Transgender Women in the Female Category of Sport: Perspectives on Testosterone Suppression and Performance Advantage.

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Emma N Hilton and Tommy R Lundberg, 2020. A lay summary.

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1. INTRODUCTION | Sports performance is strongly influenced by muscle, skeleton and cardiovascular (CV) capacity, which differ significantly between males and females. Comparing like-for-like competition, the male advantage appears insurmountable. Further, male advantage may create safety and athlete welfare concerns. Thus, to ensure that both men and women can enjoy sport in terms of fairness, safety and inclusivity, most sports are divided into male and female categories.
Transgender women (TW) may wish to compete in the female category. Current IOC policy: "*it is necessary to ensure insofar as possible that trans athletes are not excluded*," yet also: *"the overriding sporting objective is and remains the guarantee of fair competition".* And the IOC concludes: "*restrictions on participation are appropriate to the extent that they are necessary and proportionate to the achievement of that objective*."

IOC criteria by which TW may compete in the female category: solemn declaration of female gender identity and maintenance of testosterone (T) levels <10 nmol/L for at least 12 months prior to competing/during competition. We surmise the IOC believes these T criteria sufficient to remove the sporting advantages of males over females and deliver fair and safe competition within the female category. Are they?

2. BIOLOGICAL BASIS FOR MALE PERFORMANCE ADVANTAGE | Males and females develop differently, and sports differences are evident pre-puberty. Compared with girls, boys can run +10% faster, jump +10% further, have +10% higher grip strength, and have higher CV (VO2max) capacity. Early differences might be mediated by genetics (6500 genes expressed differently between males and females, 3000 muscle-related) and/or "mini-puberty" (male babies get a burst of T at 1-6 months old). During puberty, testes-derived T levels increase 20-fold in males, but remain low in females. T in males induces changes in muscle, strength, skeleton and hemoglobin levels and thus, divergence of athletic performances.

As a result of androgenization, males have (briefly): larger and denser muscle mass, greater muscular force production, lower fat and different fat-muscle distribution, stiffer connective tissue, longer and larger skeletal structure, and superior CV function. These properties are advantageous in almost all sports.

3.1 SPORTS PERFORMANCE DIFFERENCES – ELITE | We compared elite athletes records/performances in a range of disciplines, and found (overview): +11-13% advantage in rowing, running and swimming; +18% advantage in jumping events (long, high, triple); +20% advantage in sports where upper body strength is dominant (e.g tennis, baseball, field hockey).
We examined performance metrics in elite athletes. Vertical jump performance is +30% greater in elite males. Throwing represents the widest sex difference from an early age and in Olympic javelin throwers, peak velocities of the shoulder, wrist, elbow and hand are +13-21% higher for male athletes.

The increasing performance gap as upper body strength becomes critical is likely explained by the observation that males have disproportionately greater strength on their upper compared to lower body. Males also have longer arms than females, which allows greater torque production from the arm when, for example, throwing a ball, punching or pushing.

We explored mass-strength relationships in Olympic weightlifting records. Males are ~30% stronger than females of the same mass and height (see 69kg [1998-2018 records] and 55kg [2019-] categories). In fact, males are stronger than higher weight category females. The performance gap increases to ~40% in open weight categories, where height and weight are no longer limited. In powerlifting the gap between open male and female records is +65%.

Translated to competition, in running events where the male-female gap is approximately 11%, approximately 10 000 males have personal best times that are faster than the current Olympic 100 m female champion. This example illustrates the “real life” effect of an 11% gap between males and females.

Furthermore, examination of selected junior male records, which surpass adult elite female performances by the age of 14-15 years, demonstrates superior male performance within a few years of the onset of puberty.

These data overwhelmingly confirm that testosterone-driven puberty, as the driving force of development of male secondary sex characteristics, underpins sporting advantages that are so large no female could reasonably hope to succeed without sex segregation in most sporting competition.

3.2. SPORTS PERFORMANCE DIFFERENCES – NON-ELITE |The male performance advantages described in athletes are similar in magnitude in untrained people. For example: VO2max is 12-15% higher in males than in females; lower-limb muscle strength is 50% higher in males and females; males have 57% greater bicep size and 89% stronger bicep curl than females; males produce 162% power than females in a punch motion.

This highlights the difference in upper body capacity between males and females, and shows that sex differences in parameters such as mass, strength and speed may combine – synergise – to produce even larger sex differences in sport-specific actions.

For example, the average 17 yr old male throws a ball further than 99% of 17 yr old females, despite no single variable (arm length, muscle mass etc.) reaching this numerical advantage. Similarly, no single parameter that produces punching actions achieves +162% magnitude of difference between males and females.

4. IS MALE PERFORMANCE ADVANTAGE LOST IN TW? | We performed a systematic search of the scientific literature addressing skeletal and muscle characteristics of TW.

4.1 SKELETON | There are multiple studies of bone health in TW. TW often have low baseline bone mineral density (BMD), attributed to low levels of physical activity, especially weight-bearing exercise, and low Vitamin D levels. However, TW generally maintain bone mass over the course of at least 24 months of T suppression. There may even be small but significant increases in BMD at the lumbar spine.

Given the maintenance of BMD and the lack of a plausible mechanism by which T suppression might affect bone length and hip width, we conclude that sporting advantage conferred by skeletal size and bone density would be retained despite T reductions compliant with the IOC's current guidelines.

4.2 MUSCLE AND STRENGTH | We found 12 longitudinal ("before-after") studies examining the effects of T suppression on lean body mass or muscle size in TW. The collective evidence suggests that 12 months, the most commonly examined intervention period, of T suppression to female-typical reference levels results in a modest (approximately -5%) loss of lean body mass or muscle size.

Comparison with baseline measurements from females shows that TW retain 13-39% more muscle mass than females. The reduction achieved by 12 months of T suppression is small relative to the initial superior mass.

Three of the above studies included strength measurements: first, hand-grip strength was reduced by -9% after 24 months of T suppression (+23% advantage retained over female controls); a second study of hand-grip strength showed -4% in grip strength after 12 months of T-suppression (+17% advantage retained over female controls); a study of quad strength after 12 months of T suppression showed negligible loss (+41% advantage retained over female controls).

These longitudinal data comprise a clear pattern of very modest to negligible changes in muscle mass and strength in TW suppressing T for at least 12 months. Muscle mass and strength are key physical parameters that constitute a significant, if not majority, portion of the male performance advantage. Thus, our analysis strongly suggests that the reduction in T levels required by many sports federation policies is insufficient to remove or reduce the male advantage, in terms of muscle mass and strength, by any meaningful degree.

We found one major cross-sectional ("after only") study that measured muscle mass and strength in TW, recruited after orchiectomy and approximately 8 years of T suppression. TW had 17% less lean mass and 25% lower quad strength than control males.

This comparison suggests that prolonged T suppression substantially reduces muscle mass and strength in TW. However, the typical gap in lean mass and strength between males and females at baseline exceeds the reductions reported in this study. For example, the final grip-strength was still +25% higher than matched female reference values.

Furthermore, given that TW often have slightly lower baseline measurements of muscle and strength, and baseline measurements were unavailable for these TW, the above calculations using control males reference values may be an overestimate of actual loss of muscle mass and strength in these TW.

4.3 ENDURANCE PARAMETERS | No controlled longitudinal study has explored the effects of T suppression on endurance-based performance.
An analysis of self-selected and self-reported race times for eight TW runners of various age categories who had, over an average 7 year period, competed in sub-elite middle-long distance races within both the male and female categories has suggested that T suppression reduces running performance by approximately the size of the typical male advantage.

However, factors affecting performances, including training, injury, race course and weather conditions, were uncontrolled for, and there were uncertainties regarding which race times were self-reported vs. which race times were actually reported and verified.

Furthermore, one runner improved substantially post-transition, which was attributed to improved training. This demonstrates that performance decrease after transition is not inevitable if training practices are improved.

Hemoglobin level appears to decrease by ~10% with T suppression in TW, with a predicted performance penalty associated with reduced oxygen-carrying capacity. However, factors such as total blood volume, heart size and contractility, and blood vessel supply also play a role for the final oxygen uptake. Thus, while a reduction in hemoglobin is strongly predicted to reduce endurance performance in TW, it is unlikely to completely close the baseline gap in aerobic capacity between males and females.

The typical increase in body fat noted in TW may also be a disadvantage for sporting activities (e.g. running) where body weight is a disadvantage. It is unclear to what extent the expected increase in body fat could be offset by nutritional and exercise countermeasures, and individual variation is likely to be present. In longitudinal studies, some TW appear resistant to increased body fat.

5. DISCUSSION | The data presented here demonstrates that superior skeletal and muscle metrics achieved by males at puberty, and underpinning a considerable portion of the male performance advantage over females, are not removed by the current regimen of T suppression permitting participation of transgender women in female sports categories. Rather, it appears that the male performance advantage remains substantial.
Currently, there is no consensus on an acceptable degree of residual advantage held by TW that would be tolerable in the female category of sport. Given the IOC position that fair competition is the overriding sporting objective, any residual advantage carried by TW raises obvious concerns about fair and safe competition in the numerous sports where muscle mass, strength and power are key performance determinants.

5.1 ATHLETIC STATUS | Despite the current absence of data from athletic TW, it is possible to evaluate potential outcomes in athletic TW compared with the untrained cohorts presented above.
The first possibility is that athletic TW will experience similar reductions (approximately -5%) in muscle mass and strength as untrained TW, and will thus retain significant advantages over a comparison group of females.

A second possibility is that by virtue of greater muscle mass at baseline, pre-trained athletic TW will experience larger relative decreases in muscle mass and strength if they converge with untrained TW, particularly if training is halted during transition, although there is no rationale to expect a weaker endpoint state than untrained TW (and thus, advantage will be retained).

Finally, training before and during the period of T suppression may attenuate the expected reductions, such that decreases in muscle mass and strength will be smaller or non-existent in TW who undergo training. Multiple, well-controlled studies of males suppressing T for research purposes or during prostate cancer treatment show that even moderate resistance training can mitigate muscle and strength loss, and even permit large gains, during T suppression. Considering TW athletes who train during T suppression, it is plausible to conclude that any losses will be similar to or even smaller in magnitude than documented in the longitudinal studies described in this review.

Thus, we argue that it is implausible that athletic TW would achieve final muscle mass and strength metrics that are at par with reference females at comparable athletic level.

5.2 BEYOND MUSCLE MASS AND STRENGTH | Muscle mass is not the only contributor to strength. The importance of the nervous system for muscle activation and strength must be acknowledged. In addition, factors such as fiber types, biomechanical levers, pennation angle (how nerves and muscles join) and tendon composition may all influence muscular force. While there is currently limited information on how these factors are influenced by testosterone suppression, impact seems to be minute.
There is no research evaluating the effects of T suppression on other performance markers known to be affected by T and some of them measurably different between

males and females, include visuospatial abilities, aggressiveness, coordination and flexibility.

5.3 TESTOSTERONE-BASED CRITERIA | Sports federations such as World Athletics have recently lowered the eligibility criterion of T to <5nmol/L. From the studies summarised here, it is apparent that most interventions result in almost complete suppression of T levels, certainly well below 5 nmol/L. Thus, we question whether current circulating T level can be a meaningful decisive factor, when in fact not even suppression down to around 1 nmol/L removes the skeletal and muscle mass/strength advantage in any significant way.

In terms of duration of T suppression, it may be argued that although 12 months of treatment is not sufficient to remove the male advantage, perhaps extending the time frame of suppression would generate greater parity with female metrics. However, based on the studies reviewed in here, evidence is lacking that this would diminish the male advantage to a tolerable degree. On the contrary, it appears that the loss of lean mass and grip strength is not substantially decreased at year 2 or 3 of T suppression, nor evident in cohorts after an average 8 years after transition.

From a medical-ethical point of view, we question whether a requirement to lower T to ensure sporting participation can be justified at all. If the advantage persists to a large degree, as evidence suggests, then targeting a certain T level will not achieve its objective and may drive medical practice that an individual may not want or require, without achieving its intended benefit.