Body composition and physical fitness in transgender versus cisgender individuals: a systematic review with meta-analysis

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ABSTRACT

Objective To compare body composition and physical fitness between transgender and cisgender individuals.

Design Systematic review with meta-analysis.

Data sources PubMed, Web of Science, Embase and SportDiscus.

Eligibility criteria Inclusion criteria comprised studies of transgender individuals comparing body composition or physical fitness pre-to-post gender-affirming hormone therapy (GAHT) or versus cisgender controls.

Results 52 studies (n=6485) were included. Transgender women had similar relative fat mass (standardised mean difference (SMD) −0.33, 95% CI −0.72 to 0.05, Grading of Recommendations Assessment, Development and Evaluation (GRADE): very low), relative lean mass (SMD 0.19, 95% CI −0.14 to 0.53, GRADE: low), upper-body strength (SMD 0.54, 95% CI −0.95 to 2.02, GRADE: very low), lower-body strength (SMD 0.05, 95% CI −1.31 to 1.40, GRADE: very low) and maximal oxygen consumption (SMD −0.28, 95% CI −0.81 to 0.25, GRADE: very low) in comparison to cisgender women. Transgender men exhibited higher relative fat mass (SMD 0.96, 95% CI 0.28 to 1.64, GRADE: moderate), lower relative lean mass (SMD −6.42, 95% CI −12.26 to −0.58, GRADE: moderate) and lower upper-body strength (SMD −1.46, 95% CI −2.52 to −0.40, GRADE: moderate) than cisgender men. In transgender women, GAHT was associated with increased fat mass and reduced lean mass and upper-body strength over 1–3 years. Transgender men demonstrated reduced fat mass and increased lean mass and strength following GAHT.

Conclusion While transgender women exhibited higher lean mass than cisgender women, their physical fitness was comparable. Current evidence is mostly low certainty and has heterogenous quality but does not support theories of inherent athletic advantages for transgender women over cisgender.

PROSPERO registration number CRD42024562210.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The inclusion of transgender women in female sports categories remains highly contentious. Literature suggests that gender-affirming hormone therapy (GAHT) may alter body composition in transgender individuals, but evidence on functional performance outcomes remains inconsistent.

⇒ Policies advocating blanket bans on transgender women in female sports often cite residual advantages from prior testosterone exposure, despite limited empirical support for sustained performance disparities post-GAHT.

WHAT THIS STUDY ADDS

⇒ By providing the most comprehensive synthesis to date, including 52 studies and 6485 participants, this review compares body composition and fitness differences between transgender and cisgender individuals across multiple designs.

⇒ Our meta-analyses show that, despite persistent differences in absolute lean mass, transgender women do not exhibit significant differences in upper-body strength, lower-body strength or maximal oxygen consumption relative to cisgender women after 1–3 years of GAHT.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This review demonstrates that functional performance in transgender women converges toward cisgender women over time, challenging assumptions about inherent or GAHT-resistant athletic advantages and strengthening the evidence base for sport-policy deliberations.

INTRODUCTION

The question of whether transgender women should be permitted to compete in female sports, and under what conditions, remains a subject of intense debate. The rationale for sex-segregated competition is rooted in ensuring equitable opportunities for cisgender women, prompting proposals that transgender (or intersex) athletes should be included only if their participation does not disproportionately disrupt competitive fairness.[1–3]

However, empirical evidence challenges initial concerns that transgender women would dominate women's sports, largely due to the physiological effects of testosterone suppression therapy.[1] In fact, transgender women remain under-represented in elite athletics, highlighting the lack of dominance by transgender athletes in practice.

The International Olympic Committee (IOC) established a framework prioritising fairness,

inclusion and non-discrimination for athletes with diverse gender identities and sex variations.[2] This approach rejects blanket bans based on gender identity, advocating instead for sport-specific eligibility criteria informed by evidence. Critics, however, argue that the framework relies on insufficiently developed research and impractical case-by-case assessments, potentially compromising protections for cisgender female athletes. Lundberg *et al*[3] contend that the IOC's 'no presumption of advantage' principle overlooks studies suggesting that transgender women retain muscle mass, strength and other physical advantages over cisgender women even after testosterone suppression. Their argument hinges on the well-established physiological disparities between cisgender males and females, which confer inherent athletic advantages to males. Nonetheless, systematic reviews comparing transgender women (those who underwent gender-affirming hormone therapy (GAHT) to modulate sex-steroid levels and induce secondary sex-characteristic changes aligned with their affirmed gender) and cisgender women report inconsistent findings regarding performance and physical differences, highlighting the need for further research.[1 4]

This systematic review with meta-analysis synthesises the existing literature on body composition and physical fitness in transgender women relative to cisgender women, and, as a secondary objective, in transgender men relative to cisgender men as well as transgender women versus cisgender men and transgender men versus cisgender women.

METHODS

This systematic review was registered in PROSPERO (CRD42024562210) and follows the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement.[5]

Equity, diversity and inclusion statement

Our research team included three women and five men, representing junior, midcareer and senior researchers from a range of disciplines. All authors are based in the Global South. Our identities include membership in marginalised communities: three as women and one as part of the LGBTQIA2S+ community.[6] This systematic review and meta-analysis focused on physical fitness and body composition in transgender compared with cisgender individuals, addressing a significant gap in the literature and aiming to promote equity in health research.

Search strategy

Searches were conducted in the following electronic databases: PubMed, Web of Science, Embase and SportDiscus on 6 June 2024, including all articles to date, supplemented by manual citation reviews until August 2025. The search strategy used descriptors related to the population and outcomes as follows: Population (Transgender OR Transexual OR Transgender Person OR Transsexualism OR Transgenderism OR "Transgender people" OR "gender reassignment procedure" OR "gender reassignment surgery" OR "gender change procedure" OR "Gender-affirming Treatment" OR transwoman OR transmen OR "gender affirming hormone therapy (GAHT)" OR transsexual OR "cross-sex hormone therapy" OR "trans people") and Outcomes (physical fitness and body composition terms, see online supplemental table S1). The search process was carried out independently by two researchers. In the case of disagreement, a third reviewer was consulted. To select search descriptors, MeSH terms (Medical Subject Headings) were used. Additionally, a manual search of the references in selected studies was conducted to identify studies for inclusion.

Eligibility for study selection

All articles identified in the search were screened by two independent members of the research team using a three-stage strategy: (1) title and abstract screening; (2) full text review; and (3) conflict resolution/consensus phase. Any discrepancies were resolved through discussion or third-party mediation, if required. The selection was made using the software Rayyan QCRI.[7]

Study eligibility was based on the PECO criteria,[8 9] described below:

- Population: Individuals identifying as transgender.
- Exposure: GAHT.
- Comparison: Before and after GAHT, and with cisgender individuals.
- Outcomes: Measures of physical fitness and body composition.

No language restrictions were applied, and there were no restrictions on publication dates.

Data extraction process

A data extraction table was created and completed to gather key information from the selected studies, including author, study population, sample size, type of hormonal therapy, outcomes and main findings.

Risk of bias

Two independent members conducted the risk of bias (ROB) analysis. Any discrepancies were resolved through discussion or third-party mediation, if required. ROB was performed using the 20-item AXIS (Appraisal tool for cross-sectional studies),[10] ROBINS-I (Risk Of Bias In Non-randomised Studies-of Interventions)[11] or ROB2 (Risk Of Bias 2),[12] depending on study design. AXIS was used to assess the ROB in cross-sectional studies. It consists of 20 items, each rated as 'Yes', 'No' or 'Don't Know'. Items 7 ('Were measures undertaken to address and categorize non-responders?') and 14 ('If appropriate, was information about non-responders described?') were marked as 'Inapplicable' when the response rate was reported as 100%. As AXIS lacks a standardised scoring system, we adopted a method used in previous studies,[13–15] assigning scores of 0 or 1 to each item to calculate an overall quality score. Specifically, for items 13 ('Does the response rate raise concerns about non-response bias?') and 19 ('Were there any funding sources or conflicts of interest that may affect the authors' interpretation of the results?'), a response of 'No' was scored as 1 and 'Yes' or 'Don't Know' as 0. For items 7 and 14, 'Yes' or 'Inapplicable' were scored as 1, and 'No' or 'Don't Know' as 0. For all other items, 'Yes' was scored as 1, and 'No' or 'Don't Know' as 0. Total scores were calculated by summing the individual item scores. Following recommendations,[16] studies were classified as high quality (scores of 14–20; 70–100%), fair quality (scores of 12–13; 60–69.9%) or low quality (scores of 0–11; 0–59.9%).

ROBINS-I was used to assess the ROB in cohorts and quasi-experimental studies and includes seven domains of bias: bias due to confounding, bias in participants' selection, bias in interventions classification, bias due to deviations from intended interventions, bias due to missing data, bias in outcomes measurement and bias in reported result selection. Each domain is assessed through signalling questions to provide a comprehensive analysis of potential biases within the study. Each domain is

assessed through signalling questions to provide a comprehensive analysis of potential biases within the study.

ROB 2.0 was used to assess the ROB in randomised controlled trials (RCTs) and consists of five domains: bias arising from the randomisation process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in outcome measurement and bias in reported result selection. Similar to ROBINS-I, it also incorporates a set of signalling questions to determine whether each domain poses a high, low or unclear ROB.

Statistical analysis

The 'metacont' function in RStudio was used to perform a comprehensive statistical analysis of the effects of hormone therapy on transgender individuals. This analysis involved aggregating data from studies comparing baseline and posthormone therapy measures, focusing on the association of hormone therapy on key physical fitness and body composition parameters. The assumption of normality within studies was evaluated using the mean-to-SD ratio for each study.[17] For continuous outcomes, the standardised mean difference (SMD) was calculated using Cohen's d ($d = (\bar{M}_1 - \bar{M}_2) / SD_{pooled}$) with 95% CIs. Whenever appropriate, the mean difference (MD) was used instead. The magnitude of SMD or MD was interpreted according to Cohen's benchmarks (15): <0.2=trivial effect; 0.2–0.5=small effect; 0.5–0.8=medium effect; >0.8=large effect.[18] A random-effects model was employed to account for variability both within and between studies, enabling a robust estimation of the overall effect of hormone therapy on physical fitness outcomes in transgender individuals. The analyses were conducted only when there were at least three studies for each subgroup.

Heterogeneity across studies was assessed using the I^2 statistic and the χ^2 (Q) test, following recommended thresholds[19]: not important (0%–40%), moderate (30%–60%), substantial (50%–90%) and considerable (75%–100%). Given the limited number of studies included in each meta-analysis and the lack of sufficient continuous variables to explain effect sizes, subgroup analyses and meta-regressions were not performed. Instead, a stepwise sensitivity analysis was conducted to assess the robustness of the pooled estimates and to explore potential sources of clinical heterogeneity. This analysis evaluated whether study design, outcome measurement instrument, confounding adjustment, quality assessment, treatment duration, population or type of intervention contributed to heterogeneity. Accordingly, sensitivity analyses were sequentially performed by restricting the data set to studies with shared characteristics: study design (cross-sectional, retrospective, prospective or RCT); body composition instrument (dual-energy X-ray absorptiometry (DXA), bioimpedance or Bod Pod); upper-limb strength assessment instrument (hydraulic, electronic or isokinetic dynamometry); lower-limb strength instrument (contact mat or force platform); absence of confounding adjustment; quality assessment (high, moderate, low, serious or fair); treatment duration (based on the median); population (adults or adolescents); and intervention type (naïve prior to intervention or with puberty suppression). Each category was systematically removed one at a time, and changes in the overall effect size and heterogeneity were examined. Additionally, publication bias was evaluated, when possible ($k \geq 10$ studies), through visual inspection of funnel plot.

Moreover, two reviewers (SMS, DRC) independently assessed the certainty of the body of evidence using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.[20] The GRADE framework evaluates five domains for potential downgrading: ROB, inconsistency, indirectness, imprecision and publication bias, and considers upgrading based on effect magnitude, dose–response relationship and residual confounding. The certainty of evidence for each outcome was rated as high, moderate, low or very low. The complete GRADE assessment is presented in online supplemental table S10 and S11.

In addition, the 'metacont' function was also used to compare the effects of GAHT between transgender and cisgender individuals. This analysis synthesised data from multiple studies examining the same physical fitness and body composition variables, aiming to quantitatively assess the magnitude and direction of treatment effects in transgender in comparison to cisgender individuals. This approach provided valuable insights into the impact of GAHT on physical fitness and body composition parameters.

Analyses were performed only when at least two studies were available for each outcome. When the number of studies included in a meta-analysis was small (≤5), the Hartung-Knapp-Sidik-Jonkman (HKSJ) method was applied. This approach provides an alternative to the traditional random-effects meta-analysis by employing a refined variance estimator for the treatment effect. Simulation studies[21–23] have demonstrated that the HKSJ method offers improved coverage probabilities compared with the conventional random-effects model.

The analysis was conducted using RStudio (V.4.4.0) with the meta statistical package.[24]

RESULTS

The database search identified 1705 studies. Three studies published later were included after checking the citations of the included articles and other sources (Google Scholar, social media). After removing duplicates (n=638), 1067 publications were screened for inclusion. Of these, 595 were excluded based on title review and 284 after abstract review. The remaining 188 papers were selected for full-text reading, from which three were excluded due to the study population, 50 for outcome and 86 for publication type. Therefore, 52 studies were included in the review[25–76] and 43 in the meta-analysis (online supplemental figure S1).

Methodological characteristics of studies

The analysis included a total of 6485 individuals: 2943 transgender women, 2309 transgender men, 568 cisgender women and 665 cisgender men. Study participants' mean age ranged from 14 to 41 years. Of the 52 studies reviewed, 45 focused on adults, while 7 involved adolescents. Only 16 studies incorporated any form of physical activity assessment. Among these, two exclusively recruited amateur athletes, and another reported that they included only sedentary individuals (online supplemental table S2).

Methods for assessing physical activity levels varied: three studies used weekly METs (metabolic equivalents); three applied the Baecke questionnaire (mean scores); two reported the percentage or number of 'active' participants; two documented weekly exercise frequency; two measured weekly exercise duration; one used the Sport Index (mean scores); one used Saltin-Grimby scale (categorising their activity as sedentary, some physical activity or regular physical); one simply noted 'regular physical activity' without further detail, and one reported including only sedentary individuals.

With respect to study design and statistical adjustments, 22 studies were prospective cohorts, 9 were retrospective cohorts,

17 were cross-sectional studies, 3 were RCTs and 1 was a quasi-experimental study (online supplemental table S3). Only a minority of studies (n=7) applied statistical adjustments for confounders in the outcome analyses. The most frequently adjusted variables were body composition (eg, lean or fat mass), age, hormone levels (eg, testosterone) and nutrient intake (eg, protein, vitamin D). Additionally, one study adjusted for cardiovascular variables, such as stroke volume, in analyses of maximal oxygen consumption (VO_2 max).

Reviewed studies provided details on various GAHT and related findings (online supplemental table S4). The type and dosage of GAHT varied substantially across studies. Among transgender women, the most common oestrogen formulations were estradiol valerate (1–4 mg/day orally), transdermal estradiol patches (100 µg/24–72 hour) and estradiol gel (1.5–3 mg/day). Antiandrogens were frequently coadministered, most often cyproterone acetate (2–100 mg/day), followed by spironolactone (100–200 mg/day) and less commonly finasteride or GnRH antagonists (GnRHa). Among transgender men, the predominant formulations were testosterone undecanoate (1000 mg intramuscularly every 6–12 weeks) and testosterone enanthate (100–250 mg every 2–4 weeks), with some studies also reporting testosterone gels (50 mg/day) and testosterone esters. Dosing regimens varied by route of administration (oral, intramuscular or transdermal), age group and clinical context (eg, puberty suppression or maintenance therapy). A few studies included GnRHa therapy, either alone or in combination with GAHT; in these cases, triptorelin (3.75–11.25 mg) and degarelix (240 mg every 3 months) were the most commonly used.

Therapy duration varied widely, ranging from 3 months to 14 years, with most studies reporting the following participants for 1–3 years of therapy. Also, of the 52 studies included, 12 included participants who had undergone gender-affirming surgery and only 6 reported the use of puberty suppression.

In 16 cross-sectional studies, information regarding naïve status to hormone therapy, adverse effects and dropouts was deemed less relevant due to the study design. Therefore, of the remaining 36 studies included, 23 exclusively enrolled hormone-naïve individuals (1 focused solely on naïve transgender women), 5 included non-naïve participants and 8 did not report this data. Regarding adverse effects, 27 studies did not report, 8 observed none and 1 study reported several adverse events in both transgender men (muscle/joint pain, mild hypertension, reduced fasting insulin, androgenic alopecia) and transgender women (depression, elevated prolactin, galactorrhoea, transient liver enzyme elevations, hypertension, increased fasting insulin and skin irritation). Moreover, 20 studies lacked dropout data, 11 reported none and 4 had significant attrition (≥20 participants) and 1 had minimal dropouts (n=2).

Regarding outcomes and measurement methods, studies assessed body composition (n=52), muscular strength (n=21) and aerobic capacity (n=8) (online supplemental table S5). DXA was the most used tool for assessing body composition (n=38), followed by bioelectrical impedance analysis (BIA) (n=7). Upper-body strength was primarily evaluated using handgrip dynamometry (n=19), with either hydraulic or electronic devices. A smaller number of studies assessed lower-body strength, assessed mainly through countermovement jump (n=5) and aerobic capacity assessed through cardiopulmonary exercise testing (n=5) or 1.5 mile run time (n=2).

Transgender women compared with cisgender women

Fat mass (kg or %)

No significant differences were observed between transgender women and cisgender women in absolute fat mass (kg) (SMD 0.46, 95% CI −0.30 to 1.22, I^2 = 89.3%, considerable; GRADE: very low) (figure 1A) or in relative fat mass (%) (SMD −0.33, 95% CI −0.72 to 0.05, I^2 = 62.8%, substantial; GRADE: very low) (figure 1B). These results remained consistent across all categories in the sensitivity analysis, except for treatment duration ≤2 years in relative fat mass (online supplemental table S8a).

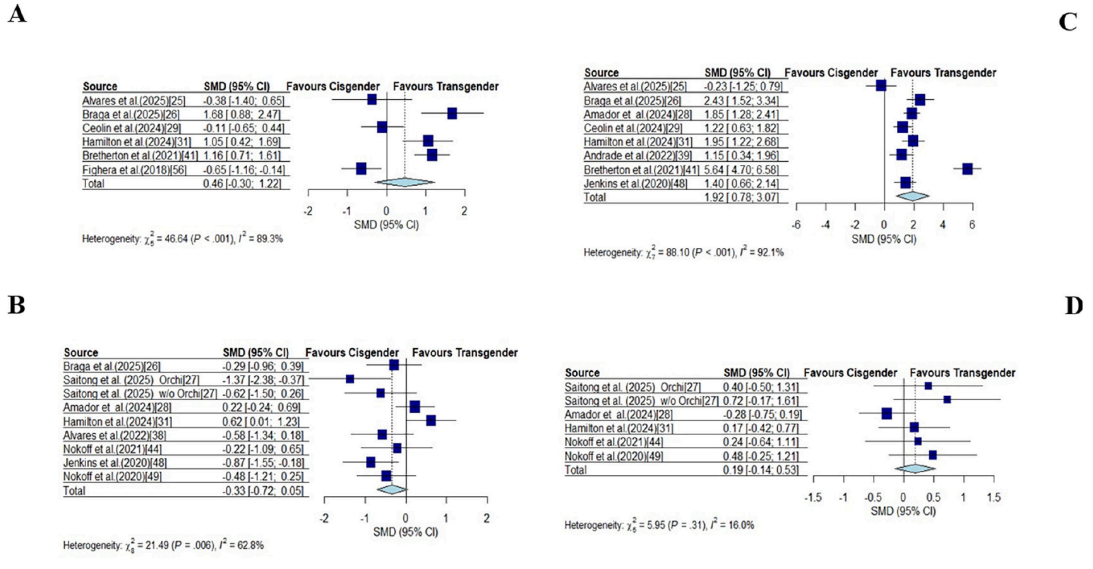


Figure 1 Forest plot: body composition—transgender women versus cisgender women. (A) Fat mass (kg); (B) fat mass (%); (C) lean mass (kg); (D) lean mass (%). SMD, standardised mean difference.

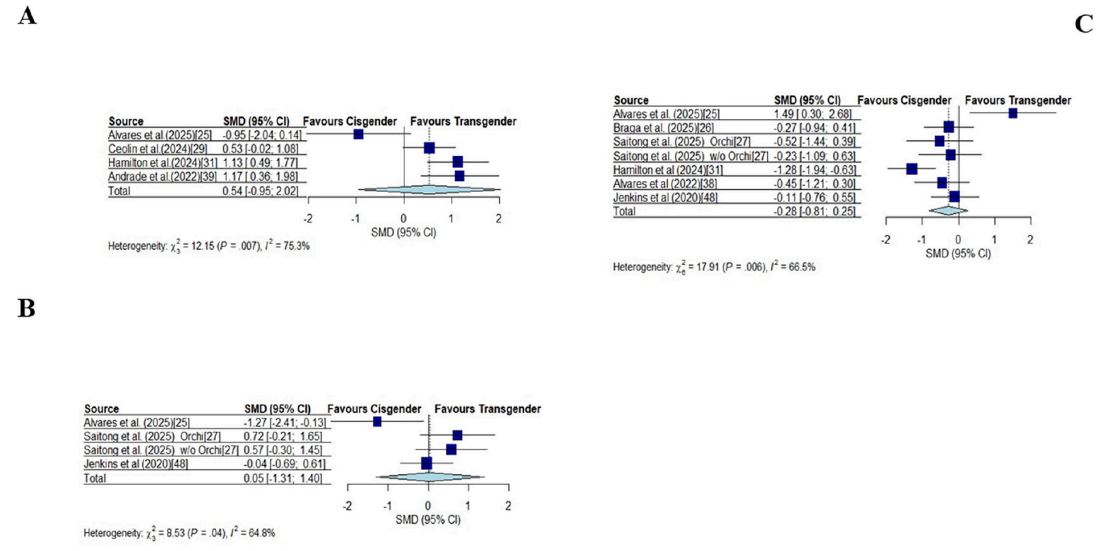


Figure 2 Forest plot: upper-body strength, lower-body strength and VO_2 max—transgender women versus cisgender women. (A) Upper-body strength; (B) lower-body strength; (C) VO_2 max. SMD, standardised mean difference; VO_2 max, maximal oxygen consumption.

Lean mass (kg or %)

Transgender women demonstrated higher absolute lean mass (kg) compared with cisgender women (SMD 1.92, 95% CI 0.78 to 3.07, I^2 = 92.1%, considerable; GRADE: low) (figure 1C). These results remained consistent across all categories in the sensitivity analysis, except for outcome measurement (BIA), quality assessment (Others) and treatment duration (online supplemental table S8a).

No significant differences were found in relative lean mass (%) (SMD 0.19, 95% CI −0.14 to 0.53, I^2 = 16.0%, not important; GRADE: low) (figure 1D). These results remained consistent across all categories in the sensitivity analysis, except for measurement (DXA) and treatment duration ≤1 year (online supplemental table S8a).

Upper-body strength (kgf)

No significant differences in upper-body strength were observed between transgender women and cisgender women (SMD 0.54, 95% CI −0.95 to 2.02, I^2 = 75.3%, substantial; GRADE: very low) (figure 2A). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S8a).

Lower-body strength (jump height, cm)

No significant differences were observed between transgender women and cisgender women in lower-body strength (SMD 0.05, 95% CI −1.31 to 1.40, I^2 = 64.8%, substantial; GRADE: very low) (figure 2B). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S8a).

VO_2 max (mL/kg/min)

No significant differences were found in VO_2 max between transgender women and cisgender women (SMD −0.28, 95% CI −0.81 to 0.25, I^2 = 66.5%, substantial; GRADE: very low) (figure 2C). These results remained consistent across all categories in the sensitivity analysis, except for studies without adjusted confounders (online supplemental table S8a).

Transgender women compared with cisgender men

Fat mass (kg or %)

No significant differences were observed between transgender women and cisgender men in absolute fat mass (SMD 0.46, 95% CI −0.24 to 1.15, I^2=90.1%, considerable; GRADE: very low) (figure 3A). These results remained consistent across all categories in the sensitivity analysis, except for outcome measurement (DXA) (online supplemental table S8b).

Results suggested that transgender women presented high fat mass percentage compared with cisgender men (SMD 1.05, 95% CI 0.83 to 1.28, I^2=1.1%, not important; GRADE: moderate) (figure 3B). These results remained consistent across all categories in the sensitivity analysis, except for treatment duration >2 years (online supplemental table S8b).

Lean mass (kg or %)

Transgender women exhibited a lower absolute lean mass than cisgender men (SMD −1.00, 95% CI −1.50 to −0.49, I^2=83.8%, considerable; GRADE: very low) (figure 3C). These results remained consistent across all categories in the sensitivity analysis, except for outcome measurement (BIA) and treatment duration ≤6 years (online supplemental table S8b).

Relative lean mass was also lower in transgender women (SMD: −1.21, 95% CI −1.52 to −0.91, I^2=20.6%, not important; GRADE: high) (figure 3D). These results remained consistent across all categories in the sensitivity analysis, except for treatment duration >1 year (online supplemental table S8b).

Upper-body strength (kgf)

Transgender women had a lower upper-body strength than cisgender men (SMD −1.25, 95% CI −1.64 to −0.85, I^2=58.6%, moderate; GRADE: moderate) (figure 4A). These results remained consistent across all categories in the sensitivity analysis, except for treatment duration (online supplemental table S8b).

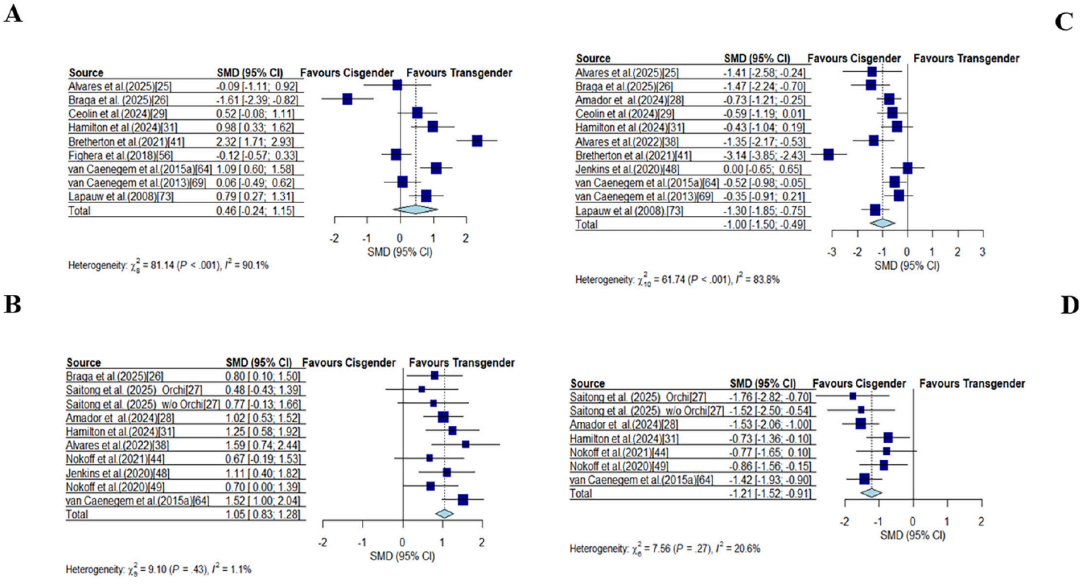


Figure 3 Forest plot: body composition—transgender women versus cisgender men. (A) Fat mass (kg); (B) fat mass (%); (C) lean mass (kg); (D) lean mass (%). SMD, standardised mean difference.

Lower-body strength (jump height, cm)

Transgender women exhibited lower lower-body strength than cisgender men (SMD −2.36, 95%CI −2.77 to −1.95, I^2=0%, not important; GRADE: moderate) (figure 4B). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S8b).

VO_2 max (mL/kg/min)

Transgender women exhibited lower VO_2 max than cisgender men (SMD −1.50, 95%CI −2.02 to −0.98, I^2=57.1%, moderate; GRADE: moderate) (figure 4C). These results remained consistent across all categories in the sensitivity analysis, except for treatment duration >2 years (online supplemental table S8b).

Transgender men compared with cisgender men

Fat mass (kg or %)

No significant differences were observed between transgender men and cisgender men in absolute fat mass (SMD 3.67, 95%CI −1.10 to 8.44, I^2 = 69.0%, substantial; GRADE: low) (figure 5A). These results remained consistent across all categories in the sensitivity analysis, except for treatment duration ≤4 years (online supplemental table S8c).

Relative fat mass was higher in transgender men compared with cisgender men (SMD 0.96, 95%CI 0.28 to 1.64, I^2 = 45.1%, moderate; GRADE: moderate) (figure 5B). These results remained consistent across all categories in the sensitivity

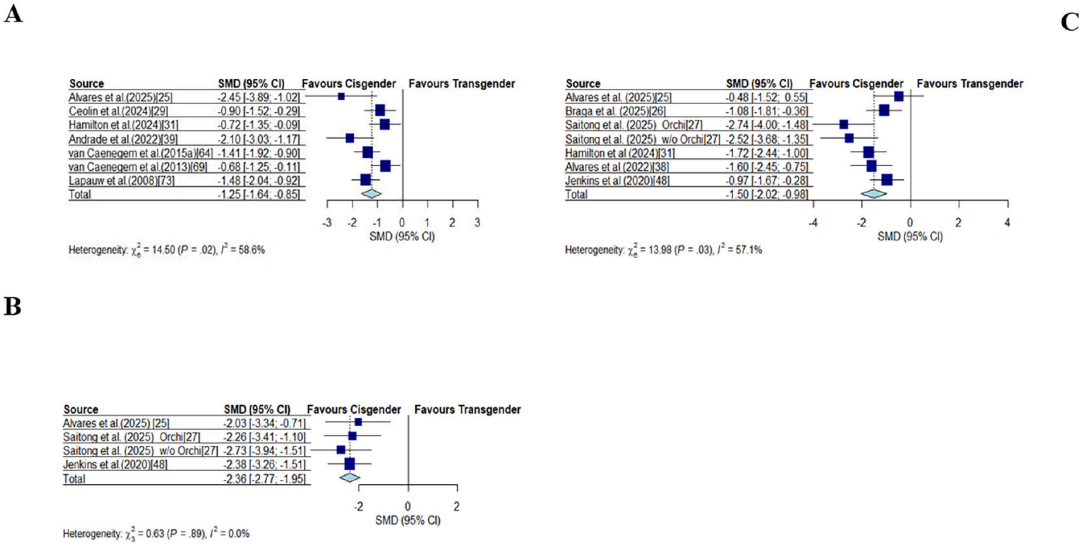


Figure 4 Forest plot: upper-body strength, lower-body strength and VO_2 max—transgender women versus cisgender men. (A) Upper-body strength; (B) lower-body strength; (C) VO_2 max. SMD, standardised mean difference; VO_2 max, maximal oxygen consumption.

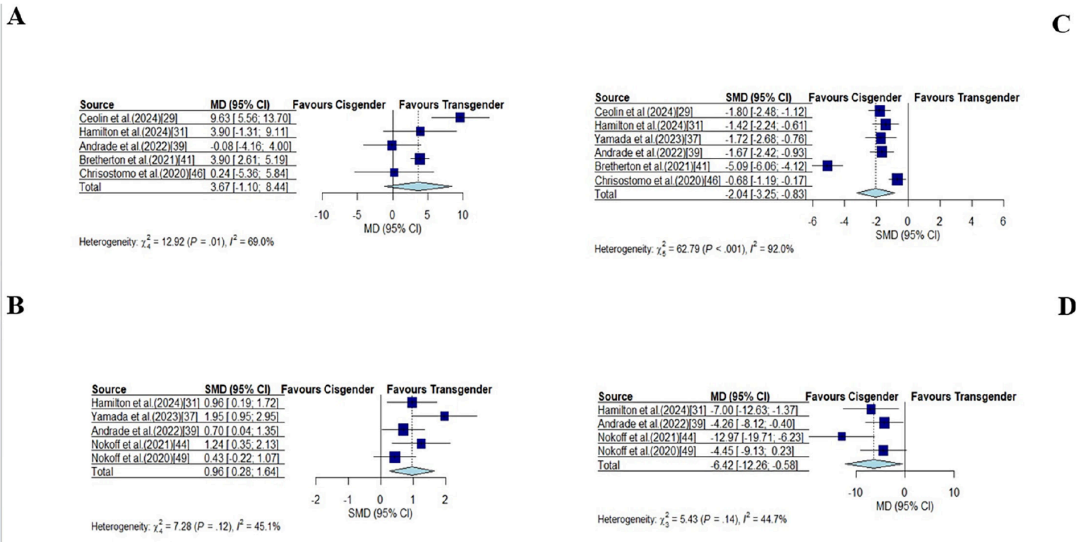


Figure 5 Forest plot: body composition—transgender men versus cisgender men. (A) Fat mass (kg); (B) fat mass (%); (C) lean mass (kg); (D) lean mass (%). MD, mean difference; SMD, standardised mean difference.

analysis except for treatment duration and population (online supplemental table S8c).

Lean mass (kg or %)

Compared with cisgender men, transgender men had lower absolute lean mass (SMD −2.04, 95% CI −3.25 to −0.83, I^2 = 92.0%, considerable; GRADE: low). These results remained consistent across all categories in the sensitivity analysis except for treatment duration ≤4 years (online supplemental table S8c).

Transgender men had lower relative lean mass (SMD −6.42, 95% CI −12.26 to −0.58, I^2 = 44.7%, moderate; GRADE: moderate) (figure 5C,D). These results remained consistent across all categories in the sensitivity analysis except for quality assessment (high), treatment duration and population (online supplemental table S8c).

Upper-body strength (handgrip, kgf)

Transgender men exhibited lower upper-body strength compared with cisgender men (SMD −1.46, 95% CI −2.52 to −0.40, I^2 = 23.8%, not important; GRADE: moderate) (figure 6). These results remained consistent across all categories in the sensitivity analysis, except for outcome measurement (electronic dynamometer) and quality assessment (others) (online supplemental table S8c).

Lower-body strength (Jump height, cm) and VO_2 max (mL/kg/min)

No meta-analyses could be performed for lower-body strength or VO_2 max in comparisons between transgender men and cisgender men.

Transgender men compared with cisgender women

Fat mass (kg or %)

No significant differences were observed between transgender men and cisgender women in absolute fat mass (SMD 0.95, 95% CI −5.20 to 3.30, I^2 = 87.9%, considerable; GRADE: very low) (figure 7A) or relative fat mass (SMD −0.23, 95% CI −0.83 to 0.37, I^2 = 42.9%, moderate; GRADE: very low) (figure 7B). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S8d).

Lean mass (kg or %)

Transgender men demonstrated higher absolute lean mass (SMD 1.44, 95% CI 0.33 to 2.55, I^2 = 94.2%, considerable; GRADE: low) (figure 7C). These results remained consistent across all categories in the sensitivity analysis except for studies without confounder adjustment, quality assessment and treatment duration (online supplemental table S8d).

Transgender men had higher relative lean mass (MD 1.67, 95% CI −3.86 to 7.20, I^2 = 46.4%, moderate; GRADE: very low) (figure 7D) compared with cisgender women. These results

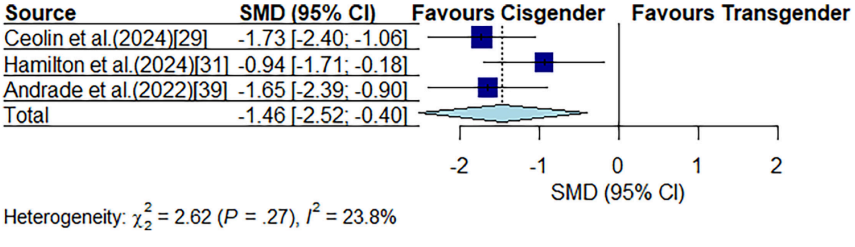


Figure 6 Forest plot: upper-body strength—transgender men versus cisgender men. SMD, standardised mean difference.

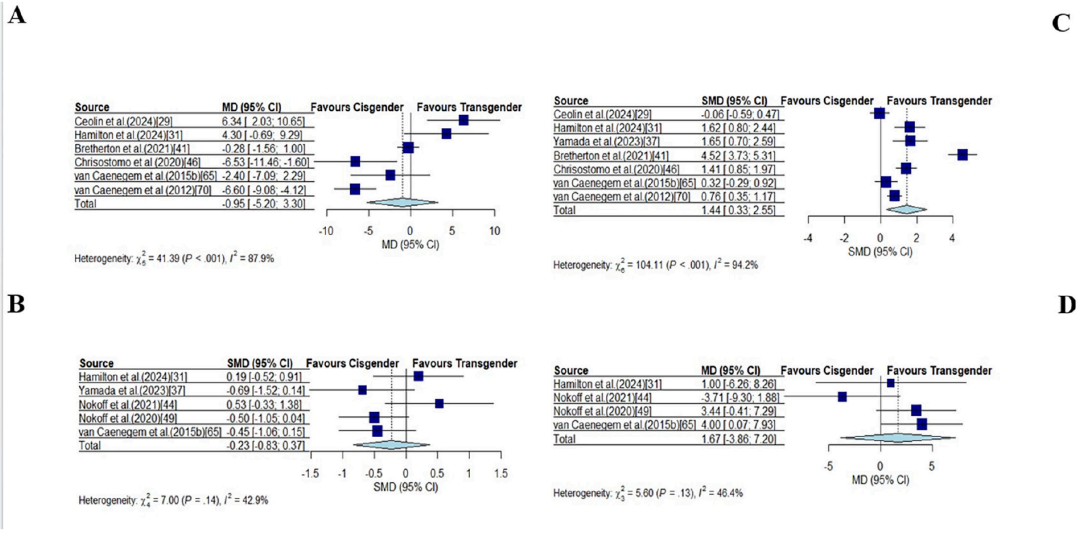


Figure 7 Forest plot: body composition—transgender men versus cisgender women. (A) Fat mass (kg); (B) fat mass (%); (C) lean mass (kg); (D) lean mass (%). MD, mean difference; SMD, standardised mean difference.

remained consistent across all categories in the sensitivity analysis (online supplemental table S8d).

Upper-body strength (handgrip, kgf)

Transgender men exhibited greater upper-body strength than cisgender women (SMD 0.76, 95% CI −0.27 to 1.79, I^2 = 84.1%, considerable; GRADE: very low) (figure 8). These results remained consistent across all categories in the sensitivity analysis except for outcome measurement (hydraulic dynamometer) and treatment duration ≤4 years (online supplemental table S8d).

Lower-body strength (jump height, cm) and VO_2 max (mL/kg/min)

Meta-analysis was not possible for lower-body strength or VO_2 max in comparisons between transgender men and cisgender women.

Longitudinal analysis of cross-sex hormone therapy in transgender women: baseline to 1 year

Fat mass (kg or %)

After 1 year of cross-sex hormone therapy, transgender women exhibited an increase in both absolute (MD 2.68, 95% CI 1.73 to 3.63, I^2 = 0%, not important; GRADE: low) (online supplemental figure S2A) and relative fat mass (SMD 0.50, 95% CI 0.15 to 0.84, I^2 = 71%, substantial; GRADE: very low) compared with baseline (online supplemental figure S2B). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S9a).

Lean mass (kg or %)

Absolute lean mass decreased after 1 year of therapy (MD −2.03, 95% CI −3.27 to −0.80, I^2 = 0%, not important; GRADE: low) (online supplemental figure S2C). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S9a).

No significant change was observed for relative lean mass (SMD −3.24, 95% CI −12.79 to 6.31, I^2 = 81.4%, considerable; GRADE: very low) (online supplemental figure S2D). These results remained consistent across all categories in the sensitivity analysis, except for intervention naïve, quality assessment moderate and adults (online supplemental table S9a).

Upper-body strength (handgrip, kgf)

Upper-body strength decreased after 1 year of therapy (MD −1.86, 95% CI −3.11 to −0.61, I^2 = 0%, not important; GRADE: very low) (online supplemental figure S3). These results remained consistent across all categories in the sensitivity analysis, except for moderate quality assessment and adults (online supplemental table S9a).

Meta-analysis was not possible for lower-body strength or VO_2 max.

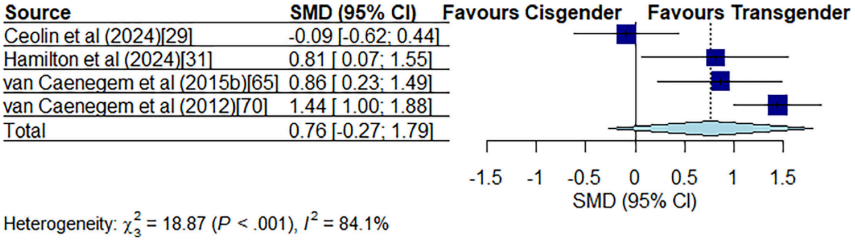


Figure 8 Forest plot: upper-body strength—transgender men versus cisgender women. SMD, standardised mean difference.

Longitudinal analysis of cross-sex hormone therapy in transgender women: 1–2 years

Fat mass (kg or %)

No significant change was observed in absolute fat mass (MD 4.22, 95% CI −16.01 to 24.46, I^2 = 69.0%, substantial; GRADE: very low) (online supplemental figure S4A). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S9b).

Relative fat mass increased (SMD 0.64, 95% CI 0.16 to 1.13, I^2 = 84.0%, considerable; GRADE: very low) (online supplemental figure S4B). These results remained consistent across all categories in the sensitivity analysis, except for prospective design, intervention pubertal block, studies without confounding, serious quality assessment and population (online supplemental table S9b).

Lean mass (kg or %)

No significant differences were observed in either absolute (MD 3.06, 95% CI −8.22 to 2.09, I^2 = 40.4%, moderate; GRADE: very low) (online supplemental figure S4C) or relative lean mass (MD −2.33, 95% CI −49.84 to 45.19, I^2 = 88.6%; considerable; GRADE: very low) (online supplemental figure S4D). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S9b).

Meta-analysis was not possible for upper-body strength, lower-body strength or VO_2 max.

Longitudinal analysis of cross-sex hormone therapy in transgender women: baseline to 3 years

Fat mass (kg or %)

No significant differences were observed in absolute (MD 3.97, 95% CI −11.97 to 19.92, I^2 = 0%, not important; GRADE: very low) (online supplemental figure S5A). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S9c).

No significant differences were observed in relative fat mass (MD 6.22, 95% CI −0.86 to 13.31, I^2 = 74.8%, not important; GRADE: very low) (online supplemental figure S5B). These results remained consistent across all categories in the sensitivity analysis, except for naïve intervention, moderate quality assessment and adults (online supplemental table S9c).

Lean mass (%)

No significant change in relative lean mass was observed (MD −2.79, 95% CI −37.60 to 32.02, I^2 = 69.7%, substantial; GRADE: very low) (online supplemental figure S5C). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S9c).

Meta-analysis was not possible for absolute lean mass, upper-body or lower-body strength, or VO_2 max.

Longitudinal analysis of cross-sex hormone therapy in transgender men: baseline to 1 year

Fat mass (kg or %)

No increase in absolute (MD −0.88, 95% CI −1.97 to 0.21, I^2 = 0%, not important; GRADE: very low) (online supplemental figure S6A). These results remained consistent across all categories in the sensitivity analysis except for retrospective design and naïve intervention (online supplemental table S9d).

No increase in relative fat mass (SMD −0.28, 95% CI −0.60 to 0.03, I^2 = 73.4%, substantial; GRADE: very low) (online supplemental figure S6B) was observed. These results remained consistent across all categories in the sensitivity analysis except for retrospective design, naïve intervention, outcome measurement (DXA), confounding and serious quality assessment (online supplemental table S9d).

Lean mass (kg or %)

Absolute lean mass increased (SMD 0.52, 95% CI 0.41 to 0.63, I^2 = 0%, not important; GRADE: very low) (online supplemental figure S7A). These results remained consistent across all categories in the sensitivity analysis, except for outcome measurement (BIA) and serious quality assessment (online supplemental table S9d).

Relative lean mass showed no significant change (MD 4.26, 95% CI −6.28 to 14.80, I^2 = 0%, not important; GRADE: very low) (online supplemental figure S7B). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S9d).

Upper-body strength (handgrip, kgf)

Upper-body strength increased (MD 3.81, 95% CI 2.56 to 5.07, I^2 = 63.7%, substantial; GRADE: very low) (online supplemental figure S8). These results remained consistent across all categories in the sensitivity analysis except for retrospective design, outcome measurement (isokinetic dynamometry) and serious quality assessment (online supplemental table S9d).

Meta-analysis was not possible for lower-body strength or VO_2 max.

Longitudinal analysis of cross-sex hormone therapy in transgender men: 1–2 years

Fat mass (%)

No difference was observed in relative fat mass (SMD −0.14, 95% CI −0.86 to 0.58, I^2 = 89.9%, considerable; GRADE: very low) (online supplemental figure S9A). These results remained consistent across all categories in the sensitivity analysis except for naïve intervention and studies without confounders (online supplemental table S9e).

Lean mass (kg)

Absolute lean mass increased (SMD 0.39, 95% CI 0.14 to 0.63, I^2 = 8.8%, not important; GRADE: very low) (online supplemental figure S9B). These results remained consistent across all categories in the sensitivity analysis except for naïve intervention and population (adults) (online supplemental table S9e).

Upper-body strength (handgrip, kgf)

Upper-body strength increased (MD 2.41, 95% CI 1.54 to 3.27, I^2 = 0%, not important; GRADE: very low) (online supplemental figure S10). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S9e).

No meta-analyses could be conducted for absolute fat mass, relative lean mass, lower-body strength or VO_2 max.

Longitudinal analysis of cross-sex hormone therapy in transgender men: baseline to 3 years

Fat mass (kg or %)

No significant differences were observed in absolute (MD 1.49, 95% CI −9.03 to 12.00, I^2 = 70.2%, substantial; GRADE: very low) (online supplemental figure S11A) or relative fat mass (SMD −0.33, 95% CI −2.00 to 1.34, I^2 = 85.0%, considerable; GRADE: very low) (online supplemental figure S11B). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S9f).

Lean mass (kg)

Absolute lean mass increased (SMD 0.73, 95% CI 0.13 to 1.33, I^2 = 74.8%, substantial; GRADE: very low) (online supplemental figure S11C). These results remained consistent across all categories in the sensitivity analysis, except for naïve intervention, outcome measurement (BIA), serious quality assessment and adults (online supplemental table S9f).

Upper-body strength (handgrip, kgf)

No significant difference was observed (MD 3.47, 95% CI −1.72 to 8.66, I^2 = 71.9%, substantial; GRADE: very low) (online supplemental figure S12). These results remained consistent across all categories in the sensitivity analysis (online supplemental table S9f).

Meta-analysis was not possible for relative lean mass, lower-body strength or VO_2 max.

Risk of bias

Quality scores ranged from 10 to 19, with most studies rated as high (70.6%; n=12) or fair (17.6%; n=3), and 11.8% as low quality (n=2) for cross-sectional studies. Using AXIS, the most common weaknesses identified in the articles were the lack of justification of the sample size (n=13) and the use of a convenience sample (n=15).

Among cohort and quasi-experimental studies, 65.6% exhibited moderate ROB, with limitations concerning confounding (15/32 studies, 46.8%, moderate risk) and selective reporting (22/32 studies, 68.8%, moderate risk). Bias in participant selection, intervention classification and deviations from intended interventions were predominantly low risk (24/32, 75%; 25/32, 78.1%; 30/32, 93.8%, respectively).

All RCTs were classified as some concerns. Methodological concerns primarily stemmed from selection of the reported result (3/3 studies, 100%, some concerns); deviation from intended interventions (3/3 studies, 100%, some concerns); and randomisation process (2/3 studies, 66.6%, some concerns).

A detailed assessment of the ROB for individual studies is provided in online supplemental table S6 and S7 and figure S13.

Publication bias

Funnel plot asymmetry suggests suspected publication bias for the following comparisons: transgender women versus cisgender men for relative fat mass and absolute lean mass (online supplemental figure S14A,B, respectively); transgender men before and up to 1 year after hormone therapy for absolute fat mass, relative fat mass and absolute lean mass (online supplemental figure S15A–C, respectively).

DISCUSSION

In addition to evaluating body composition and physical fitness differences between transgender and cisgender individuals, this systematic review and meta-analysis also aimed to examine the influence of GAHT duration on the outcomes, assess variations between transgender men and transgender women in response to therapy, compare naïve versus non-naïve individuals and explore the impact of puberty suppression on body composition and strength.

The primary findings indicate that transgender women exhibit body composition distinct from both cisgender men and cisgender women. Specifically, transgender women possess significantly higher fat mass than cisgender men but levels comparable to cisgender women. Regarding lean mass, transgender women show values significantly higher than cisgender women but significantly lower than cisgender men. Of relevance, despite differences in lean mass, no significant differences were found in upper-body or lower-body strength between transgender women and cisgender women. In contrast, both upper-body and lower-body strength was markedly lower in transgender women compared with cisgender men. Longitudinal analysis demonstrated that 1–3 years of hormone therapy in transgender women leads to progressive increases in fat mass and concurrent declines in lean mass and upper-body strength. Finally, VO_2 max in transgender women did not differ significantly from cisgender women but was significantly lower than in cisgender men. The convergence of transgender women's functional performance with cisgender women, particularly in strength and aerobic capacity, challenges assumptions about inherent athletic advantages derived solely from GAHT or residual lean mass differences.

The meta-analysis comparing transgender men and cisgender men revealed significant differences, with transgender men showing intermediate body composition and strength metrics between cisgender women and cisgender men, even after an average therapy duration of 4 years.

Practical implications

This review shows transgender women exhibited higher absolute lean mass compared with cisgender women; however, no significant differences in upper-body or lower-body strength were observed between the two groups after 1–3 years of hormone therapy. Because the lean mass and performance data were not necessarily derived from the same cohorts or study designs, direct correlations between muscle mass and functional strength cannot be inferred. Nevertheless, one may postulate that residual lean mass may not translate into clear functional strength advantages in this population. In line with this, the current results are consistent with evidence[4] indicating that, although transgender women retain higher absolute lean mass, body composition-adjusted strength metrics (eg, relative strength per kg lean mass) tend to converge with cisgender women over time within the same cohort. This suggests that lean mass alone is an incomplete proxy for transgender women's athletic performance, as neuromuscular efficiency, training history and fat distribution may play compensatory roles. In fact, when height-normalised, transgender women and cisgender women appear to show comparable appendicular lean mass/height^2 or lean mass/height^2.[25 31] Importantly, a greater absolute lean mass not accompanied by increased functionality may actually impair performance, especially in weight-sensitive sports (eg, cycling and climbing), which not surprisingly have the lightest athletes.[77]

In fact, the absence of strength disparities between transgender women and cisgender women found in the current review was consistent and contradicts narratives framing male puberty as conferring irreversible athletic advantages despite GAHT. In a narrative review, Lundberg *et al*[3] argue that male developmental traits (eg, height, skeletal proportions) inherently disrupt fairness, yet the lack of measurable strength differences in the present systematic review suggests such claims may overemphasise structural factors while underestimating the impact of GAHT. For instance, transgender women's VO_2 max, when adjusted for weight, aligns with cisgender women,[4] further supporting parity in endurance capabilities. Furthermore, transgender women's pretherapy advantages in push-ups and sit-ups disappeared after 2 years of feminising hormones among 46 individuals who started GAHT while in the US Air

Force.[50] These findings are corroborated by the current meta-analysis, endorsing nuanced, sport-specific policies rather than blanket bans.

Limitations of the available evidence and the review

This systematic review aligns with previous ones[1 4] in highlighting critical research limitations. This includes the typically short study durations (<3 years) and a lack of data on elite athletes. Additionally, the potential conflation of trained and untrained individuals complicates extrapolation. The available evidence remains limited for specific outcomes (eg, lower-body strength and VO_2 max), particularly regarding RCTs examining the effects of GAHT on physical fitness and body composition (n=3), as well as studies assessing the impact of puberty suppression (n=6). Another weakness in the literature is the inconsistent reporting and adjustment for confounders, as few studies controlled for training history, diet, baseline fitness, physical activity and body composition or previous hormone therapy, potentially hindering the isolated effects of GAHT, since high-dose oestrogen may alter both fat and muscle mass estimates. Finally, there is very little literature involving transgender athletes of any age, across all sport settings and at any competitive level. Therefore, future studies must prioritise transgender athletes, assess sport-specific performance metrics and evaluate long-term (eg, >5 years) physiological and psychological changes, controlling for puberty suppression whenever possible.

The limitations of this review are related to the identified gaps in literature and include: the reliance on short-term assessments, limiting conclusions about the effects of GAHT on targeted outcomes in the long run; the heterogeneity of the studies assessed, variability in hormone regimens (eg, types/doses of antiandrogens, oestrogens), measurement methods (eg, DEXA vs MRI for body composition) and control groups (eg, inconsistent physical activity tracking); the reliance on lean mass and strength as proxies for performance, rather than sport-specific outcomes (eg, race times, power output), which limits practical importance to real-world sport scenarios; under-representation of puberty-suppressed cohorts, hampering the meta-analytical comparison between suppressed and non-suppressed individuals; and the inclusion of studies with ROB and with cross-sectional or retrospective designs; studies with small sample sizes and unmeasured confounding were included, potentially leading to overestimated results due to heterogeneity, sampling error and/or publication bias.[78] While the main results and conclusions are confirmed by multiple sensitivity analyses, some of them still show moderate to considerable heterogeneity (eg, transgender women vs cisgender women for lean mass and fat mass, in kg) and potential publication bias (eg, transgender women vs cisgender men, in relative fat mass and absolute lean mass) which affects the certainty of the evidence.

Another limitation of the existing literature is its predominant focus on physiological outcomes, with little consideration of the social, psychological and cultural factors that also shape sport performance (eg, stigmatisation, discrimination, access to opportunities, self-concept, self-esteem). Transgender individuals are known to face elevated risks of adverse mental health outcomes,[79] largely due to systemic stigma and discrimination across multiple contexts,[80] including sports.[81 82] Yet, the impact of these sociocultural factors on athletic engagement and achievement remains insufficiently addressed in the available studies and, consequently, in this review.

Perspectives

Although the current data do not justify blanket bans, critical gaps in literature were found, notably the under-representation of transgender athletes who may retain more 'muscle memory'. Ideally, to resolve speculation, future long-term, longitudinal studies should prioritise performance-specific metrics in transgender athletes. However, one should be aware of the scarce number of transgender athletes, particularly in the elite sport, which complicates the feasibility of conducting powered studies involving high-performance transgender athletes within specific sport disciplines. Considering this context of imperfect evidence and despite the methodological challenges, continued research into physiological as well as psychosocial trajectories among transgender athletes with diverse demographics and clinical characteristics remains essential for developing equitable frameworks that balance justice, inclusion and scientific rigour. Policies should remain dynamic, guided by evolving evidence and ethical imperatives, whereas acknowledging that fairness and non-discrimination are interdependent objectives necessitating nuanced, context-sensitive strategies.

CONCLUSIONS

This systematic review and meta-analysis shows transgender women exhibited higher absolute lean mass compared with cisgender women. However, no significant differences in physical fitness metrics (ie, upper-body strength, lower-body strength and VO_2 max) were observed after 1–3 years of therapy. Given that lean mass and performance data were not necessarily derived from the same cohorts or study designs, direct correlations between muscle mass and functional strength cannot be established.

Contributors SMS and DRC searched studies in the databases, ran statistical analysis, elaborated results and drafted the manuscript. SMS, BCM, DRC, IL, ARC and JDFVMPdH extracted data. BCM and IL evaluated the risk of bias, edited and revised the manuscript. BG conceived the study design and drafted the manuscript. HR conceived the study design and revised the manuscript. All authors contributed to critical revision of the report for important intellectual content. BG is the guarantor of data and integrity of this study. ChatGPT (OpenAI, San Francisco, California, USA) was used to proofread the final version of the manuscript to improve clarity and grammar.

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Competing interests None declared.

Patient consent for publication Not applicable.

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