1 Sporting Performance of Athletes of the Gender Spectrum: A Cross-sectional

2 Comparison Study Protocol.

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1   Abstract

2   The question of integrating transgender athletes into their affirmed gender categories is becoming
3   more prominent with sport's governing bodies portraying mixed messaging when it comes to
4   answering this question. Testosterone is beneficial to baseline sports performance, and it has been
5   suggested that the differences in circulating testosterone concentrations between cisgender men and
6   cisgender women explain most of the baseline differences in sports performance between the two
7   groups. However, a secondary factor relative to sports performance is the physiological re-distribution
8   of fat mass driven by gender-affirming hormone treatment (GAHT) and the loss of/gain of muscle
9   mass with GAHT in both trans women and trans men and their effects on transgender sporting
10 performance. Previous studies lack data on sports performance measures outside muscular strength
11 and performance measures such as aerobic capacity, power and strength should be studied in tandem
12 within an athletic cohort of trans women and trans men and compared with cisgender women and
13 cisgender male athletes to ascertain whether any lasting advantages are present. New sports
14 performance data on transgender athletes must be generated to inform a decision-making process to
15 inform if the current policies in place are accurate or inexact to maintain fairness and the integrity of
16 sport. Accordingly, this manuscript aims to further provide sports performance and anthropometrical
17 data from a cross-sectional analysis of athletes from 4 groups, trans men (n = ≥6) and trans women (n
18 = ≥6) who have undergone ≥ 1 year of GAHT, cis men (n = ≥6) and cis women (n = ≥6) to provide
19 further evidence and consequently, guidance to sport's governing bodies for the eligibility of
20 transgender athletes

1. Background

Transgender athletes experience conflict between the gender that they were assigned at birth and their experienced gender[1-3]. Some [3-5] but not all [2, 3, 6] will choose to undergo gender-affirming hormone therapy (GAHT) and patients accessing transgender health services have increased considerably in recent years in many European countries [7-9]. The question of integrating transgender athletes into their affirmed gender categories is becoming more prominent with sport's governing bodies portraying mixed messaging when it comes to answering this question, with some opting for blanket bans on trans women in the female category [10, 11], some opting to ask for the reduction of testosterone in the female category for a period of time [12, 13] and the IOC opting for the premise of self-identification into the athletes chosen category [14].

Testosterone is beneficial to baseline sports performance, and it has been suggested that the differences in circulating testosterone concentrations between cisgender men and cisgender women explain most of the baseline differences in sports performance between the two groups [15] before an athletes skill or opportunities in the sport are considered. Circulating testosterone is greatly correlated with fat free mass ($R = 0.73$, $p < 0.0001$),), thigh ($R = 0.66$, $p < 0.0001$) and quadricep ($R = 0.73$, $p < 0.0001$) muscle volume, while being moderately correlated with leg strength ($R = 0.48$, $p < 0.0005$) [15]. The argument against trans women competing in the female category of sport assumes that trans women have benefitted from high testosterone concentrations from the onset of puberty until the administration of GAHT, that this assumed benefit cannot be mitigated [16], and those cisgender female competitors cannot naturally possess this benefit of high testosterone concentrations [17]. This argument is not present in trans men, as serum testosterone concentrations are recommended to be maintained in the mid-normal range for healthy young men from the onset of GAHT [18], hypothetically not giving trans men the competitive advantages of exogenous testosterone concentrations over cisgender men and this viewpoint is reflected in the current inclusion sports policies for trans men [10-12], although this hypothesis is as yet unconfirmed. It should also be noted, the presence of high circulating testosterone concentrations does not guarantee increased performance, but the way an individual's body physiologically responds to testosterone does [15].

Loss of muscle mass has been reported in trans women following GAHT [19-24] and gains in muscle mass have been shown in trans men [20, 22-24]. Studies have shown that testosterone suppression in cisgender men resulted in decreased muscular strength [25, 26] although this result has been disputed in trans women, with some studies showing increases of 0.5-2% in muscle strength [22, 27, 28] and others showing decreases between 4.3-25% [29-31]. Trans men's muscular strength has been shown to improve by 12-26% during GAHT [22, 31]. However, a secondary factor relative to sports performance is the physiological distribution of fat mass driven by GAHT in both trans women and trans men. As a result of testosterone suppression and oestradiol (E2) supplementation, total body fat has been shown to consistently increase in trans women by 20 - 30% [23, 24, 32, 33] and testosterone

1   administration decreases body fat in trans men by 11 - 20% [23, 24, 32, 33]. The data above shows

2   trans women reducing their percentage of fat-free mass and trans men increasing their percentage of

3   fat-free mass. This data is intriguing as the differences in percentages of fat-free mass are suggested as

4   the cause of the difference in sports performance between cisgender males, and cisgender females [34,

5   35]. Cisgender men and women have been shown to have similar relative muscular strength and trans

6   women have also been shown to have 33.8 % weaker relative muscular strength than cisgender men

7   and women while showing a similar absolute strength to cisgender women (31.9 kg ± 2.4 vs. 29.2 kg

8   ± 4.4, [35]).

9   Previous studies lack data on sports performance measures outside muscular strength. Performance

10   measures such as aerobic capacity, power and strength should be studied in tandem within a cohort of

11   trans women and trans men and compared with cisgender women and cisgender male athletes to

12   ascertain whether any lasting advantages are present. To the author's knowledge, only one study

13   assessed $\dot{V}O_{2max}$ in trans women ($n = 8$) after GAHT (~15 years), discovering that trans women's

14   absolute $\dot{V}O_{2max}$ sat between cisgender men and cisgender women's $\dot{V}O_{2max}$ [36]. Like muscular

15   strength discussed above [35], dividing absolute $\dot{V}O_{2max}$ by their fat-free mass, trans women again

16   came out below both cisgender men and women, showing relatively, trans women's maximum O_2

17   uptake is inferior to cisgender men and women. No $\dot{V}O_{2max}$ data has been gained from athletic trans

18   men. It is a well-accepted concept that Hb and Hct concentrations of trans women drop to cisgender

19   female levels after 3-6 months [16, 37, 38] and that trans men's Hb and Hct rise to cisgender male

20   concentrations [38]. It is also well-accepted that reductions in Hb are generally associated with a

21   reduced aerobic capacity [16, 39, 40]. Therefore, lung function should be measured independently and

22   in conjunction with Hb concentrations to understand if any changes in Hb concentrations cause any

23   effect on the VO_{2max} of transgender athletes independent or dependent of lung size.

24   In contrast to the growing amounts of data highlighting the effects of GAHT in non-athletic

25   transgender populations, sports performance data on transgender athletes is scarce. Roberts *et al* [41],

26   retrospectively found in an athletically trained transgender population that was compared against am

27   athletically trained cisgender population, the upper body strength (37.09%) and core strength

28   (15.94%) baseline advantages of trans women over cisgender women had been reduced (upper body

29   6.26%, core -1.99%) after 2 years of GAHT while running performance over 1.5-miles remained 12%

30   (baseline 18.81%) faster after 2 years of GAHT [41]. Trans men's upper body strength (-35.42%) and

31   core strength disadvantages (-3.89%) over cisgender men had been overturned into an advantage

32   (upper body 8.55%, core 10.66%) after 2 years of GAHT while trans men's running performance over

33   1.5-miles was 1.26% (baseline -16.70%) faster than cisgender men after 2 years of GAHT [41]. These

34   findings would suggest a different rate and extent of mitigation of any potential sporting performance

35   advantage conferred by pubertal high testosterone concentrations of trans women given that strength

36   advantages, but not cardiovascular advantages of trans women were mitigated after 2 years of GAHT.

The data above also highlights the performance-enhancing effect of trans men's exogenous testosterone administration and highlights the need to investigate the effects of GAHT on their sporting performance. Particularly, as all 3 metrics had baseline disadvantages under cisgender men ranging from -3.89% to -35.42%, overturned into advantages over cisgender men ranging from 1.66% to 10.66% after 2 years of GAHT. Due to the retrospective and uncontrolled nature of this research, this data requires replication in trained trans women and trans men athletes before any firm conclusions can be drawn.

As a consequence of the little performance data for sport's governing bodies to centre their decisions on, new sports performance data on transgender athletes must be generated to inform a decision-making process, as previously illustrated [42], to inform if the current policies in place are accurate or inexact to maintain fairness and the integrity of sport. Accordingly, this manuscript aims to further provide sports performance and anthropometrical data from a cross-sectional analysis of athletes from 4 groups of the gender spectrum to provide further evidence and consequently, recommendations to sports governing bodies for the eligibility of transgender athletes.

2. Methods

2.1. Study design

This cross-sectional study involves one visit to the laboratory at the School of Applied Sciences, University of Brighton, UK. Each participant will arrive at ~9 am after an overnight fast and depart from testing at ~3 pm. The full study design and the order of tests that will be undertaken by the participants can be found in Figure 1.
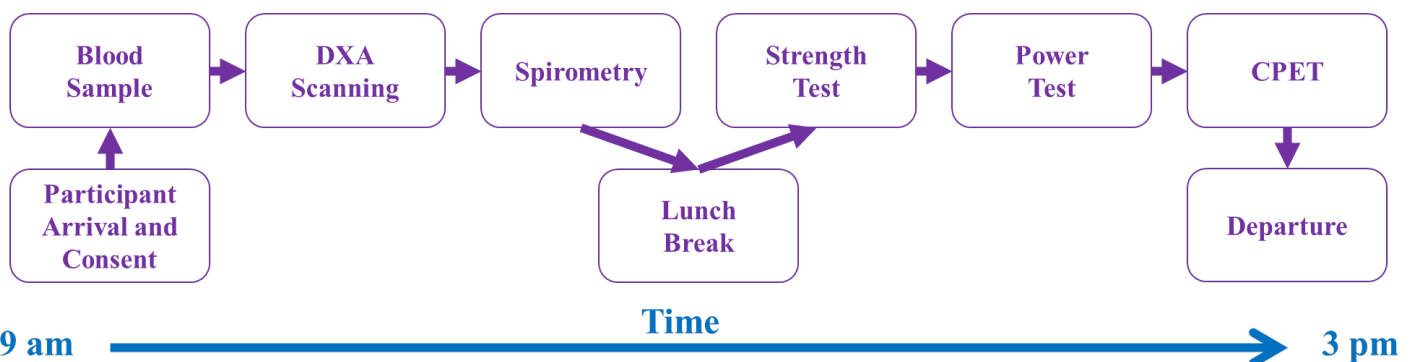
Figure 1. Schedule of activities during participant testing in the laboratory. *DXA, Dual-energy X-ray Absorptiometry; CPET, Cardiopulmonary Exercise Testing.*

2.2. Recruitment

Participants will be recruited through social media advertising on Facebook (Meta Platforms, Inc, California, USA), Instagram (Meta Platforms, Inc, California, USA), and Twitter (Twitter, Inc, California, USA) with the recruitment poster that is supplied in the supplementary materials. All participants will contact the first author (BH) through the email provided in the advert. After the participant responds to the advert, the first author (BH) will email the participant information sheet in return, on the reception of the participant information sheet the participant will have a minimum of 1 week to consider their participation before being invited to travel to the laboratory in Brighton. Before participation, all participants will be orally informed of the study procedures and their written informed consent will be obtained.

2.3. Participants and eligibility criteria

24 participants (6 trans men, 6 trans women, 6 cisgender men, and 6 cisgender women) will be sought that participate in a sport at a competitive level or undergo physical training three times per week. Trans men and trans women athletes must have completed ≥1 year of GAHT, which will be voluntarily disclosed during consent and verified during blood test analysis. The full inclusion/exclusion criteria can be found in Table 1.

Table 1: Inclusion/exclusion criteria for a study participants

Primary Inclusion Criteria

Trans Men and Trans Women	Cisgender Men and Cisgender Women
GAHT for +1 year.	-
Play a Competitive Sport	Play a Competitive Sport
or	or
Physically train 3x per week	Physically train 3x per week

Secondary Exclusion Criteria

The Physical Activity Readiness Questionnaire highlights health/fitness concerns

Exclude from DXA scanning only if the participant is:

1. pregnant
2. has a total annual radiation dose above 1mSV

Notes: GAHT, Gender-Affirming Hormone Therapy; DXA, Dual-energy X-ray absorptiometry; mSV, millisievert.

2.4. Laboratory assessments

2.4.1. Blood sampling

Capillary blood samples will be collected from the ring finger of the non-dominant hand via a Unistik® 3 Comfort lancet (Owen Mumford Ltd, Woodstock, UK) due to capillary samples yielding a higher Hb value than venous samples [43]. Venous blood samples will be collected by the first author (BH) or the third author (FG) from an antecubital vein utilizing a closed vacuette system. Two 10 mL whole blood samples will be collected into a BD® serum tube (Becton, Dickinson, and Company, Wokingham, Berkshire, UK) for serum extraction. Once collected the tubes will be left at room temperature (18 ± 5°C) for 1 hour and then stored in a fridge (3 ± 2°C) for up to 4 hours maximum before being centrifuged by the first (BH) or second (CC) author at 1300G for 10 min at 4°C.

2.4.2. Body composition and Bone Mass

The participants will undertake a pre-DXA health questionnaire to screen for previous radiation exposure and a Physical Activity Readiness Questionnaire for Everyone to screen the participant's ability to undertake exercise. Body composition and Bone Mass will then be measured by DXA (Horizon W, Hologic Inc., Massachusetts, USA). Each participant will undergo a whole-body scan, a femoral neck scan and a lumbar spine scan in succession. The participant will be asked to lie on the scan bed and all participant placement for the three scans will be done by the first author (BH).

2.4.3. Lung Function

Lung function will be measured using a Vitalograph Alpha spirometer (Vitalograph Inc, Kansas, USA) with an antibacterial filter placed on the spirometer and a nose clip placed on the bridge of the participant's nose. Each participant will be asked to perform 2 tests, the Vital Capacity (VC), and the Forced Vital Capacity (FVC) test. The participant will be seated in a slightly reclined chair so as not to close the lungs. For the VC test, the participant will be asked to breathe maximally and then exhale into the spirometer as forcefully and as long as possible. For the FVC test, the participant will perform a flow-volume loop manoeuvre with the nose clip on by inhaling as deeply as possible with their lips tightly over the tube followed by exhaling as forcefully as the participant can, repeating this manoeuvre twice. The two tests will be repeated until a trend of declining performance occurs for each test. The best result for each test will then be recorded.

2.4.4. Strength

Testing of strength will be measured with a handgrip dynamometer (TAKEI 5401, TAKEI Scientific Instruments Co., Ltd, Japan). The participant's hand size will be measured around the metacarpophalangeal joints of both hands before the testing begins, afterwards, the participants will be seated in a chair with their ankles placed against the legs of the chair and their backs against to back of the chair. The participants will then place their non-testing hand on their closest thigh, while

their testing arm is flexed to a 90° angle, with the palm facing medially. If the participants feet or hands move from the protocol during their attempt this will render that attempt void and this data will be excluded. The dynamometer will then be placed in their hand by the first (BH) or second author (CC) and the participant will be asked to squeeze for 10 seconds. Each hand will be tested 3 times in sequential order of left-right to allow each hand to rest, for a total of 6 repetitions and the mean scores will be taken for each hand.

2.4.5. Lower Body Power

Lower body power will be measured with the counter-movement jump (CMJ) manoeuvre on a JUM001 Jump Mat (Probotics Inc, Alabama, USA). Before testing, the participants will be asked to cycle on a cycle ergometer (Monark Exercise AB, Vansbro, Sweden) for 20 minutes at 60 revolutions per minute to warm up the muscle groups of the legs. During this cycle, the participants will be shown the technique of the CMJ procedure by the first (BH) or second author (CC). The test will be controlled to ~45° of counter-movement and hands must be placed on hips to prevent arm swing. The participant will then be allowed a period of sub-maximal familiarization and coaching by the first (BH) or second author (CC). During the test, if the participant went beyond 45° of counter-movement, or the hands came off the hips the test would be declared void for that attempt. After the recording of 3 legal maximal attempts, the mean scores will be recorded.

2.4.6. Cardiopulmonary Exercise Testing (CPET)

CPET will be performed using a 95T Engage Treadmill ergometer (Life Fitness, Illinois, USA). A landing crash mat was placed behind the treadmill for participant safety in case of falls. To ensure test accuracy, the metabolic gas will be calibrated before each test with COSMED™ certified reference gas of 16% O_2 and 5% CO_2 and the turbine flowmeter will be calibrated before each test using a certified 3L calibration syringe (Hans Rudolph, Kansas, USA) according to manufacturer instructions. The participants will wear a mask (Hans Rudolph, Kansas, USA) that will be strapped to the participant's head via Velcro™ straps and the participants' inspiration and expiration will be measured by O_2 and CO_2 analysers in the flowmeter sample line via breath-by-breath analysis (Omnia, Quark CPET, COSMED™ Srl, Rome, Italy). Heart Rate (HR and HR_{Max} will be recorded using Huawei Watch GT smartwatch HR technology (Huawei Technologies Co., Ltd, Shenzhen, China) secured to the participant's right wrist. The participants will be monitored under relaxed conditions for ~5 minutes to make sure that their resting Respiratory Quotient (RQ) will be ~0.80 and the participant's resting $\dot{V}O_2$ is ~ 500ml/min to prevent a false positive test. During the test, the participant's HR was monitored every minute and recorded after 2 minutes of each elevation of workload and the participant was then also asked to point to or signal a Rating of Perceived Exertion (RPE) scale (revised Borg 10-grade scale), allowing for compensation of each workload to occur. The participant will be considered to have reached their $\dot{V}O_{2max}$ if three out of four of the following occurred: a plateau or 'peaking over' in oxygen uptake, an RQ of ≥1.1, maximal HR is reached, and/or volitional

exhaustion. If three out of the four do not occur, then the test will not be considered for analysis. All $\dot{V}O_{2max}$ tests will be conducted and analysed by the first author (BH) to avoid any inter-investigator variability. The ramp protocol of Badawy and Muaidi [44] treadmill $\dot{V}O2max$ testing will be used for each $\dot{V}O_{2max}$ test.

2.5. Outcome measures

2.5.1. Blood measurements

Capillary Hb will be analysed by a HemoCue® 201+ (HemoCue AB, Ängelholm, Sweden) reported in grams per litre (g/l), Oestradiol (E2) concentrations in serum will be measured using tandem mass spectrometry (Model to be confirmed) and will be reported in picograms per millilitre (pg/mL), and testosterone in serum concentrations will also be measured using tandem mass spectrometry and will be reported in nanomoles per litre (nmol/L).

2.5.2. Body composition and Bone Mass

All analysis will be completed immediately after the 3 scans using Apex v5.6.0.5 software (Hologic, Connecticut, USA) by the first author (BH). Due to the in-built analysis assumptions regarding the measurement of head fat mass and percentage fat of 17%, subtotal data (whole-body less head) data will be used to report anthropometric data, which will also be reported regionally. Anthropometric data will be reported as fat mass (Kg), lean mass (Kg), and Fat-free mass (Kg). Bone measures will be reported as bone area (cm^{-3}), bone mineral content (BMC, g) and bone mineral density (BMD, g·cm^3). A report of the DXA analysis will be given to each participant.

2.5.3. Lung function

All lung function tests will be analysed by the inbuilt analysis hardware of the Vitalograph Alpha spirometer. Lung function data will be presented as vital capacity (VC) in litres (L), to determine the maximum amount of air exhaled in a relaxed state; forced vital capacity (FVC) in L to determine the maximum volume of air exhaled forcefully; forced expiratory volume in 1 second (FEV^1) in L to determine the volume of air that the participant can forcibly expire in the first 1 second; FEV$^{1\%}$ as a percentage (%), to determine the proportion of the participants VC that they can expire in the FEV^1 to the full, FVC; peak expiratory flow (PEF) in L per minute (L/min), to determine the maximum speed of maximally forced expiration initiated at full inspiration. Lastly, forced expiratory flow (FEF$^{25\text{-}75}$) in L to determine the mean flow of expired air between 25-75% of FVC. A report of the lung function analysis will be given to each participant.

2.5.4. Muscular Strength

Hand size for both the participant's right hand and the left hand will be presented in centimetres (cm). Absolute handgrip scores will be presented in Kg, relative handgrip scores will be presented as the

absolute handgrip score divided by hand size (kg/cm) and the absolute hand grip score divided by FFM reported by DXA (kg/kg).

2.5.5. Lower Body Power

Counter movement jump height in inches (in) and airtime will be reported in seconds (s) and analysed by the inbuilt hardware of the JUM001 Jump Mat. Jump height will be converted to cm by multiplying the result in inches by 2.54. Peak power in watts (W) and Average power in W will be determined by the equations developed by Johnson and Bahamonde [45] shown below:

$$Peak\ power\ (W)$$
$$= \big((78.6 \times Jump\ Height[cm]) + (60.3 \times mass[kg])\big)$$
$$- \big((15.3 \times height\ [cm]) - 1308\big)$$

$$Average\ Power\ (W)$$
$$= \big((43.8 \times Jump\ Height[cm]) + (32.7 \times mass[kg])\big)$$
$$- \big((16.8 \times height\ [cm]) + 431\big)$$

2.5.6. Maximal Oxygen Uptake ($\dot{V}O_{2max}$)

Each $\dot{V}O_{2max}$ test will be analysed immediately using COSMED Omnia software (COSMED Srl, Rome, Italy) while the participant is in a cool-down period and the results will be immediately emailed to the participant. Absolute $\dot{V}O_{2max}$ and absolute anaerobic threshold (AT) will be reported in millilitres per min (ml/min). Relative $\dot{V}O_{2max}$ and AT will be presented by dividing ml/min by body mass (ml/min/kg) and FFM reported by DXA (ml/min/kg). The respiratory quotient (RQ) at $\dot{V}O_{2max}$, defined as the volume of carbon dioxide released over the volume of oxygen absorbed during respiration, will be reported alongside the HR_{max} recorded at the participant's $\dot{V}O_{2max}$.

2.6. Statistical analyses

Statistical analysis was performed using Jamovi [46]. The mean and standard deviations (SD) will be presented to compare the differences between the means. The mean scores for the measures of, testosterone, E2, and Hb will be compared using a two-way ANOVA with the two factors of gender and length of GAHT. The measures of body composition and bone mass will be compared with a three-way ANOVA with three factors being gender, testosterone and E2. Lung function, muscular strength, lower body power and maximal oxygen uptake will be compared with a four-way ANOVA with the four factors being gender, testosterone, E2 and FFM. All ANOVAs will be combined with a Turkey post-hoc correction. Pearson's correlation coefficient will be used to assess the relationship between the blood measures of testosterone, E2 and Hb, in addition to the DXA measure of FFM, with the measures of muscular strength, lower body power, and maximal oxygen uptake. Due to the large number of comparisons expected, a Bonferroni correction will be applied for the correlation

analysis which will be determined by $\alpha = \frac{\alpha}{m}$ where α is the desired alpha level of 0.05 and m is the number of hypotheses tested. This will be calculated manually.

2.7. Ethical Approval and Funding

Acknowledgements

Competing interests

All authors declare no competing interests in this research.

Author Contributions

Conceptualization, BH and FG; Methodology, BH; Data Collection: BH and CC; writing–original draft preparation: BH, CC and FG Writing–review and editing: ALL.

Data Availability

An Open Science Framework project titled Sporting Performance of Athletes of the Gender Spectrum: A Cross-sectional Comparison Study with all materials can be found here: (insert link)

References

1.   Jones BA, Arcelus J, Bouman WP, Haycraft E. Sport and transgender people: a systematic review of the literature relating to sport participation and competitive sport policies. Sports Medicine. 2017;47(4):701-16.

2.   Kuyper L, Wijsen C. Gender identities and gender dysphoria in the Netherlands. Archives of sexual behavior. 2014;43(2):377-85.

3.   NHS. Gender dysphoria. 2020 28th May 2020 [cited 2020 29th July]; Available from: https://www.nhs.uk/conditions/gender-dysphoria/

4.   Coleman E, Bockting W, Botzer M, Cohen-Kettenis P, DeCuypere G, Feldman J, et al. Standards of care for the health of transsexual, transgender, and gender-nonconforming people, version 7. International journal of transgenderism. 2012;13(4):165-232.

5.   Wylie K, Barrett J, Besser M, Bouman WP, Bridgman M, Clayton A, et al. Good practice guidelines for the assessment and treatment of adults with gender dysphoria. Sexual and Relationship Therapy. 2014;29(2):154-214.

6.   Hargie OD, Mitchell DH, Somerville IJ. 'People have a knack of making you feel excluded if they catch on to your difference': Transgender experiences of exclusion in sport. International Review for the Sociology of Sport. 2017;52(2):223-39.

7.   Arcelus J, Bouman WP, Van Den Noortgate W, Claes L, Witcomb G, Fernandez-Aranda F. Systematic review and meta-analysis of prevalence studies in transsexualism. European Psychiatry. 2015;30(6):807-15.

8.   Aitken M, Steensma TD, Blanchard R, VanderLaan DP, Wood H, Fuentes A, et al. Evidence for an altered sex ratio in clinic-referred adolescents with gender dysphoria. The Journal of Sexual Medicine. 2015;12(3):756-63.

9.   De Vries A, Kreukels B, T'sjoen G, Ålgars M, Mattila A. Increase of referrals to gender identity clinics: a European trend. Transgender healthcare in Europe Book of abstracts. 2015:10.

10.   World Rugby. World Rugby Transgender Guideline. 2020 October 9th 2020 [cited 2021 November, 29th]; Available from: https://playerwelfare.worldrugby.org/?documentid=231

11.   FINA. Policy on eligibility for the men's and women's competition categories. In: FINA, editor. Online; 2022.

12.   Union Cycliste Internationale. Chapter V Eligibilty Regulations for Transgender Athletes. In: Union Cycliste Internationale, editor. Part 13 Medical Rules. Online; 2022.

13.   USA Gymnastics. USA gymnastic policy for transgender inclusion. 2020 [cited 2021 November, 29th]; Available from: https://usagym.org/PDFs/About%20USA%20Gymnastics/transgender_policy.pdf

14.   International Olympic Committee. Framework on fairness, inclusion and non-discrimination on the basis of gender identity and sex variations. 2021 [cited 2021 November, 29th]; Available from: https://stillmed.olympics.com/media/Documents/News/2021/11/IOC-Framework-Fairness-Inclusion-Non-discrimination-2021.pdf

15.   Handelsman DJ, Hirschberg AL, Bermon S. Circulating testosterone as the hormonal basis of sex differences in athletic performance. Endocrine reviews. 2018;39(5):803-29.

16.   Hilton EN, Lundberg TR. Transgender women in the female category of sport: perspectives on testosterone suppression and performance advantage. Sports Med. 2020 2020/12/08.

17.   Bianchi A. Transgender women in sport. Journal of the Philosophy of Sport. 2017;44(2):229-42.

18.   Bhasin S, Brito JP, Cunningham GR, Hayes FJ, Hodis HN, Matsumoto AM, et al. Testosterone therapy in men with hypogonadism: an Endocrine Society clinical practice guideline. The Journal of Clinical Endocrinology & Metabolism. 2018;103(5):1715-44.

19.   Elbers J, Asscheman H, Seidell J, Gooren LJ. Effects of sex steroid hormones on regional fat depots as assessed by magnetic resonance imaging in transsexuals. American Journal of Physiology-Endocrinology and Metabolism. 1999;276(2):E317-E25.

20.   Gooren LJ, Bunck MC. Transsexuals and competitive sports. European Journal of Endocrinology. 2004;151(4):425-30.

21. T'Sjoen G, Weyers S, Taes Y, Lapauw B, Toye K, Goemaere S, et al. Prevalence of low bone mass in relation to estrogen treatment and body composition in male-to-female transsexual persons. Journal of Clinical Densitometry. 2009;12(3):306-13.

22. Wiik A, Lundberg T, Rullman E, Andersson D, Holmberg M, Mandić M, et al. Muscle Strength, Size, and Composition Following 12 Months of Gender-affirming Treatment in Transgender Individuals. The Journal of clinical endocrinology and metabolism. 2020;105(3).

23. Klaver M, van Velzen D, de Blok C, Nota N, Wiepjes C, Defreyne J, et al. Change in visceral fat and total body fat and the effect on cardiometabolic risk factors during transgender hormone therapy. The Journal of Clinical Endocrinology & Metabolism. 2022;107(1):e153-e64.

24. Klaver M, De Blok C, Wiepjes C, Nota NM, Dekker MJ, de Mutsert R, et al. Changes in regional body fat, lean body mass and body shape in trans persons using cross-sex hormonal therapy: results from a multicenter prospective study. European Journal of Endocrinology. 2018;178(2):163-71.

25. Mauras N, Hayes V, Welch S, Rini A, Helgeson K, Dokler M, et al. Testosterone deficiency in young men: marked alterations in whole body protein kinetics, strength, and adiposity. The Journal of Clinical Endocrinology & Metabolism. 1998;83(6):1886-92.

26. Kvorning T, Andersen M, Brixen K, Madsen K. Suppression of endogenous testosterone production attenuates the response to strength training: a randomized, placebo-controlled, and blinded intervention study. Am J Physiol Endocrinol Metab. 2006;291(6):E1325-E32.

27. Tack LJ, Heyse R, Craen M, Dhondt K, Bossche HV, Laridaen J, et al. Consecutive cyproterone acetate and estradiol treatment in late-pubertal transgender female adolescents. The journal of sexual medicine. 2017;14(5):747-57.

28. Auer MK, Cecil A, Roepke Y, Bultynck C, Pas C, Fuss J, et al. 12-months metabolic changes among gender dysphoric individuals under cross-sex hormone treatment: a targeted metabolomics study. Scientific reports. 2016;6(1):1-10.

29. Lapauw B, Taes Y, Simoens S, Van Caenegem E, Weyers S, Goemaere S, et al. Body composition, volumetric and areal bone parameters in male-to-female transsexual persons. Bone. 2008;43(6):1016-21.

30. Van Caenegem E, Wierckx K, Taes Y, Schreiner T, Vandewalle S, Toye K, et al. Preservation of volumetric bone density and geometry in trans women during cross-sex hormonal therapy: a prospective observational study. Osteoporosis International. 2015;26(1):35-47.

31. Scharff M, Wiepjes CM, Klaver M, Schreiner T, t'Sjoen G, Den Heijer M. Change in grip strength in trans people and its association with lean body mass and bone density. Endocrine connections. 2019;8(7):1020-8.

32. Klaver M, Dekker M, de Mutsert R, Twisk J, den Heijer M. Cross-sex hormone therapy in transgender persons affects total body weight, body fat and lean body mass: a meta-analysis. Andrologia. 2017;49(5):e12660.

33. Spanos C, Bretherton I, Zajac JD, Cheung AS. Effects of gender-affirming hormone therapy on insulin resistance and body composition in transgender individuals: a systematic review. World journal of diabetes. 2020;11(3):66.

34. Nickerson BS, McLester CN, McLester JR, Kliszczewicz BM. Relative accuracy of anthropometric-based body fat equations in males and females with varying BMI classifications. Clinical nutrition ESPEN. 2020;35:136-40.

35. Alvares LA, Santos MR, Souza FR, Santos LM, Ramos HA, Mendonca BB, et al. Muscle Strength in Transgender Women After Long-Term Hormone Therapy: A Cross-Sectional Study. Journal of the Endocrine Society. 2021;5(Suppl 1):A792.

36. Alvares LA, Santos MR, Souza FR, Santos LM, Mendonca BB, Alves M-JNN, et al. First Evidence of Cardiopulmonary Adaptation to Physical Effort in Transgender Women After Long-Term Hormone Therapy: A Cross-Sectional Study. Journal of the Endocrine Society. 2021;5(Supplement_1):A790-A1.

37. Harper J, O'Donnell E, Khorashad BS, McDermott H, Witcomb GL. How does hormone transition in transgender women change body composition, muscle strength and haemoglobin? Systematic review with a focus on the implications for sport participation. British Journal of Sports Medicine. 2021.

1 38.   Antun A, Zhang Q, Bhasin S, Bradlyn A, Flanders WD, Getahun D, et al. Longitudinal
2 changes in hematologic parameters among transgender people receiving hormone therapy. Journal of
3 the Endocrine Society. 2020;4(11):bvaa119.
4 39.   Kanstrup I-L, Ekblom B. Blood volume and hemoglobin concentration as determinants of
5 maximal aerobic power. Medicine and science in sports and exercise. 1984;16(3):256-62.
6 40.   Otto JM, Montgomery HE, Richards T. Haemoglobin concentration and mass as determinants
7 of exercise performance and of surgical outcome. Extreme physiology & medicine. 2013;2(1):1-8.
8 41.   Roberts TA, Smalley J, Ahrendt D. Effect of gender affirming hormones on athletic
9 performance in transwomen and transmen: implications for sporting organisations and legislators.
10 British Journal of Sports Medicine. 2020:bjsports-2020-102329.
11 42.   Hamilton BR, Guppy FM, Barrett J, Seal L, Pitsiladis Y. Integrating transwomen athletes into
12 elite competition: the case of elite archery and shooting. European Journal of Sport Science. 2021:1-
13 22.
14 43.   Patel AJ, Wesley R, Leitman SF, Bryant BJ. Capillary versus venous haemoglobin
15 determination in the assessment of healthy blood donors. Vox sanguinis. 2013;104(4):317-23.
16 44.   Badawy MM, Muaidi QI. Cardio respiratory response: Validation of new modifications of
17 Bruce protocol for exercise testing and training in elite Saudi triathlon and soccer players. Saudi
18 journal of biological sciences. 2019;26(1):105-11.
19 45.   Johnson DL, Bahamonde R. Power output estimate in university athletes. Journal of strength
20 and Conditioning Research. 1996;10:161-6.
21 46.   Jamovi. The Jamovi Project. 2021 [cited 2022 May 9th]; Version 1.6:[Available from:
22 https://www.jamovi.org

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