Effect of Cross-Sex Hormone Therapy on Athletic Performance among Transgender Military Personnel

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What are the new findings?

- Transgender women retain an advantage in upper body strength (push-ups) over cis-gender women for 1-2 years after starting gender-affirming hormonal therapy
- Transgender women retain an advantage in endurance (1.5-mile run) over cis-gender women for over 2 years after starting gender-affirming hormonal therapy
- The 1-year treatment period of testosterone suppression required for inclusion of transgender women into elite level women's competition may be inadequate to ensure a level playing field

Abstract:

Objective: Examine the effect of cross-sex hormone therapy on athletic performance among transgender military personnel.

Methods: Record review of fitness test results and medical records among 29 transgender men (TM) and 46 transgender women (TW) in the United States Air Force. We compared pre- and post-treatment fitness test results of TM and TW with the average performance of males and females in the Air Force. We also measured the rate of hormone-associated changes in body composition and athletic performance.

Results: Our subjects were 26.2 years old (S.D. 5.5). TW performed more push-ups and sit-ups in one minute and ran 1.5 miles faster than cis-gender women in the AF prior to treatment. These differences were no longer significant after 2-years on hormones except for run times where the TW were still faster. TM performed fewer push-ups and ran 1.5 miles slower than cis-gender men in the AF prior to treatment. After 1 year on hormones, there was no longer a significant difference in push-ups or run times and the number of sit-ups performed in 1 minute exceeded the average performance of cis-gender men. Hormonal therapy did not influence waist circumference in either gender but did increase weight in TW.

Conclusion: Athletic advantages of transgender over cis-gender females decline with hormonal therapy but persist beyond the 1-year period recommended for inclusion by some international athletic governing committees. Further research on the timing of these changes is needed to support development of evidence-based guidelines for inclusion of transgender athletes.

Background:

Most competitive sports segregate male and female athletes due to biologic differences between the sexes. Because exposure to testosterone in males leads to physiologic advantages in strength and endurance, female sports need to be a protected category to ensure fairness in competition.[1] Questions arise, then, as to which category a transgender athlete competes in and how society balances the benefits to the athlete of sports participation in their experienced gender with perceptions of fairness to other athletes.[2-5] Administration of supraphysiologic doses of androgenic sex hormones has a known positive effect on athletic performance.[6-7] However, the effect of sex hormone treatment on athletic performance among transgender individuals during gender transition and guidelines for inclusion of transgender individuals in sports have received limited attention. Prior to 2004, there was no accepted pathway for transgender athletes to participate in most professional sports or at the elite international level. Since that time several guidelines have been proposed, but they have been based on limited research.[8]

Testosterone treatment in transgender men (TM) decreases adiposity and increases muscle mass, hemoglobin, and grip strength.[9-11] Testosterone blockage and estrogen administration in transgender women (TW) has the opposite effect.[9,12] The majority of the changes in body composition occur within the first year on treatment and remain relatively stable after that time.[9,13] Wiik et al. found that TM experience an increase in thigh muscle volume and knee extension strength during the first 12 months of hormone therapy, while TW did not experience a change in strength during the first year on hormonal therapy despite a decrease in muscle volume.[14]

But how do these body composition changes affect athletic performance? Harper (2015) did a retrospective review of run times in 8 TW runners, comparing their pre- and post-treatment race

times and found an overall decline in times but not in the runners' age grade for gender. However, the results of this study must be interpreted with caution because of the reliance on self-reported run times and the passage of months to years between the timed runs and the start of hormonal therapy.[15]

Rules for the inclusion of transgender athletes in sports are a patchwork of different guidelines at various levels of competition.[9] The International Association of Athletics Federations (IAAF) and the International Olympic Committee (IOC) have attempted to put in place guidelines requiring female athletes to demonstrate suppression of testosterone levels to less than 5 to 10 nmol/L, depending on the guideline, for at least 12 months prior to competing in women's events. However, part of these guidelines that addressed women with DSD and other causes of hyperandrogenism have been challenged in court in lawsuits alleging insufficient research to support them.[16, 17] We conducted this study to examine the effect of gender-affirming hormonal therapy on body composition and athletic performance among transgender individuals to help improve future guidelines for inclusion of transgender athletes in sporting competition.

Methods:

Study Population

This is a retrospective review of medical records and fitness tests results from 222 self-identified military personnel (airmen) who filed a request to begin gender transition or continue gender-affirming treatment while serving in the United States Air Force or Air National Guard.

Patient Involvement

The idea for this study arose from our discussions with the transgender airmen seen in Air Force Transgender Clinic about the effect of gender-affirming hormone therapy on body composition

and athletic performance on the Air Force physical fitness assessment. Based on our review of the medical literature we were unclear how to advise them. We conducted this study to address these concerns.

Demographic Variables

We recorded the airman's age, service branch, military rank, gender assigned at birth, date gender-affirming hormone therapy started, type of gender-affirming hormone therapy used, and days between starting treatment and the first serum hormone level in the adult range recorded in the military electronic medical record. Data on gender-affirming care obtained outside of the military healthcare system was incomplete because we only had access to health records that were transmitted to the military healthcare system and placed in the military electronic medical record. For TW, we also recorded the medication used to suppress testosterone levels and the days between starting treatment and the first lab test indicating suppression of endogenous testosterone.

Outcome Measures

We recorded the results of all physical fitness tests occurring before and after starting hormonal therapy. Airmen are required to participate in a physical fitness assessment every 12 months including measurement of height, weight, waist circumference, number of push-ups performed in 1 minute, number of sit-ups performed in 1 minute, and time required to run 1.5 miles. Results from these tests are used to assess suitability for promotion, inclusion in special training programs, and retention in the military service. Airmen are required to participate in all events unless they are granted a waiver for participation in a specific event secondary to an injury or medical condition. Airmen with a waiver for a portion of the assessment are required to retake

the assessment at a 6-month interval. Enlisted airmen engage in regular group exercise. However, the type and intensity of training can vary by military occupation. Airmen who fail to meet physical fitness standards are required to attend physical training sessions until they can meet the fitness requirements, or they are discharged from military service.

In our study, we included airmen with records from at least one physical fitness assessment occurring before and after the date they started gender-affirming hormonal therapy. We used the most recent score from each event on the physical fitness assessment prior to starting gender-affirming hormones as our measurement of pre-treatment fitness. We also recorded the time elapsed between the baseline assessment and the start of hormonal therapy for each event. We recorded the scores for each event and time on hormonal therapy for each fitness assessment occurring in the first 30 months after starting hormonal therapy.

We used the results of over 2.3 million Air Force fitness tests performed by men under age 30 and over 567 thousand fitness tests performed by women under age 30 between 2004 and 2014 as a proxy for performance among cis-gender men and women in the Air Force. [18]

Statistical Analysis

We used generalized linear mixed models with a first-order autoregressive repeated covariance type in SPSS version 24 to assess the association of hormonal therapy with changes in measurements on the physical fitness assessment. We selected this analysis method to account for correlation between repeated measures, variable number of follow-up assessments, variable follow-up times, and missing data points for each subject. We conducted a bivariable analysis to assess the impact of gender-affirming hormone therapy on athletic performance. In this analysis we measured an estimated mean of push-ups performed in 1 minute, sit-ups performed in 1

minute, and 1.5-mile run time for TM and TW before hormonal treatment, between 0 and 1 years on treatment, 1-2 years on treatment, and over 2 years on treatment. Then we compared these results with the historical average performance of men and women under age 30 in the Air Force. We conducted a multivariable assessment of the association between months on hormonal therapy and changes from baseline assessment for each of our outcome variables after adjusting for pre-treatment performance and age at initiation of hormonal therapy. We performed our multivariable analyses separately for TM and TW. This study was approved by the 59th Medical Wing IRB.

Results:

Subject Characteristics

Two hundred and twenty-two Air Force military personnel (airmen) self-identified as transgender in 2016-2018 and filed a request to begin gender transition or continue gender-affirming treatment while serving in the United States Air Force, Air Force Reserves, or Air National Guard. We excluded 147 of these subjects for the following reasons: 28 had not started gender-affirming hormonal therapy, 3 were on hormonal therapy but did not have a start date available, 99 did not have pre-treatment physical assessment scores available, and 16 did not have any post-treatment physical assessment scores available. This left us with a sample of 29 transgender men (TM) and 46 transgender women (TW). The pre-treatment characteristics of TM and TW in our sample are listed in table 1. The mean age of our sample was 26.2 years old (S.D. 5.5) with a median age of 25 years old and a range of 19 to 46. The majority (78.3%) of our subjects were under age 30 when they began hormonal therapy. The baseline physical fitness assessment occurred an average of 144.4+/-101.4 days prior to starting hormonal therapy. We followed subjects for an average of 394.0+/-288.2 days after they started hormonal therapy.

Subjects had an average of 2.2+/-0.9 assessments after starting hormonal therapy (median 2, range 1-4). Among TM, two subjects were medically excused from the push-up assessment during the follow-up period, and 11 were excused from the run. Among TW, 2 were excused from the push-up assessment, 1 from the sit-up assessment, and 4 from the run. The details of the gender-affirming hormonal therapies selected and time to first therapeutic hormone levels are listed in table 2.

Effect of Gender-Affirming Hormonal Therapy on Body Composition and Athletic Performance

Tables 3-5 and Figure 1 provide a summary of changes in patient outcomes over time while on gender-affirming hormonal therapy and a comparison between transgender individuals on and off hormonal therapy with cis-gender servicemembers. In multivariable analyses, including baseline performance, age at initiation of gender-affirming hormonal therapy, and months on gender-affirming hormonal therapy, a higher baseline score was associated with a greater decline (or smaller increase) in score at follow-up for all outcomes except for 1.5-mile run time among TW where baseline run time had no effect on the changes observed at follow-up (data not shown). Age at initiation of hormonal therapy had no significant effect on outcomes for TM or TW (data not shown). For TW, time on hormonal therapy was associated with an increase in weight (table 3) and a decline in athletic performance. (table 4 and figure 1) For TM, time on hormonal therapy had no effect on body composition (table 3) but was associated with an improvement in athletic performance (table 5 and figure 1).

Athletic Performance among Cis-gender Airmen and Transgender Airmen before and after Gender-Affirming Hormonal Therapy

Prior to hormonal therapy, TW performed fewer push-ups in 1 minute than cis-gender men (CM) and this gap increased with hormonal therapy. TW were able to perform more push-ups than cis-gender women (CW) prior to treatment but this difference disappeared after 2 years on hormonal therapy. (Table 4 and Figure 1) Prior to treatment there was no difference in sit-ups performed in one minute among TW compared to CM but there was with CW. After 2 years on hormones, TW performed fewer sit-ups than CM but the difference with CW had closed. (Table 4 and Figure 1) Run times among TW were similar to times among CM and faster than times among CW prior to treatment. Run times declined among TW after starting cross-gender hormone therapy and became slower than times in CM. The gap in run times between TW and CW diminished in size with treatment but did not close. (Table 4, Figure 1)

TM were able to perform more push-ups in one minute than CW prior to treatment and this gap increased with hormonal therapy. TM performed fewer push-ups than CM prior to therapy but this gap closed after 1 year on testosterone. (Table 5, Figure 1) TM consistently performed more sit-ups than CW at all stages of treatment. There was no difference in number of sit-ups performed in 1 minute between TM and CM prior to starting therapy and TM performance exceeded that of CM after 1 year on testosterone. There was no difference in 1.5-mile run times between TM and CW prior to treatment, but TM were faster after 1 year on therapy. TM were slower than CM prior to therapy but had closed the time gap after one year. (Table 5 and Figure 1)

Discussion:

In this study we assessed the effects of hormone therapy in transgender individuals on a standardized test over time in a non-laboratory setting. We demonstrated an improvement in performance associated with gender-affirming hormone therapy in TM and a decline in

performance among TW. Among TW, the duration of time on hormone therapy before they no longer showed evidence of a competitive advantage from the effects of prior testosterone exposure was greater than the 12-month standard currently being proposed for inclusion in elite level women's competition.[16] This finding suggests that the policies regulating testosterone levels for TW, who wish to participate in elite-level women's athletic competition need to be adjusted to require a longer period of suppression of testosterone prior to participation.

Transgender Military Members

Our findings about the effects of hormonal therapy on transgender military members (airmen) have implications for the military as well. Part of social transition for transgender airmen is to request an official change in the gender marker listed in the military data system. This change allows transgender airmen to use the housing, bathroom facilities, and appearance standards that match their experienced gender without obtaining permission from their commanding officer. However, the airman must also meet physical fitness and body composition standards of the gender marker in the military data system. Changes in body weight and physical performance associated with medical transition can make this challenging. The findings of our study can assist transgender airmen with planning the timing of a gender marker change.

Study Findings and Prior Research

Like previous studies, our study showed an association between gender-affirming hormonal therapy and increased strength measures among transgender men.[11,14] We confirmed the decrease in strength associated with hormonal therapy in transgender women that was found in some studies,[12] but not others.[14] Unlike several of these previous studies, our measure of muscular strength assessed repeated efforts (push-ups) over a 1-minute period as opposed to

single repetition with maximal effort. Our results probably have more relevance to sports that require sustained effort over time rather than single explosive efforts like power lifting. Further studies are needed to determine if the changes we saw in number of push-ups performed also apply to measures of explosive strength. Also, we had no access to qualitative measures of subject's exercise intentions or training habits before or after starting hormonal therapy. This makes it difficult to determine the etiology of differences in push-up performance between cis- and transgender airmen prior to starting hormonal therapy. It is possible that TM were seeking out exercises to increase upper body muscle mass in order to given them a more masculine appearance and decrease their gender dysphoria while also improving push-up performance relative to CW. Gender dysphoria could also incentivize the opposite behavior in TW decreasing push-up performance explaining why TW performed fewer push-ups than CM prior to starting hormonal therapy. Differences in exercise habits could also influence the relationship between athletic performance and gender affirming hormone therapy examined in this study. However, without the information on strength training among our transgender subjects it is impossible to make any definitive determinations.

TM also performed a larger number of sit-ups in 1 minute when compared to CW prior to starting hormonal therapy. This may also reflect a behavioral response to gender dysphoria among TM. There was no difference between TW and CM in sit-up performance. Unlike the increased size of upper body musculature associated with pushups, a flat and toned appearing abdomen is seen a positive attribute for achieving an ideal masculine or feminine appearance making it less likely that TW would avoid this exercise type at a greater rate than CM.

We also demonstrated a decline in run times associated with hormonal therapy among TW that was seen in a previous study using a smaller sample and self-reported data.[15] Increasing

testosterone exposure is associated with an increase in muscle volume and blood hemoglobin content producing most of the ergogenic effects of testosterone.[1] This is demonstrated by the improvement in run times seen among TM with exposure to testosterone and the decline in TW undergoing testosterone blockade seen in our study. However, exposure to testosterone during puberty results in sex differences in height, pelvic architecture, and leg bones in the lower limbs that confer an athletic advantage to males after puberty.[1] These anatomic differences do not respond to changes in testosterone exposure among post-pubertal adults. This may explain why TW retained an advantage in 1.5 mile run times over CW after beginning gender affirming hormone therapy as an adult while push-up and sit-up performance, which are less influenced by differences in skeletal architecture, declined to the level CW after two years on hormonal therapy. It is possible that these results could be different among TW who begin gender affirming hormone therapy shortly after the onset of puberty and would never experience the ergogenic benefits of testosterone exposure. Further research is required to determine if the effects of hormonal therapy on athletic performance vary by level of pubertal development at the time of initiating gender-affirming hormonal therapy and if guidelines for athletic inclusion of transgender individuals need to account for the athlete's pubertal stage when gender transition began.

Study Limitations and Future Directions

The strengths of this study include the larger sample size than previous studies, a longer follow-up period, and the focus on performance on a standardized fitness test rather than isolated muscle strength. This study has limitations as well. We could not assess the exercise patterns among our subjects so we do not know how training regimens influenced our results. Also, the lack of a longitudinal control group not on hormone therapy makes changes in performance due to the

passage of time a potential confounding factor. The high variability in time between baseline assessment and initiation of hormonal therapy could also confound our assessment of the effect of time on hormonal therapy. However, the uniformity of the data showing improvement in performance scores in TM and the decline in TW makes it highly unlikely that the changes in performance are random or can be attributed to changes over time alone. Finally, hormonal therapy was tailored to individual provider and patient preferences, and uniform medication dosages were not used across the study. We do not have any measurement of patient adherence treatment or the hormonal therapy dosage provided to the patient. It is possible that variations in hormonal exposure between patients could confound our measurement of the effects or hormonal therapy on athletic performance and body composition. Most subjects had documentation of therapeutic hormone levels and suppression of testosterone, suggesting medications were dosed at physiologic levels, however, the time between starting hormones and documentation of physiologic levels varied widely between subjects. It is unclear if this variability represents differences in medication dosing or inadequate access to medical records from outside the military healthcare system. Future studies should address these limitations. Further research is needed to define the timing of changes associated with gender-affirming hormone treatment to assist with development of evidence-based guidelines for participation in elite athletic competition by transgender athletes.

Conclusion

In this study, we confirmed that transgender hormone therapy is associated with changes in athletic performance and demonstrated that the pretreatment differences between transgender female athletes and cis-gender female athletes persist beyond the 12-month time requirement currently being proposed for athletic competition by the IAAF and the IOC.[16] This study

suggests that more than 12 months of testosterone suppression may be needed to ensure that transgender female athletes do not have an unfair competitive advantage when participating in elite women's athletic competition.

References:

1. Handelsman DJ, Hirschberg AL, Bermon S. Circulating testosterone as the hormonal basis of sex differences in athletic performance. Endocrine reviews. 2018 Oct;39(5):803-29.
2. Singh B, Singh K, Sharma N. Equality, Equity and Inclusion: Transgender Athletes' Participation in Competitive Sports -a New Era. Phys Cult Sport Stud Res 2010;49:85–8.
3. Semerjian TZ, Cohen JH. "FTM Means Female to Me": Transgender Athletes Performing Gender. Women Sport Phys Act J 2016;15:28.
4. Genel M. Transgender Athletes: How Can They Be Accommodated? Curr Sports Med Rep. 2017;16(1):12–13.
5. Bianchi A. Transgender women in sport. J Philos Sport 2017;44:229–42.
6. Hartgens F, Kuipers H. Effects of androgenic-anabolic steroids in athletes. Sports Med. 2004;34(8):513–554.
7. Franke WW, Berendonk B. Hormonal doping and androgenization of athletes: a secret program of the German Democratic Republic government. Clin Chem. 1997;43(7):1262–1279.
8. Ingram BJ, Thomas CL. Transgender Policy in Sport, A Review of Current Policy and Commentary of the Challenges of Policy Creation. Curr Sports Med Rep. 2019;18(6):239-47.
9. Gooren LJ, Bunck MC. Transsexuals and competitive sports. Eur J Endocrinol. 2004;151(4):425–429.
10. Van Caenegem E, Wierckx K, Taes Y, Dedecker D, Van de Peer F, Toye K, Kaufman JM, T'Sjoen G. Bone mass, bone geometry, and body composition in female-to-male

transsexual persons after long-term cross-sex hormonal therapy. J Clin Endocrinol Metab. 2012;97(7):2503–2511.

11. Van Caenegem E, Wierckx K, Taes Y, Schreiner T, Vandewalle SA, Toye K, Lapauw B, Kaufman JM, T'Sjoen G. Body composition, bone turnover, and bone mass in trans men during testosterone treatment: 1-year follow-up data from a prospective case-controlled study (ENIGI). Eur J Endocrinol. 2015;172(2):163–171.
12. Lapauw B, Taes Y, Simoens S, Van Caenegem E, Weyers S, Goemaere S, Toye K, Kaufman JM, T'Sjoen GG. Body composition, volumetric and areal bone parameters in male-to-female transsexual persons. Bone. 2008;43(6):1016–1021.
13. Elbers JM, Asscheman H, Seidell JC, Gooren LJ. Effects of sex steroid hormones on regional fat depots as assessed by magnetic resonance imaging in transsexuals. Am J Physiol. 1999;276(2):E317–E325.
14. Wiik A, Lundberg TR, Rullman E, Andersson DP, Holmberg M, Mandić M, Brismar TB, Leinhard OD, Chanpen S, Flanagan J, Arver S. Muscle strength, size and composition following 12 months of gender-affirming treatment in transgender individuals. J Clin Endocrinol Metab 2019 (Epub ahead of print) doi:10.1210/clinem/dgz247
15. Harper J. Race times for transgender athletes. Journal of Sporting Cultures and Identities. 2015;6:1-9.
16. International Olympic Committee. IOC consensus meeting on sex reassignment and hyperandrogenism. Available from: http://www.olympic.org/Documents/Commissions_PDFfiles/Medical_commission/2015-

11_ioc_consensus_meeting_on_sex_reassignment_and_hyperandrogenism-en.pdf. 2016. Accessed 12/30/19

17. Camporesi S. A question of 'fairness': Why ethics should factor in the Court of Arbitration for Sport's decision on the IAAF Hyperandrogenism Regulations. British Journal of Sports Medicine 2019;53:797-798.
18. Griffith JR. The Air Force Fitness Test: Creating New Fitness Assessment Charts Using Waist to Height Ratios (2017). Theses and Dissertations. 782. https://scholar.afit.edu/etd/782. Accessed 4/29/2020

Table 1: Pre-treatment demographics and body composition

Pre-treatment demographics and body composition	**Transgender Women (n=46)**	**Transgender Men (n=29)**
	Mean (S.D.)	Mean (S.D.)
Age at initiation of hormone therapy (years)	26.6 (4.8)	25.6 (6.6)
Height (cm)	176.3 (7.1)	165.6 (5.3)
Weight (kg)	76.7 (12.6)	69.5 (10.0)
Body Mass Index (kg/m^2)	24.4 (3.7)	25.3 (3.3)
Waist Circumference (cm)	80.8 (8.4)	76.7 (8.9)
Rank		
Enlisted	100%	93.1%
Officer		6.9%
Duty Status		
Active Duty	95.7%	86.2%
Reserves	2.2%	6.9%
Air National Guard	2.2%	6.9%

Table 2: Gender-affirming treatments prescribed

	Transgender Women (n=46)	Transgender Men (n=29)
Gender-Affirming Hormones Prescribed	Oral estradiol: 67.4% Transdermal estradiol: 15.2% Estradiol valerate IM: 13.0% Estradiol cypionate IM: 2.2% Unknown: 2.2%	Testosterone cypionate: 89.7% Testosterone enanthate: 3.4% Transdermal testosterone: 3.4% Testosterone 2% gel: 3.4%
Median Days to First Therapeutic Level (39 transgender women, 26 transgender men)	234.0 days (Range: 27-1270)	98.5 days (Range: 23-1116)
Testosterone Blockade Prescribed (Transgender Women Only)	Spironolactone: 80.4% Spironolactone and finasteride: 13.0% Gonadotropin releasing hormone (GnRH) agonist IM: 2.2% GnRH agonist and spironolactone: 2.2% Unknown: 2.2%	
Median Days to First Documented Suppression (n=35)	200 days (Range: 27-979)	

Table 3: Effect of gender-affirming hormone therapy on weight and waist circumference

	Transgender Women	**Transgender Men**
Weight (kg)	Mean (95% CI)	Mean (95% CI)
Time on hormones		
Pre-Treatment	76.7 (73.3-80.2)	69.5 (66.0-72.9)
0-1 years	75.6 (75.1-79.1)	72.1 (68.6-75.5)
1-2 years	77.1 (73.4-80.9)	71.1 (67.4-74.8)
2-2.5 years	76.7 (70.8-82.6)	70.0 (65.8-74.2)
	β (95% CI)	β (95% CI)
Change in weight per month on hormones*	0.15 (0.04- 0.25)	-0.07 (-0.21- 0.06)
Waist Circumference (cm)	Mean (95% CI)	Mean (95% CI)
Time on hormones		
Pre-Treatment	80.8 (78.7-82.8)	76.7 (73.9-79.2)
0-1 years	79.0 (77.0-81.0)	79.2 (76.5-81.8)
1-2 years	79.0 (76.2-81.5)	78.5 (75.2-81.8)
2-2.5 years	82.0 (76.5-87.9)	78.5 (74.4-82.3)
	β (95% CI)	β (95% CI)
Change in waist per month on hormones*	0.05 (-0.08- 0.18)	-0.03 (-0.15- 0.10)

All analyses adjust for variation in the number of measurements per subject

*adjusted for pre-treatment measurements and age when started gender-affirming hormone.

Table 4: Effect of gender-affirming hormone therapy on athletic performance among transgender women

Push-Ups in 1 minute	Mean (95%CI)	Mean Difference TW vs. CW[a] (95%CI)	Mean Difference TW vs. CM[b] (95%CI)
Time on hormones			
Pre-Treatment	47.3 (44.6-50.0)	14.8 (12.1-17.4)	-6.2 (-8.9- -3.6)
0-1 years	44.6 (41.8-47.4)	12.1 (9.3-14.8)	-8.9 (-11.7- -6.1)
1-2 years	43.2 (39.3-47.1)	10.7 (6.8-14.5)	-10.3 (-14.2- -6.5)
2-2.5 years	34.6 (26.1-43.1)	2.1 (-6.4-10.5)	-18.9 (-27.3- -10.5)
	β (95%CI)		
Change in push-ups per month on hormones*	-0.38 (-0.63- -0.13)		
Sit-Ups in 1 minute	Mean (95%CI)		
Time on hormones			
Pre-Treatment	53.5 (51.3-55.7)	7.9 (5.7-10.0)	1.1 (-1.7- 3.2)
0-1 years	54.1 (51.9-56.3)	8.5 (6.3-10.7)	1.7 (-0.5- 3.9)
1-2 years	51.8 (48.6-55.0)	6.2 (3.0- 9.3)	-0.6 (-3.8- 2.5)
2-2.5 years	44.8 (37.1-52.4)	-0.9 (-8.4- 6.7)	-7.7 (-15.2- -0.1)
	β (95%CI)		
Change in sit-ups per month on hormones*	-0.37 (-0.58- -0.15)		

1.5-mile run time (seconds)	Mean (95% CI)		
Time on hormones			
Pre-Treatment	708 (681-734)	-147 (-173- -121)	-12 (-38- 14)
0-1 years	758 (731-786)	-97 (-124- -70)	39 (12- 65)
1-2 years	791 (753-829)	-64 (-101- -26)	72 (34-109)
2-2.5 years	765 (685-846)	-90 (-169- -10)	45 (-34-125)
	β (95%CI)		
Change in run time per month on hormones*	2.9 (0.5-5.3)		

All analyses adjust for variation in the number of measurements per subject

*Adjusted for pre-treatment measurements and age when started gender-affirming hormone.

TW: Transgender Women, CW: Cis-gender Women, CM: Cis-gender Men

a: Average performance on Air Force Physical Fitness Tests by females <30 years old conducted between 2004-2014[18]

b: Average performance on Air Force Physical Fitness Tests by males<30 years old conducted between 2004-2014[18]

Table 5: Effect of gender-affirming hormone therapy on athletic performance among transgender men

Push-Ups in 1 minute	Mean (95%CI)	Mean difference TM vs. CW[a] (95%CI)	Mean difference TM vs. CM[b] (95%CI)
Time on hormones			
Pre-Treatment	37.4 (33.2-41.5)	4.8 (0.7- 9.0)	-16.1 (-20.3- -12.0)
0-1 years	44.8 (40.5-49.0)	12.2 (8.1-16.4)	-8.7 (-12.9- -4.6)
1-2 years	51.8 (46.2-57.5)	19.3 (13.8-24.8)	-1.7 (-7.2- 3.9)
2-2.5 years	56.1 (49.9-62.4)	25.6 (19.4-31.8)	4.6 (-6.4- 10.5)
	β (95%CI)		
Change in push-ups per month on hormones*	0.46 (0.22-0.70)		
Sit-Ups in 1 minute	Mean (95%CI)		
Time on hormones			
Pre-Treatment	50.4 (47.4-53.4)	4.8 (1.8- 7.7)	-2.0 (-4.9- 0.9)
0-1 years	52.8 (49.8-55.8)	7.2 (4.2-10.2)	0.4 (-2.6- 3.4)
1-2 years	58.2 (54.0-62.3)	12.5 (8.5-16.6)	5.7 (1.7- 9.8)
2-2.5 years	58.3 (53.8-62.8)	12.7 (8.2-17.1)	5.9 (1.4-10.3)
	β (95%CI)		
Change in sit-ups per month on hormones*	0.32 (0.16-0.49)		
1.5-mile run time (seconds)	Mean (95%CI)		

Time on hormones			
Pre-Treatment	850 (802-899)	-4 (-52- 43)	131 (83-178)
0-1 years	826 (776-876)	-29 (-78- 20)	106 (57-155)
1-2 years	751 (687-815)	-104 (-167- -41)	31 (-32- 94)
2-2.5 years	711 (640-783)	-144 (-214- -74)	-9 (-79- 61)
	β (95%CI)		
Change in run time per month on hormones*	-3.2 (-5.3- -1.2)		

All analyses adjust for variation in the number of measurements per subject

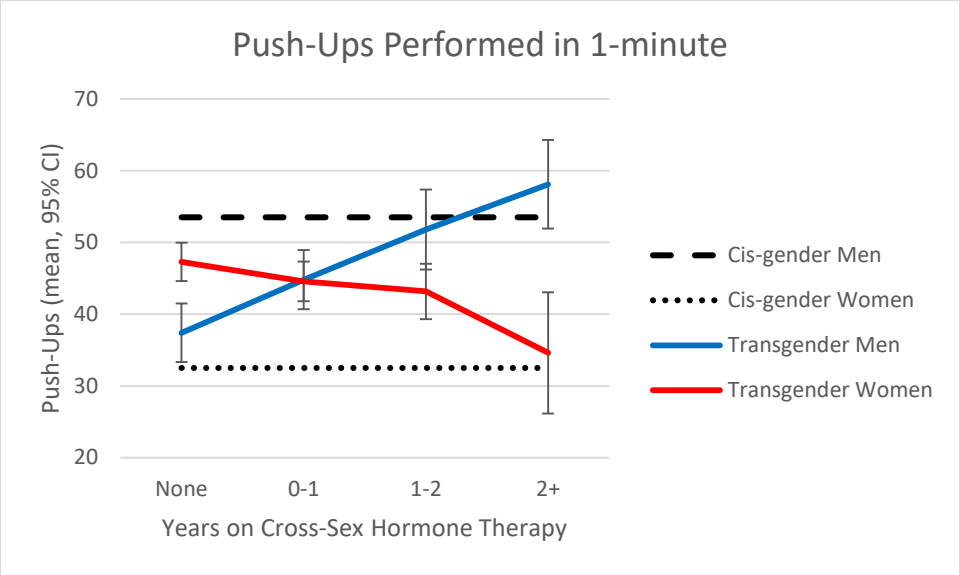
*Adjusted for pre-treatment measurements and age when started gender-affirming hormone.

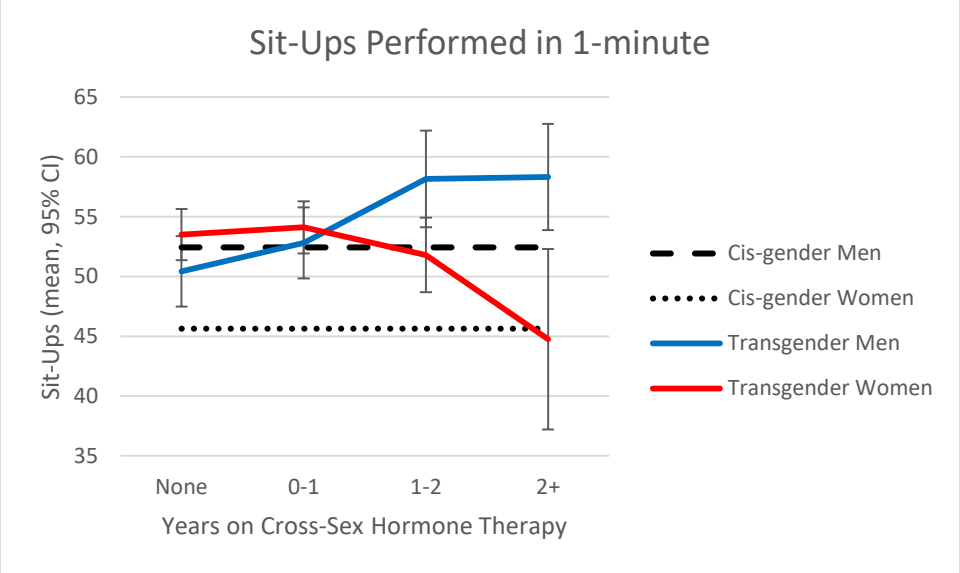
TM: Transgender Men, CW: Cis-gender Women, CM: Cis-gender Men

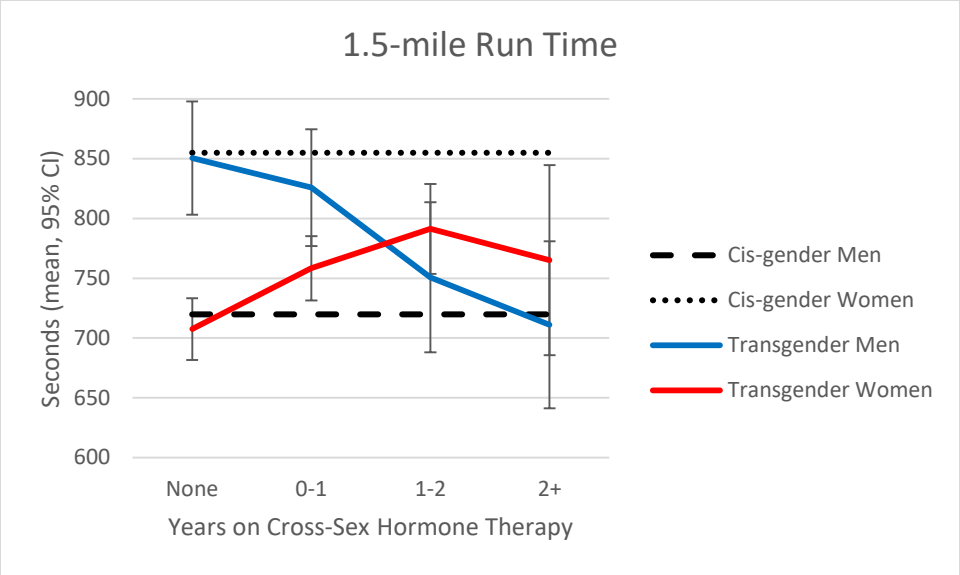
a: Average performance on Air Force Physical Fitness Tests by females <30 years old conducted between 2004-2014 [18]

b: Average performance on Air Force Physical Fitness Tests by males<30 years old conducted between 2004-2014 [18]

Figure 1 A-C: Cross-Sex Hormone Therapy and Athletic Performance







Cis-gender men represents the average performance on over 2.3 million Air Force Physical Fitness Tests performed by males under age 30 between 2004 and 2014 [18]

Cis-gender women represents the average performance on over 567 thousand Air Force Physical Fitness Tests performed by females under age 30 between 2004 and 2014 [18]