as necessary for fairness.
- The debate around how to address inclusion of female athletes with DSDs has intensified following a series of legal challenges.

Background

Sex generally refers to biological and physiological characteristics, determined by sex chromosomes, hormones and their interactions.[1–3] Differences in Sex Development (DSDs, Box 1) is an umbrella term for a diverse range of uncommon physical traits that differ from typical sex development for male or female bodies, with regard to chromosomal, anatomical, hormonal or gonadal sex, with at least 40 different known conditions.[4–7] Typically, males have XY sex chromosomes and females have XX sex chromosomes. Individuals with DSDs may have XX or XY chromosomes, or other chromosome patterns.[8] For individuals with DSDs, differences begin at the earliest stages of foetal development and may be identified prenatally, at birth, during puberty or at other points in life.[9]

Almost all elite sports are separated into two biological sex categories (male and female). These categories offer fairness in competition to the female category from the male performance advantage.[10–12] Sex testing has existed in elite sport in various forms for decades, beginning as visual observations, followed by chromosomal and genetic testing, to hormone tests in the present day.[13–15] In the last decade, legal challenges have taken place against regulations restricting entry in the female category.[16] Legal cases have related to human rights issues, and to contest the scientific basis of the regulations. This POSTnote focuses on recent international developments surrounding the participation of women with certain DSDs in the female category of elite professional sport. Some DSDs can result in a woman producing high levels of the hormone testosterone. This hormone is a focus because of its established role in conferring a performance advantage in sport.[17] Some sports bodies manage participation by female athletes with DSDs by imposing a limit on testosterone levels. However, suppressing testosterone levels in athletes with DSDs to mitigate what may be perceived as an unfair performance advantage and manage inclusion is contested on both scientific and ethical grounds.

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Box 1: Differences in sex development (DSD)
DSDs are also known as disorders of sex development, diverse sex development, variations in sex characteristics and intersex.[18,19] The language is evolving and contextual. For example, DSD is widely used in a clinical context, whereas an individual or advocacy group might prefer an alternative term such as intersex.[20] Groups representing intersex people generally reject the term DSD as it medicalises sex variations.[21,22] Individuals may be raised and identify as men, women or intersex. In the UK, individuals are registered at birth as either male or female.[4]

Testosterone, sex development and sport

Androgens are sex steroid hormones present in males and females and have a range of functions, including the development of male characteristics. They are part of a complex system comprising other hormones.[23] The most biologically active androgens are testosterone and the related hormone dihydrotestosterone (DHT).[24] Testosterone mainly has tissue-building (anabolic) functions while DHT is primarily responsible for development of external male characteristics (virilisation, Box 2).[24] Hormone levels are measured in scientific units representing their concentration in blood. Blood testosterone levels are typically 15-fold higher in men than women and do not overlap (7.7-30.9 nmol/L in men, 0.06-2.0 nmol/L in women).[17,25,26] Testosterone levels decrease with age[27,28] and some conditions result in high testosterone levels in women, the most common is polycystic ovary syndrome (0.3-5.5 nmol/L).[25] Testosterone is the established key factor for sex differences in sports performance.[17]

Box 2: Testosterone, puberty and development
In the developing male foetus, a gene on the Y-chromosome triggers testosterone secretion and the formation of male genitals.[29] The age at which puberty begins varies; on average at age 11 in females and 12 in males.[30] During puberty, testosterone secreted from the testes leads to virilisation: the development of male secondary sexual characteristics such as body hair and deepening of the voice.[31,32] Studies have examined the effects on the body of giving testosterone to people. Testosterone promotes growth and maintenance of several tissues, including bones (mass, density and strength) both during puberty and throughout life.[33] It increases the area of muscle by increasing the number and size of muscle cells.[34–36] The concentration of red blood cells (that carry oxygen) increases with testosterone dose.[37]

Blood testosterone levels and sports performance

Research has characterised the influence of testosterone by examining its effects on the body. Administration of external testosterone (for example via injections or orally) increases muscle mass and strength and decreases total body fat, which are key determinants of success in sports requiring power and speed.[38–42] Testosterone is a banned substance in sport doping rules for these reasons.[43] However, the fact that testosterone is a performance-enhancing drug does not mean that naturally occurring testosterone production determines female athletes' performance; evidence is contested as to what performance advantage having high levels of naturally produced (endogenous) testosterone confers.[44–53] A widely referenced study commissioned by World Athletics found that female athletes with the highest levels of testosterone performed better in certain events (400m and 800m running, hammer throw and pole vault), than those with the lowest levels.[44] In other events (such as 1500m running), there was no correlation. Following criticism and discussion in the scientific community, the paper was amended to clarify that there was no direct causal link.[46–48,54] Other studies report no correlation between blood testosterone levels and sports performance.[51,52]

Athletes with DSDs

In the context of sport policy most of the relevant DSDs are those that are classed as 46,XY DSDs. These can occur in women who have XY chromosomes. Some of these conditions can lead to naturally high levels of testosterone, also termed hyperandrogenism. Box 3 discusses the specific DSD conditions that are named in sports policy. Testosterone levels in individuals with 46,XY DSDs vary widely but they can exceed that in women without DSDs:

- **5ARD2:** 3.6-47.2 nmol/L[25]
- **CAIS or PAIS**: 4.8-68.3 nmol/L[25]
- **Women without DSDs:** 0.06-2.00 nmol/L[17,25]
- **Men without DSDs:** 7.7-30.9 nmol/L.[17,25]

Some scientists think that this potentially gives these women advantages over women without DSDs in terms of training capacity, endurance, strength, speed and power.[17,55] There is a lack of scientific consensus and few high quality research studies giving robust conclusions comparing the performance of female athletes with DSDs with those without DSDs. Research on athletes with DSDs is challenging due to the low numbers of eligible study participants. There are only observational studies and none directly comparing athletes with a control group.[56] Therefore results may be prone to confounding effects, making it difficult to differentiate between cause and effect.[57]

Testosterone suppression

Some governing bodies impose restrictions on the testosterone levels for athletes with DSDs competing in the female category to mitigate a possible performance advantage. This can be done by:

- Hormone therapy to suppress testosterone levels to specified limits, such as the oral contraceptive pill.
- Irreversible surgery to remove internal sex organs (testes) that produce testosterone.[55]

There is very limited evidence on the performance impact of these interventions; commonly cited studies used weak methodologies, had small sample sizes, lacked transparent methods, or were not conducted in an ethical way.[47,58] One study on four athletes with 5ARD2 who were identified through routine sex testing[56] was criticised on medical ethics grounds, with concerns about confidentiality and unnecessary medical interventions these athletes may have felt pressured to undergo.[59]

Stakeholder opinions

Given that there is limited research, opinions vary. Some consider there to be sufficient evidence that athletes with DSDs have a performance advantage and that testosterone levels should be suppressed.[50,60–62] Others argue there is poor evidence about the magnitude of any competitive advantage that athletes with DSDs have, and that testosterone

Box 3: 46,XY DSDs referred to in sport policy

The DSDs named here are those referenced in sports policies.[63] They are those that may result in individuals who are registered female at birth having higher testosterone levels than the typical female range (hyperandrogenism).

- **5-alpha reductase deficiency type 2 (5ARD2):** individuals with XY chromosomes have a mutation in 5-alpha reductase, the enzyme that produces DHT.[64] At puberty, a large increase in testosterone produced by internal testes may result in partial virilisation.[64]
- **Androgen insensitivity syndrome (AIS):** individuals may have high testosterone levels but mutations make them unable to respond to androgens.[25,65] In the complete form (CAIS), individuals do not respond to androgens and appear typically female. In the partial form (PAIS), there is a spectrum as to the degree to which individuals have typically female or male traits.
- **17β-hydroxysteroid dehydrogenase type 3 (17β-HSD3) deficiency**: mutations in an enzyme in the testes results in little testosterone in development. However, during puberty the testes begin to produce large amounts of androgens, with varying degrees of virilisation.[66]
- **Ovotesticular DSD:** individuals develop ovarian and testicular tissue and are born with ambiguous genitalia.[67]

Box 4: Timeline of World Athletics DSD regulations and the cases of Caster Semenya and Dutee Chand

2009 - 18-year-old South African runner Caster Semenya was banned from competing for 11 months after winning the women's 800m World Athletics Championships, undergoing a gender verification process and hormone treatment.[76–78]
2011 - World Athletics introduced the Hyperandrogenism Regulations, with a 10 nmol/L testosterone level limit.[79]
2014 - 18-year-old Indian sprinter Dutee Chand was banned from competing in the Commonwealth Games due to elevated testosterone levels. She successfully argued at the Court of Arbitration for Sport (CAS) that there was insufficient scientific evidence supporting the regulations.[80]
2015 - CAS suspended the 2011 World Athletics rules for 2 years, instructing them to present evidence establishing the degree of performance advantage.[81]
2018 - World Athletics introduced new rules with an upper limit for testosterone of 5 nmol/L for specific events.[63]
2019 - Semenya unsuccessfully challenged the regulations at CAS.[82]
2020 - Semenya lost her appeal to the Swiss Federal Supreme Court.[83] She is in the process of appealing to the European Court of Human Rights.[84]

suppression will not remove any advantage.[59,61,68] Other opinions are that while there is insufficient research specifically on athletes with DSDs, there is enough evidence about the "legacy" effects of higher testosterone levels during puberty (such as increased muscle mass and strength), that they should be mitigated in athletes with DSDs.[69] Some argue that DSDs should be treated no differently to other genetic advantages.[70]

The World Medical Association advised physicians not to administer testosterone-suppressing treatment to alter sporting performance in a healthy individual.[71] Concerns about this treatment relate to the safety and potential long-term side effects of testosterone suppression, particularly regarding surgical removal of the internal gonads (testes, that produce testosterone).[72,73] However, those in favour of regulations on athletes with DSDs believe that they are proportionate in maintaining fair competition in the female category.[74,75]

Regulatory approaches

The challenge for policymakers is to promote inclusion and maintain fairness in the female category. Regulations on the female category have been reviewed in recent years, shaped by emerging research evidence, stakeholder consultation, human rights and ethical perspectives, and legal challenges brought in response to rules imposed on participation. The most prominent sports to have reviewed and regulated on this area are athletics and more recently, swimming.

World Athletics

World Athletics (formerly IAAF) is the most high profile international federation (IF) with longstanding rules governing the participation of female athletes with certain DSDs in order to "ensure fair and meaningful competition within the female classification" (see Box 4 for timeline).[55,63] The 2019 regulations cover female athletes who have certain 46,XY DSDs (listed in Box 3), are able to respond to androgens to some degree, and have testosterone levels above the threshold specified by World Athletics (5 nmol/L).[63] One study found that the prevalence of individuals with 46,XY DSDs was 140 times higher (7 in 1,000) in an elite athlete population than the general population.[85] Other conditions where women may have higher than typical testosterone levels, such as PCOS, may participate without restriction. Relevant athletes cannot compete in international track events between 400m to 1 mile in the female category unless they reduce their blood testosterone level to 5 nmol/L or below for 6 months prior to, and during competition. They may compete without restriction in all other events. This is on the basis that "the ergogenic advantage in having circulating testosterone levels in the normal male range rather than in the normal female range is greater than 9%."[55] Athletes thought to have a DSD can be referred for assessment by an expert panel of specialists.[15,63] This involves blood tests for hormones and clinical assessment in accordance with clinical standards,[86] such as examination of genitalia.[79] The regulations have been subject to intense debate, with criticism raised regarding the lack of causal scientific evidence and human rights concerns for the athletes involved (discussed later).[47,58,87] World Athletics stated that some relevant data they hold about athletes with DSDs cannot be published as it would breach individual confidentiality.[88]

Fédération Internationale de Natation (FINA)

In June 2022, the international swimming federation FINA released new guidelines on the inclusion of female athletes with 46,XY DSDs and transgender women athletes in the female category.[89] All athletes must certify their chromosomal sex with their national federation. Any athlete can compete in the male category. For the female category, women with 46,XY DSDs can enter provided that they "have not experienced any part of male puberty beyond Tanner Stage 2 or before age 12" (Tanner Stage 2 refers to a distinct stage of development of children during puberty[90,91]), and must have continuously maintained testosterone levels at 2.5 nmol/L or below. As yet, FINA has no publicly available scientific evidence review. The rules have broadly been welcomed by some former professional swimmers, for protecting fairness in the female category, while others have been critical.[92,93] The rules have been criticised for being potentially discriminatory and not enforceable without

"seriously violating the privacy and human rights of any athlete looking to compete in the women's category".[94]

International Olympic Committee (IOC)

The IOC coordinates the Olympic Games and works with IFs,[95] which create and enforce rules for their sports.[96] From 2015 to 2019, the IOC and World Athletics had the same rules for athletes with DSDs (10 nmol/L testosterone limit).[97] In 2021, the IOC updated its 2015 consensus statement[97], with a Framework on Fairness, Inclusion and Non-discrimination on the Basis of Gender Identity and Sex Variations.[98] It states that it should not be assumed that athletes have an "unfair or disproportionate competitive advantage due to their sex variations, physical appearance and/or transgender status", and that it cannot regulate a one-size-fits-all approach across all sports. Instead, each IF should determine how to manage this in the context of their own sport, creating evidence-based policies. Eligibility restrictions should be based on research that demonstrates "a consistent, unfair, disproportionate competitive advantage in performance and/or an unpreventable risk to the physical safety of other athletes."

The IOC framework was praised for the shift in its approach towards human rights in sports by groups such as Organisation Intersex International Europe, LEAP Sports Scotland and Human Rights Watch, on the grounds of recognising and prioritising the prevention of harm for athletes with sex variations.[99–101] Some scientists (including those from IFs including World Athletics, Union Cycliste Internationale and World Triathlon) argued that the framework "mainly focuses on a particular human rights perspective, and the scientific, biological or medical aspects are not considered", and that it places the burden on IFs that may lack the funds or capacity to implement policies without offering concrete guidance.[102]

Human rights

The UK is a founding member of the UN Human Rights Council. In 2021, the Government signed a joint statement to the UN on the human rights of intersex persons. This states the right to autonomy, to physical and mental integrity, and the need to address all forms of discrimination, including in sport.[103] Few countries, except Malta and Greece, have specific laws protecting the rights of intersex people, such as from forced medical interventions and protection from discrimination.[104–106] It is common practice in many countries (including the UK[107]) for surgery to be performed on children to "normalise" the appearance of atypical genitalia, although this approach is debated; unnecessary surgical interventions are strongly condemned by human rights groups, including the UN.[108–110]

Many groups, including women's sport groups, have raised human rights concerns for athletes with DSDs relating to discrimination, dignity and privacy.[77,111–115] DSD regulations are criticised for facilitating the coercion of women into unnecessary medical interventions, and causing psychological harm.[59,73,116] The UN Human Rights Commission wrote that DSD regulations violate international human rights laws, such as the right to non-discrimination and equal rights for participation in sports.[117] World Athletics stated that it is an athlete's choice to undergo treatment to reduce testosterone levels to compete in the female category.[118] A Human Rights Watch report on the lived experiences of athletes with DSDs highlighted that some felt they had to choose between their career and human rights, resulting in an environment enabling coercion into unwanted medical treatment.[116] Others have highlighted how women from the Global South are disproportionately affected; they are less likely to have had medical interventions before puberty compared with individuals from the Global North.[116,119] Intersex Human Rights Australia called on sports governing bodies to allow people with intersex traits to compete in their legal sex in accordance with international human rights standards.[120] The International Lesbian, Gay, Bisexual, Trans and Intersex Association (ILGA) viewed the regulations as "an attack on intersex women", arguing that it singled out athletes.[121]

Legal challenges to sport regulations

Legal challenges to regulations have been heard in the international Court of Arbitration for Sport (CAS).[122] The most high profile are those brought against World Athletics by two female athletes with DSDs, Caster Semenya and Dutee Chand (see Box 4 for timeline). In 2019, CAS ruled in favour of World Athletics against Semenya, who claimed that the rules "unfairly discriminate against athletes on the basis of sex and/or gender".[123] The court stated that while the scientific evidence is contested and the rules are discriminatory, this is a "necessary, reasonable and proportionate means" to preserve integrity in the female category.[82] It also raised concerns that it would be difficult for athletes to comply with testosterone rules, and about the "paucity of evidence" regarding the inclusion of the 1500m and 1-mile events within the regulations.[123] Semenya is challenging the regulations at the European Court of Human Rights, on the basis that the rules infringe her human rights.[124]

Further considerations for policy

Accountability of international sports governing bodies

Some legal experts point to wider issues surrounding the organisation of international sports governing bodies, which are autonomous private organisations that run with minimal government intervention, potentially leading to a lack of accountability in terms of protecting athletes' rights.[125–128] Some stakeholders note that bringing a legal challenge is very expensive and invasive of athletes' privacy.[129]

Conflation of women with DSDs and transgender women

The debate on the inclusion of athletes with DSDs is often conflated with the separate debate on transgender athletes,[2,130] discussed in POSTnote 683.[131] However, regulations sometimes group them together in the context of eligibility in the female category.[89]

Implications for recreational sports

Policies have impacts on recreational sport; participation in sport is lower in women and girls than men, resulting from social and cultural barriers.[132,133] Little research exists on the experiences of intersex women in recreational sport, but a consultation by ILGA Europe found that many intersex women in Europe are deterred from participating in sport by the negative media surrounding intersex athletes and the prospect of potentially undergoing medical testing.[134] The Government Equalities Office is evaluating a consultation on the experiences of people with variations in sex characteristics, including those related to participating in sport.[4,135]

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to the Medical Research Council for funding a parliamentary fellowship to support this work, and to all contributors and reviewers. For further information on this subject, please contact the author, Dr Sarah Bunn.

References

1. There is a debate around how exactly sex should be defined.
2. Office for National Statistics (2019). What is the difference between sex and gender? *Office for National Statistics*.
3. Bhargava, A. *et al.* (2021). Considering Sex as a Biological Variable in Basic and Clinical Studies: An Endocrine Society Scientific Statement. *Endocrine Reviews*, Vol 42, 219–258.
4. Government Equalities Office (2019). Variations in Sex Characteristics - Call for Evidence. Government Equalities Office.
5. Council of Europe Commissioner for Human Rights (2015). Human rights and intersex people.
6. IGLYO *et al.* (2018). Supporting your intersex child.
7. Carpenter, M. (2018). Intersex Variations, Human Rights, and the International Classification of Diseases. *Health Hum Rights*, Vol 20, 205–214.
8. (2017). Differences in sex development. *nhs.uk*.
9. Carpenter, M. (2021). Health needs of people with intersex variations. General Practice Supervisors Australia.
10. Gleaves, J. *et al.* (2016). Beyond fairness: the ethics of inclusion for transgender and intersex athletes. *Journal of the Philosophy of Sport*, Vol 43, 311–326. Routledge.
11. Devine, C. (2021). Female Sports Participation, Gender Identity and the British 2010 Equality Act. *Sport, Ethics and Philosophy*, Vol 0, 1–23. Routledge.
12. Ospina Betancurt, J. *et al.* (2018). Sex-differences in elite-performance track and field competition from 1983 to 2015. *Journal of Sports Sciences*, Vol 36, 1262–1268. Routledge.
13. Elsas, L. J. *et al.* (2000). Gender verification of female athletes. *Genetics in Medicine*, Vol 2, 249–254.
14. Padawer, R. (2016). The Humiliating Practice of Sex Testing Female Athletes. *The New York Times Magazine*.
15. Photopoulos, J. (2021). The future of sex in elite sport. *Nature*, Vol 592, S12–S15.
16. Ingle, S. (2021). Caster Semenya launches final bid to save career and defend Olympic title. *The Guardian*.
17. Handelsman, D. J. *et al.* (2018). Circulating Testosterone as the Hormonal Basis of Sex Differences in Athletic Performance. *Endocrine Reviews*, Vol 39, 803–829.
18. Lee, P. A. *et al.* (2016). Global Disorders of Sex Development Update since 2006: Perceptions, Approach and Care. *HRP*, Vol 85, 158–180. Karger Publishers.
19. Hughes, I. A. *et al.* (2006). Consensus statement on management of intersex disorders. *Archives of Disease in Childhood*, Vol 91, 554. BMJ Publishing Group.
20. Lundberg, T. *et al.* (2018). Making sense of 'Intersex' and 'DSD': how laypeople understand and use terminology. *Psychology & Sexuality*, Vol 9, 161–173. Routledge.
21. FRA (2015). The fundamental rights situation of intersex people.
22. The term DSD is used throughout this POSTnote as it is commonly used in policies by sport governing bodies.
23. Nassar, G. N. *et al.* (2022). Physiology, Testosterone. in *StatPearls*. StatPearls Publishing.
24. Handelsman, D. J. (2000). Androgen Physiology, Pharmacology, Use and Misuse. in *Endotext*. (eds. Feingold, K. R. et al.) MDText.com, Inc.
25. Clark, R. V. *et al.* (2019). Large divergence in testosterone concentrations between men and women: Frame of reference for elite athletes in sex-specific competition in sports, a narrative review. *Clinical Endocrinology*, Vol 90, 15–22.
26. (2019). Erratum. *Clinical Endocrinology*, Vol 91, 471–473.
27. Feldman, H. A. *et al.* (2002). Age Trends in the Level of Serum Testosterone and Other Hormones in Middle-Aged Men: Longitudinal Results from the Massachusetts Male Aging Study. *The Journal of Clinical Endocrinology & Metabolism*, Vol 87, 589–598.
28. Davison, S. L. *et al.* (2005). Androgen Levels in Adult Females: Changes with Age, Menopause, and Oophorectomy. *The Journal of Clinical Endocrinology & Metabolism*, Vol 90, 3847–3853.
29. Brennan, J. *et al.* (2004). One tissue, two fates: molecular genetic events that underlie testis versus ovary development. *Nat Rev Genet*, Vol 5, 509–521. Nature Publishing Group.
30. (2019). Early or delayed puberty. *NHS*.
31. Siervogel, R. M. *et al.* (2003). Puberty and body composition. *Horm Res*, Vol 60, 36–45.
32. Hall, J. E. *et al.* (2020). *Guyton and Hall Textbook of Medical Physiology*. Saunders, Elsevier.
33. Almeida, M. *et al.* (2017). Estrogens and Androgens in Skeletal Physiology and Pathophysiology. *Physiol Rev*, Vol 97, 135–187.
34. Sinha-Hikim, I. *et al.* (2002). Testosterone-induced increase in muscle size in healthy young men is associated with muscle fiber hypertrophy. *American Journal of Physiology-Endocrinology and Metabolism*, Vol 283, E154–E164. American Physiological Society.
35. Kadi, F. *et al.* (1999). Effects of anabolic steroids on the muscle cells of strength-trained athletes. *Medicine & Science in Sports & Exercise*, Vol 31, 1528.
36. Egner, I. M. *et al.* (2013). A cellular memory mechanism aids overload hypertrophy in muscle long after an episodic exposure to anabolic steroids. *The Journal of Physiology*, Vol 591, 6221–6230.
37. Coviello, A. D. *et al.* (2008). Effects of Graded Doses of Testosterone on Erythropoiesis in Healthy Young and Older Men. *The Journal of Clinical Endocrinology & Metabolism*, Vol 93, 914–919.
38. Herbst, K. L. *et al.* (2004). Testosterone action on skeletal muscle. *Current Opinion in Clinical Nutrition & Metabolic Care*, Vol 7, 271–277.
39. Suchomel, T. J. *et al.* (2016). The Importance of Muscular Strength in Athletic Performance. *Sports Med*, Vol 46, 1419–1449.
40. Huang, G. *et al.* (2014). Testosterone Dose-Response Relationships in Hysterectomized Women with and without Oophorectomy: Effects on Sexual Function, Body Composition, Muscle Performance and Physical Function in a Randomized Trial. *Menopause*, Vol 21, 612–623.
41. Hirschberg, A. L. *et al.* (2019). Effects of moderately increased testosterone concentration on physical performance in young women: a double blind, randomised, placebo controlled study. *Br J Sports Med*,
42. Franke, W. W. *et al.* (1997). Hormonal doping and androgenization of athletes: a secret program of the German Democratic Republic government. *Clin Chem*, Vol 43, 1262–1279.
43. The Prohibited List. World Anti-Doping Agency.
44. Bermon, S. *et al.* (2017). Serum androgen levels and their relation to performance in track and field: mass spectrometry results from 2127 observations in male and female elite athletes. *Br J Sports Med*, Vol 51, 1309–1314. BMJ Publishing Group Ltd and British Association of Sport and Exercise Medicine.
45. Sőnksen, P. H. *et al.* (2018). Hyperandrogenism controversy in elite women's sport: an examination and critique of recent evidence. *Br J Sports Med*, Vol 52, 1481–1482.
46. Menier, A. (2018). Use of event-specific tertiles to analyse the relationship between serum androgens and athletic performance in women. *Br J Sports Med*, Vol 52, 1540–1540. BMJ Publishing Group Ltd and British Association of Sport and Exercise Medicine.
47. Pielke Jr., R. *et al.* (2019). Scientific integrity and the IAAF testosterone regulations. *Int Sports Law J*, Vol 19, 18–26.
48. (2021). Correction: Serum androgen levels and their relation to performance in track and field: mass spectrometry results

from 2127 observations in male and female elite athletes. *Br J Sports Med*, Vol 55, e7–e7. BMJ Publishing Group Ltd and British Association of Sport and Exercise Medicine.
49. Healy, M. L. *et al.* (2014). Endocrine profiles in 693 elite athletes in the postcompetition setting. *Clinical Endocrinology*, Vol 81, 294–305.
50. Ritzén, M. *et al.* (2015). The regulations about eligibility for women with hyperandrogenism to compete in women's category are well founded. A rebuttal to the conclusions by Healy et al. *Clinical Endocrinology*, Vol 82, 307–308.
51. Eklund, E. *et al.* (2017). Serum androgen profile and physical performance in women Olympic athletes. *Br J Sports Med*, Vol 51, 1301–1308. BMJ Publishing Group Ltd and British Association of Sport and Exercise Medicine.
52. Crewther, B. *et al.* (2016). The Effect of Steroid Hormones on the Physical Performance of Boys and Girls During an Olympic Weightlifting Competition. *Pediatric Exercise Science*, Vol 28, 580–587. Human Kinetics, Inc.
53. Jordan-Young, R. *et al.* (2019). Testosterone: An Unauthorized Biography. Harvard University Press.
54. Sőnksen, P. H. *et al.* (2018). Hyperandrogenism controversy in elite women's sport: an examination and critique of recent evidence. *Br J Sports Med*, Vol 52, 1481–1482.
55. (2018). IAAF publishes explanatory notes and Q&A on Female Eligibility Regulations. International Association of Athletics Federations.
56. Fénichel, P. *et al.* (2013). Molecular Diagnosis of 5α-Reductase Deficiency in 4 Elite Young Female Athletes Through Hormonal Screening for Hyperandrogenism. *The Journal of Clinical Endocrinology & Metabolism*, Vol 98, E1055–E1059.
57. Mariani, A. W. *et al.* (2014). Observational studies: why are they so important? *Sao Paulo Med. J.*, Vol 132, 01–02. Associação Paulista de Medicina - APM.
58. Franklin, S. *et al.* (2018). What statistical data of observational performance can tell us and what they cannot: the case of Dutee Chand v. AFI & IAAF. *Br J Sports Med*, Vol 52, 420–421.
59. Sonksen, P. *et al.* (2015). Medical and Ethical Concerns Regarding Women With Hyperandrogenism and Elite Sport. *The Journal of Clinical Endocrinology & Metabolism*, Vol 100, 825–827.
60. Hirschberg, A. L. (2020). Female hyperandrogenism and elite sport. *Endocrine Connections*, Vol 9, R81–R92. Bioscientifica Ltd.
61. Wahl, V. (2020). Science, Sports, and Sex. *Issues in Science and Technology*.
62. Science Media Centre expert reaction to ruling on caster semenya appeal regarding athletes with differences of sex development and testosterone levels.
63. International Association of Athletics Federations (2019). ELIGIBILITY REGULATIONS FOR THE FEMALE CLASSIFICATION (ATHLETES WITH DIFFERENCES OF SEX DEVELOPMENT).
64. Imperato-McGinley, J. *et al.* (2002). Androgens and male physiology the syndrome of 5α-reductase-2 deficiency. *Molecular and Cellular Endocrinology*, Vol 198, 51–59.
65. Batista, R. L. *et al.* (2018). Androgen insensitivity syndrome: a review. *Arch Endocrinol Metab*, Vol 62, 227–235.
66. George, M. M. *et al.* (2010). The Clinical and Molecular Heterogeneity of 17βHSD-3 Enzyme Deficiency. *HRP*, Vol 74, 229–240. Karger Publishers.
67. Syryn, H. *et al.* (2021). Ovotesticular Difference of Sex Development: Genetic Background, Histological Features, and Clinical Management. *HRP*, Vol 94, 275–284. Karger Publishers.
68. Stebbings, G. *et al.* (2021). The BASES Expert Statement on Eligibility for Sex Categories in Sport: DSD Athletes. *The Sport and Exercise Scientist*. 12–13.
69. Hamilton, B. R. *et al.* (2021). Response to the United Nations Human Rights Council's Report on Race and Gender Discrimination in Sport: An Expression of Concern and a Call to Prioritise Research. *Sports Med*, Vol 51, 839–842.
70. Camporesi, S. *et al.* (2021). The construction of categories in sport: Unfair advantages, equality of opportunity and strict attainability. *European Journal of Sport Science*, Vol 21, 1492–1499. Routledge.
71. World Medical Association General Assembly (2021). WMA Declaration on Principles of Health Care in Sports Medicine.
72. Kumar, R. J. *et al.* (2005). Adverse Events Associated with Hormonal Therapy for Prostate Cancer. *Rev Urol*, Vol 7, S37–S43.
73. Jordan-Young, R. M. *et al.* (2014). Sex, health, and athletes. *BMJ*, Vol 348, g2926. British Medical Journal Publishing Group.
74. Coleman, D. L. (2019). Semenya and ASA v IAAF: Affirming the Lawfulness of a Sex-Based Eligibility Rule for the Women's Category in Elite Sport. *International Sports Law Review*, Vol 19, 83–90.
75. Hamilton, B. R. *et al.* (2021). Integrating Transwomen and Female Athletes with Differences of Sex Development (DSD) into Elite Competition: The FIMS 2021 Consensus Statement. *Sports Med*, Vol 51, 1401–1415.
76. Statement on Caster Semenya, World Athletics.
77. Camporesi, S. (2016). Ethics of Regulating Competition for Women with Hyperandrogenism. *Clin Sports Med*, Vol 35, 293–301.
78. (2009). Semenya told to take gender test. *BBC Sport*.
79. International Association of Athletics Federations (2011). IAAF regulations governing eligibility of females with hyperandrogenism to compete in women's competition.
80. Macur, J. (2014). Fighting for the Body She Was Born With. *The New York Times*.
81. (2015). CAS 2014/A/3759 Dutee Chand v. Athletics Federation of India (AFI) & The International Association of Athletics Federations (IAAF).
82. (2019). CAS 2018/O/5794 Mokgadi Caster Semenya v. International Association of Athletics Federations; CAS 2018/0/5798 Athletics South Africa v. International Association of Athletics Federations.
83. Swiss Federal Supreme Court (2020). DSD Regulations: Caster Semenya's appeal against the decision of the Court of Arbitration for Sport dismissed.
84. (2021). Semenya appeals to European court. *BBC Sport*.
85. Bermon, S. *et al.* (2014). Serum androgen levels in elite female athletes. *J Clin Endocrinol Metab*, Vol 99, 4328–4335.
86. Lee, P. A. *et al.* (2006). Consensus Statement on Management of Intersex Disorders. *Pediatrics*, Vol 118, e488–e500.
87. Tannenbaum, C. *et al.* (2019). Sex, gender, and sports. *BMJ*, Vol 364,
88. IAAF publishes briefing notes and Q&A on Female Eligibility Regulations. World Athletics.
89. FINA (2022). Policy on Eligibility for the Men's and Women's Competition Categories.
90. Child Growth Foundation (2018). Puberty and the Tanner Stages.
91. Puberty. *111.wales.nhs.uk*.
92. Ingle, S. (2022). Transgender women swimmers barred from female competitions by Fina. *The Guardian*.
93. (2022). Former Olympic swimmer says the policing of women's bodies doesn't stand up. *ABC Radio National*.
94. Futterman, M. (2022). FINA Restricts Transgender Women From Competing at Elite Level. *The New York Times*.
95. (2021). What is the International Olympic Committee IOC and what is its mission. *International Olympic Committee*.
96. International Olympic Commitee (2021). Olympic Charter.

97. International Olympic Committee (2015). IOC Consensus Meeting on Sex Reassignment and Hyperandrogenism November 2015.
98. (2021). IOC framework on fairness, inclusion and non-discrimination on the basis of gender identity and sex variations. International Olympic Committee.
99. (2021). New IOC framework for inclusion of trans and intersex athletes. *LEAP Sports*.
100. (2022). OII Europe statement on the new IOC framework. *OII Europe*.
101. Human Rights Watch (2021). New Olympic Framework Backs Inclusion. *Human Rights Watch*.
102. Pigozzi, F. *et al.* (2022). Joint position statement of the International Federation of Sports Medicine (FIMS) and European Federation of Sports Medicine Associations (EFSMA) on the IOC framework on fairness, inclusion and non-discrimination based on gender identity and sex variations. *BMJ Open Sport & Exercise Medicine*, Vol 8, e001273. BMJ Specialist Journals.
103. (2021). 48th session Joint Statement on the Human Rights of Intersex Persons. United Nations Human Rights Council.
104. (2015). Gender Identity, Gender Expression and Sex Characteristics Act. *CAP. 540.*
105. Ghattas, D. C. (2019). Protecting Intersex People in Europe: a Toolkit for Law and Policymakers.
106. Theofilopoulos, T. *et al.* (2021). The status of intersex people in Greece. BRING-IN.
107. Bauer, M. *et al.* (2019). Intersex Genital Mutilations | Human Rights Violations Of Children With Variations Of Reproductive Anatomy. Intersex NGO Coalition UK.
108. United Nations Human Rights Council (2013). Report of the Special Rapporteur on torture and other cruel, inhuman or degrading treatment or punishment, Juan E. Méndez.
109. Ghattas, D. C. (2015). Standing up for the Human Rights of Intersex People – How Can You Help? ILGA-Europe.
110. Zillén, K. The Rights of Children in Biomedicine: Challenges posed by scientific advances and uncertainties.
111. Karkazis, K. *et al.* (2018). Impossible "Choices": The Inherent Harms of Regulating Women's Testosterone in Sport. *Bioethical Inquiry*, Vol 15, 579–587.
112. Carpenter, M. (2020). Caster Semenya's life and achievements are cause for celebration, respect and inclusion; her exclusion is consequential. *Journal of Medical Ethics*, Vol 46, 593–594. Institute of Medical Ethics.
113. The International Working Group (IWG) on Women & Sport *et al.* (2019). Caster Semenya: IWG, WSI & IAPESGW write to IAAF | IWG. *IWG Women & Sport*.
114. Women's Sport Foundation (2016). Participation of Intersex Athletes in Women's Sports.
115. (2019). Caster Semenya: Combined Statement: International Working Group on Women & Sport, Women Sport International & International Association of Physical Education for Girls and Women write to the International Association of Athletics Federations.
116. Human Rights Watch *et al.* (2020). "They're Chasing Us Away from Sport": Human Rights Violations in Sex Testing of Elite Women Athletes.
117. United Nations High Commissioner for Human Rights (2020). Intersection of race and gender discrimination in sport.
118. (2019). Press Release - IAAF letter to the World Medical Association, World Athletics.
119. Karkazis, K. *et al.* (2018). The Powers of Testosterone: Obscuring Race and Regional Bias in the Regulation of Women Athletes. *Feminist Formations*, Vol 30, 1–39. Johns Hopkins University Press.
120. Carpenter, M. (2019). Sport. *Intersex Human Rights Australia*.
121. Paletta, D. (2019). Caster Semenya ruling: "Forcing her to undergo medical intervention to compete is a devastating and humiliating push back against her human rights". *ILGA*.
122. The Court of Arbitration for Sport.
123. Court of Arbitration for Sport (2019). Semenya, ASA and IAAF: Executive Summary.
124. European Court of Human Rights (2021). Notification of Semenya v. Switzerland.
125. Pielke Jr., R. (2019). Caster Semenya ruling: sports federation is flouting ethics rules. *Nature*,
126. Patel, S. (2021). Gaps in the protection of athletes gender rights in sport—a regulatory riddle. *Int Sports Law J*, Vol 21, 257–275.
127. Krech, M. (2016). To Be a Woman in the World of Sport. *Institute for International Law and Justice Emerging Scholars Paper*, Vol 25, 29.
128. Patel, S. (2022). Law and Regulatory Barriers to Increasing Inclusivity for Trans Athletes. in *Gender Diversity and Sport: Interdisciplinary Perspectives on Increasing Inclusivity*. (eds. Witcomb, G. L. et al.) Routledge.
129. Karkazis, K. *et al.* (2021). Women Athletes Subjected to 'Sex Testing' are Faced With Impossible Choices. *Foreign Policy*.
130. Lucas, C. B. *et al.* (2019). Out of the Frame: How Sports Media Shapes Trans Narratives. in *LGBT Athletes in the Sports Media*. (ed. Magrath, R.) 99–124. Springer International Publishing.
131. Bunn, S. (2022). Performance, Inclusion and Elite Sports - Transgender Athletes. Parliamentary Office of Science & Technology, UK Parliament.
132. Women in Sport (2021). Stats pack for media.
133. Women's Sport and Fitness Foundation (2008). Barriers to sports participation for women and girls.
134. ILGA-Europe *et al.* (2021). LBTI women in sport: violence, discrimination, and lived experiences.
135. Government Equalities Office (2019). Variations in Sex Characteristics Technical Paper. *GOV.UK*.