Sex Differences in Track and Field Elite Youth

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ABSTRACT

INTRODUCTION: To understand athletic performance before and after puberty, this study determined (1) the age at which the sex difference increases among elite youth track and field athletes for running and jumping events; and (2) whether there is a sex difference in performance prior to puberty among elite youth athletes. **METHODS:** Track and field records of elite USA male and female youth (7-18 years) across three years (2019, 2021, and 2022) were collected from an online database (athletic.net). The top 50 performances were recorded for 100m, 200m, 400m, and 800m track running, long jump, and high jump. **RESULTS**: Males ran faster than females at every age in the 100, 200, 400 and 800 m (*P*<0.001). When combining all running events, the sex difference (%) was 4.0 ± 1.7% between 7-12 years and increased to 6.3 ± 1.1% at 13 years, and 12.6 ± 1.8% at 18 years (*P*<0.001). Similarly, males jumped higher and further than females at every age (*P*<0.001). For long jump, the sex difference was 6.8 ± 2.8% between 7-12 years, increasing to 8.5 ± 1.7% at 13 years, and 22.7 ± 1.4% at 18 years (*P*<0.001). For high jump, the sex difference was 5.3 ± 5.2% between 7-12 years, increasing to 10.3 ± 2.4% at 14 years, and 18.4 ± 2.04% at 18 years (*P*<0.001). **CONCLUSION:** Prior to puberty in elite youth track and field athletes, there is a small but consistent sex difference, such that males run faster and jump higher and further than females. The sex difference in performance was event dependent and increased significantly from ~12 years for running and 13-14 years in jumping events.

KEY WORDS: adolescence, aerobic power, athletics, gender, maturation, puberty

INTRODUCTION

After puberty, adult males outperform females in sports that involve muscular power, strength, and endurance (1, 2). Sex differences in athletic performance are associated with differences between males and females in androgen concentrations -- primarily greater testosterone concentrations among males (1-3). From the perspective of athletic performance, prolonged exposure to higher testosterone concentrations confers many performance-enhancing effects, including larger and stronger skeletal muscle mass and bones, higher hemoglobin mass and concentrations, a larger heart and lungs and less body fat to carry during weight bearing exercise. These sex-based differences in testosterone concentrations and the physiological effects from testosterone are the primary basis for dichotomizing sport categories based on sex (1-5). However, the magnitude of the sex differences in athletic performance can range from ~10-30%, depending on the athletic event (2), with larger sex differences observed in events that rely heavily on muscular power including weightlifting and jumping events (2, 3, 5).

Before male puberty, which typically begins around 11-12 years of age (6), there are no sex differences in testosterone levels, with the exception of 'minipuberty', where males have transiently higher testosterone levels during infancy around age 3- to 6-months (5, 7, 8). After male puberty, circulating testosterone levels are about 15 times greater in males compared to females (3, 9). The emergence of increased testosterone in males during and after puberty has been shown to coincide with increases in muscle mass and strength (3), ultimately leading to increased exercise capacity and performance (1, 3). As an example, a recent study (10) provided evidence that endogenous testosterone concentrations explained about 98% of the variance of sex differences in swimming performance of elite youth after the age of 12 years. However, it is unknown whether these minimal sex differences before puberty are present across a large range of sports, including more power-based events (e.g., 100-meter dash and long jump) or more aerobic-based (e.g., 800-meter) events. Additionally, although it is well known that there are large sex differences in athletic performance among elite adult athletes (2), including track and field performance (11), the precise age at which this divergence in athletic performance between the sexes begins has not been thoroughly investigated.

Accordingly, the primary objectives of our study were to: 1) determine the sex difference in track and field performances among elite youth males and females, and 2) determine the age of divergence in track and field performances between elite youth males and females. This retrospective, observational study used ‘'real-world data” to test the hypotheses that: 1) there would be minimal sex differences in track and field performances of males and females during pre-pubescent years up to ~12 years of age, and 2) a sex difference in track and field performance would emerge at ~12-13 years of age. Moreover, as a secondary objective, this study compared the sex difference in performance between track running events and field jumping events. To accomplish these objectives, we analyzed performances of key track and field events of the annual top 50 male and female youth athletes aged 7 to 18 years. By focusing on elite performances, the potential impact of sociocultural factors, such as biological talent and sex differences in participation, were limited.

METHODS

All procedures involved accessing public information and did not require ethical review as determined by the Marquette University Institutional Review Board in accordance with the Code of Federal Regulations, 45 CFR 46.102, and the Declaration of Helsinki. Performances of key outdoor track and field events of the top 50 male and female youth athletes participating in USA Track & Field Club division were collected.

Data Sources

The USA Track & Field (USATF) represents one of the largest track and field organizations in the world and includes more than 3,000 clubs in the United States. Thus, USATF outdoor, club-level track and field performances served as the primary data source and were downloaded from a publicly available online database. Performances from four track events (100 m, 200 m, 400 m, and 800 m) and two field events (long jump and high jump) across three years of competition (2019, 2021, and 2022) for 12 one-year age groups (7 to 18 years) were collected and analyzed for the top 50 male youth athletes and top 50 female youth athletes. Notably, data associated with the 2020 competition year were not analyzed due to limited performance opportunity in response to the COVID-19 pandemic. Additionally, data associated with several track and field events were excluded from analyses due to potential confounding— hurdle events (110 m, 300 m, and 3,000 m steeple chase) were excluded due to changes in hurdle height between age-groups and sexes; throwing events (shot put, discus, javelin, and hammer) were excluded due to changes in implement size and weight between age-groups and sexes; longer distance running events (1,500 m; 3,000 m; 5,000 m; and 10,000 m) were excluded due to limited or no participation among younger age-groups; and two jumping events (triple jump and pole vault) were excluded due to limited or no participation among younger age groups.

In this framework, up to 21,600 potential data points could be abstracted (6 track and field events × 3 competition years × 12 one-year age groups × 50 places × 2 sexes). Although complete datasets were almost ubiquitously available, data associated with high jump performances were incomplete for elite youth for both the 7-year age-group (males, *n* = 7; females, *n* = 7) and 8-year age-group (males, *n* = 17; females, *n* = 17). Thus, of the 21,600 potential data points, 21,048 performances were included in the analyses due to incomplete datasets.

Data Transformations

For track running events, average running speed ($m \cdot s^{-1}$) was calculated from the finishing time as: (race distance, m) × $(\text{finishing time, s})^{-1}$. Sex differences in performance were calculated for analogous male and female youth athletes within each event, competition year, age group, and place as: [(male performance) – (female performance)] × $(\text{male performance})^{-1}$ × 100%. Additionally, data were stratified into quintiles based on annual rank (1st to 50th).

Statistical Analysis

Data are reported as mean ± standard deviation in the tables and text, unless otherwise noted. Data are reported as mean ± standard error in the figures to graphically show the bounds of the sample mean. Separate mixed-model univariate analyses of variance (ANOVAs) were used to compare the dependent variables (track and field performance time or distance and sex differences in track and field performance as a percentage) between independent variables [sex (male and female); track and field event (100 m, 200 m, 400 m, 800 m, long jump, and high jump); age group (7 to 18 years); and record place (1st to 50th or quintiles)]. *Post hoc* analyses (Tukey's HSD multiple comparisons) were used to test for differences between pairs within a dataset when significant main effects or interactions were identified for age group, record place, or track and field event. Analyses were performed using IBM Statistical Package for Social Sciences version 28 statistical package (IBM, Armonk, NY, USA). Statistical significance was set at $\alpha = 0.05$, and all tests were two-tailed. Figures were created using SigmaPlot 14.5 software (Systat Software Inc, Chicago, Illinois, USA).

RESULTS

Athletic performances improved with increasing age for both male youth ($P < 0.001$) and female youth ($P < 0.001$) across all track and field events analyzed, including track running events (100 m, 200 m, 400 m, and 800 m) and field jumping events (high jump and long jump). Additionally, male youth had better performances than female youth ($P < 0.001$) across all ages and track and field events analyzed. Further, there was an interaction of age and sex for each event ($P < 0.001$), such that males demonstrated greater improvements than females across age, particularly after ages associated with male puberty (about 12 to 14 years). Supporting data may be found in **Supplemental Table 1** and **Supplemental Table 2** (see Supplemental Digital Content).

Age-related Performance Improvements

As described above, athletic performance for all analyzed track and field events improved across age groups for both male and female youth athletes. Pairwise comparisons showed that performance improvements continued between each one-year age-group for male youth through 18 years of age for all analyzed track and field events ($P < 0.001$). Among female youth, performance improvement increased until 17 years of age ($P < 0.001$) at which time performances plateaued for all analyzed track and field events ($P < 0.001$). See **Figure 1**.

Sex Differences in Performance (%)

In addition to analyses of absolute performance presented above, we compared the relative sex difference in performance (percentage difference) between male and female youth athletes of similar age. Consistent with analyses of absolute performance, there were sex differences in performance across all track and field events and age groups ($P < 0.001$) — except there was no significant difference between male and female youth for high jump at 7 years with low numbers in this age group. The sex difference in performance for all events was larger after ages associated with male puberty (about 12 to 14 years). The age at which this large increase in the sex difference in performance was broadly homogenous (12 to 14 years), although, the precise age differed between track running events (between 12 and 13 years) and field jumping events (between 13 and 14 years). For example, the 100-meter dash had the largest increase between 12 years and 13 years (2.13% increase) and 13 years to 14 years (2.42% increase). These increases were similar across all running events. For the long jump, the increase between 12 and 13 years (1.85% increase) was less than the large increase between 13 and 14 years (6.34% increase). For high jump, the largest increase occurred between 13 and 14 years (5.91% increase). Lastly, pairwise comparison showed the sex difference was least between 10 to 12 years of age for most events (100: ~2.9%; 200: ~2.8%; 400: ~3.4%; 800: ~4.6%; LJ: ~6.1%; HJ: ~3.8%).

Performance Ranking

We determined whether the sex differences in performance increased with the place of the runner between 1st and 50th place (stratified by quintile) for the 7- to 11-year-olds before the large sex differences emerged, and from 12 to 18 years after the sex differences are prominent. Among the 7- to 11-year-olds, the sex difference in running times did not differ across rank (1st-50th) when all running events (100, 200 and 400 and 800 m) were combined (rank effect, $P = 0.19$). However, an interaction of place and event ($P < 0.001$) occurred because the sex difference in the 100 and 200m decreased among higher (lower ranked) runners while the 400m increased and the 800m showed no change (see **Figure 4**). **Figure 2** also shows the top 10 and top 50 with similar patterns in the change of the sex difference with age. Similar to running events, the sex difference in jumping performance did not differ with the rank of the athlete for high jump (rank effect, $P = 0.64$) or long jump (rank effect, $P = 0.41$). Among 12- to 18-year-olds, the sex difference in track and field performance generally increased among athletes with higher rankings (e.g., 50th rank; $P = 0.018$), however, this relation was not observed among all track and field events. The sex difference in track running performance increased among athletes with higher rankings for the 200, 400, and 800 m events ($P < 0.05$ for all). However, the sex difference in track running performance did not differ with the rank of the athlete for the shortest running event (100 m, $P = 0.971$) or the jumping events (high jump, $P = 0.977$; long jump, $P = 0.387$).

DISCUSSION

This retrospective, observational study used 'real-world data' — elite youth track and field performances — as a proxy to estimate the ergogenic advantage of androgens (the increase in testosterone) among male compared to female youth during puberty. The major findings from this study are twofold. First, before the ages of puberty, there was a consistent sex difference in performance of about 5% across key track and field events. This sex difference in performance among youth is lower than the sex difference in performance among adult males and females. Second, the sex difference in track and field performances demonstrably increased around the ages of puberty (12 to 14 years) and was, on average, about 15% at 18 years of age, with a larger sex difference for the jumping than running events. These data suggest that among track and field events, male youth have a performance advantage compared to female youth, and this sex divergence in athletic performance markedly increases near the onset of male puberty. These data may provide additional evidence to inform fair and inclusive policies for youth athletes.

Sex differences in athletic performance *before* male puberty

Although there is broad-based availability of data on athletic performance of youths, there is limited scientific evidence evaluating potential sex differences in athletic performance among pre-pubertal youth. Among the key track and field events we evaluated, performance of male youth was 5% better than performance of female youth — male youth ran faster and jumped higher or further than female youth. Our findings are generally consistent with previous observations of sex differences in athletic performance among pre-pubertal youth, including data from all-time best Norwegian track and field athletes (11), Polish athletes (12),and world record performances in track and field (1). Notably, however, sex differences in athletic performance among pre-pubertal youth are small (<5%) (1) or negligible in swimming (1, 10) and weightlifting (13, 14). This study extends previous findings - which have focused on athletic performance beginning at about age 10 years - by examining track and field performance at a younger age than previous studies.

Potential contributing factors. Although limitations associated with the design of our study limited mechanistic insights that may be inferred from our findings, there are several potential contributing factors to the observed sex differences in performance before the age of puberty. First, within the first few months of life, human infants experience a transient increase in sex hormones called 'minipuberty', and evidence supports that the transient surge of testosterone in male infants is linked to increased growth velocity (15) and reduced adipose accumulation (16) among male infants compared to female infants. Additionally, there is evidence of a relationship between endogenous testosterone concentration and increased muscle mass (6) and strength (17). In this context, minipuberty may confer physiological changes that predispose male youth to better athletic performance compared to female youth. This is an area for future research.

Second, there is some evidence that male youth spend more time engaging in physical activity (18, 19) and, particularly, higher intensity physical activity (20) compared to female youth. These potential sex differences in engagement of physical activity – which are possibly due to differences in positive reinforcement of physical activity between males and females (21, 22) – could contribute to sex differences in athletic performance. Notably, physical fitness is found to be significantly associated with time engaged in physical activity in youth (23). By focusing on elite performances, the design of this study likely mitigated the impact of potential sex differences in physical activity, as it may be presumed that elite athletes are homogenous for intensive training and high levels of physical activity.

The potentially confounding effects of participation were also considered. Among adult athletes, there is evidence that lower participation among females contributes to an exaggerated sex difference in athletic performance even amongst the most elite athletes (24, 25). However, our analyses examining the sex difference in track and field performance across rank quintile suggest that before the age of 12, place of the athlete does not influence the sex difference in performance, emphasizing that depth of field was not a major contributor to the sex differences observed.

Sex differences in athletic performance *during* adolescence

Sex divergence in athletic performance dramatically increases (or emerges in the cases of swimming (1, 10) and weightlifting (13, 14)) near the onset of male puberty due to the performance-enhancing effects associated with male testosterone concentrations (1, 10). In the current study, the sex difference in track and field performance demonstrably increased at 12 years of age for track running events and 13 years of age for field jumping events. Our findings support previous research which found that while there were small sex differences in performance between ages 11-13, the sex difference were significantly greater at 14-15 years of age (12).

Generally, athletic performance improves during youth and then gradually declines during adulthood after about 30 years of age (26). Our data confirmed this improvement. However, there is more limited research examining at what age the plateau in performance occurs for elite athletes, and whether this age differs between males and females or between sports. In this study of key track and field events, males had improved performances throughout the range of observed ages (through 18 years). In this context, males likely have their age of peak performance after 18 years for track and field events. Among females, there was an observed plateau in track and field performances between ages 17 and 18 years. Thus, females may have a plateau in track and field performances at a younger age than males. Similar findings have also been observed in swimming (10), that is elite female swimmers have a plateau in performance at a younger age than elite male swimmers. Interestingly, the ages at which the plateau in swimming performance initiated was 15 years for females and 17 years for males, suggesting the age at which the plateau in performance initiates may be different between sports (i.e., younger age for swimming events compared to track and field events).

Limitations

Our study faced several limitations associated with the design of the study. First, this retrospective, observational study focused on performance of key track and field events from elite youth males and females, which limits the mechanistic insights that may be inferred from our results. We did, however, analyze the sex difference in ranking to determine whether social factors often associated with lower participation and a reduced talent pool of females and which widens the sex difference in performance, contributed prior to puberty. This was not the case. Second, our analyses were limited to publicly available information and did not include information on key performance-influencing factors such as maturation status, testosterone concentrations, history of training and physical activity, and anthropometrics. Third, our analyses were restricted to only a few track and field events, which may limit the generalizability of the current findings. Despite these limitations, our data provide novel evidence of sex differences in athletic performance among elite athletes throughout youth years beginning at seven years.

CONCLUSION

Before puberty in elite youth track and field athletes there is a small (~5%) but consistent sex difference in athletic performance, such that males run faster and jump higher and further than females. However, the sex difference in performance increased significantly by ~13 years of age, and this age of sex divergence in performance marginally differed between track running events and field jumping events with a larger and later emergence of the sex difference for the jumping events.

ACKNOWLEDGEMENTS

None.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

DATA AVAILABILITY STATEMENT

The datasets analyzed during the current study are available in the publicly available AthleticNet database (https://www.athletic.net/). All aggregate data generated and analyzed during the study are included in the published article and its supplementary information files.

AUTHOR CONTRIBUTIONS

MA, JJJ, JWS & SKH conceived and designed the research; MA, JJJ, MEQ, JWS collected and analyzed the data; MA, JJJ, JWS & SKH interpreted results of experiments; MA and JWS prepared figures; MA, JJJ, JWS & SKH drafted manuscript; MA, JJJ, MEQ, JWS & SKH edited and revised manuscript; MA, JJJ, MEQ, JWS & SKH approved final version of manuscript.

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FIGURES

Figure 1.

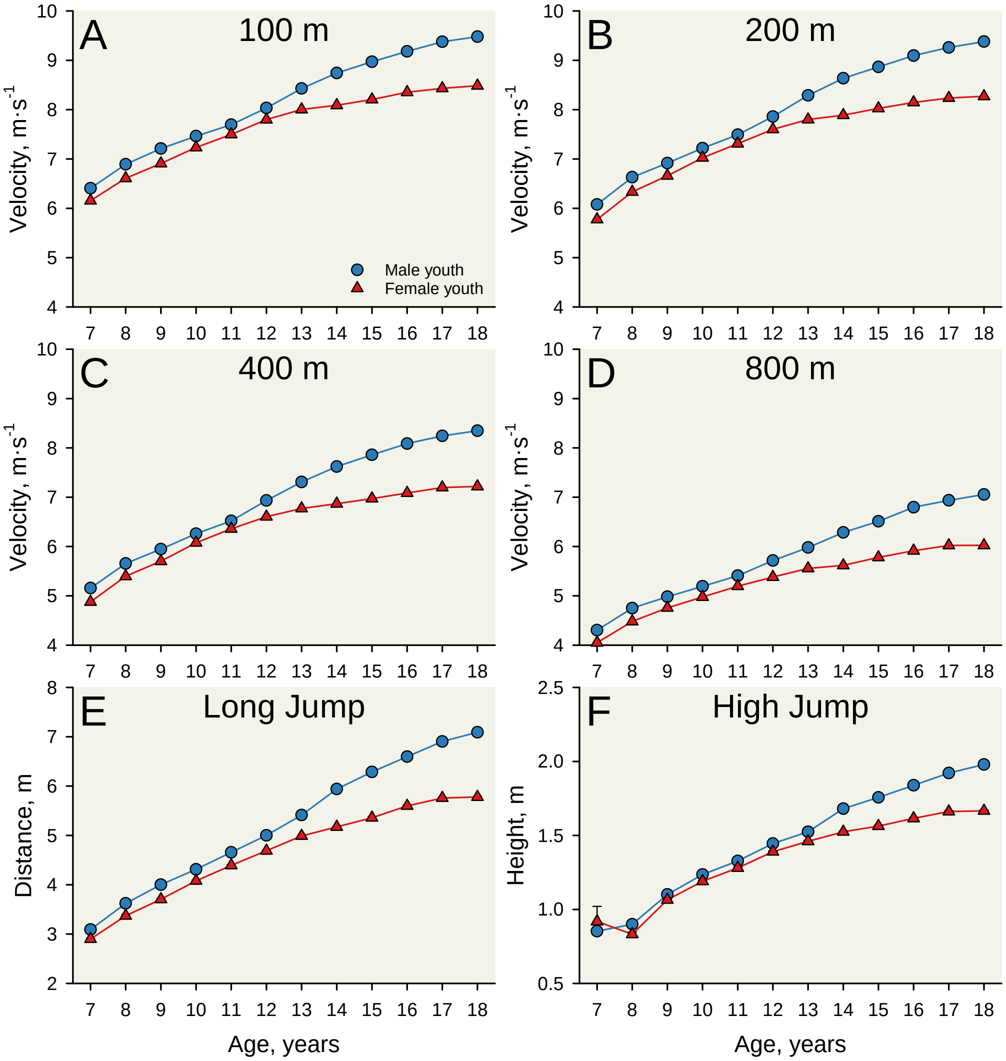

Figure 1. Age-related improvements in track and field performances of elite youth males and females. Scatter and line plots display the improvement in performance across youth years among male youth (blue circles) and female youth (red triangles) for key track running events and field jumping events, including 100 m (A), 200 m (B), 400 m (C), 800 m (D), long jump (E), and high jump (F). Data represent an amalgam of the top 50 athletes across three years of

competition (2019, 2021, and 2022), such that individual data points generally represent 150 athletes — except high jump for ages 7 years (*n* = 7 athletes) and 8 years (*n* = 17 athletes). Symbols represent group means and the error bars represent standard error.

Figure 2.

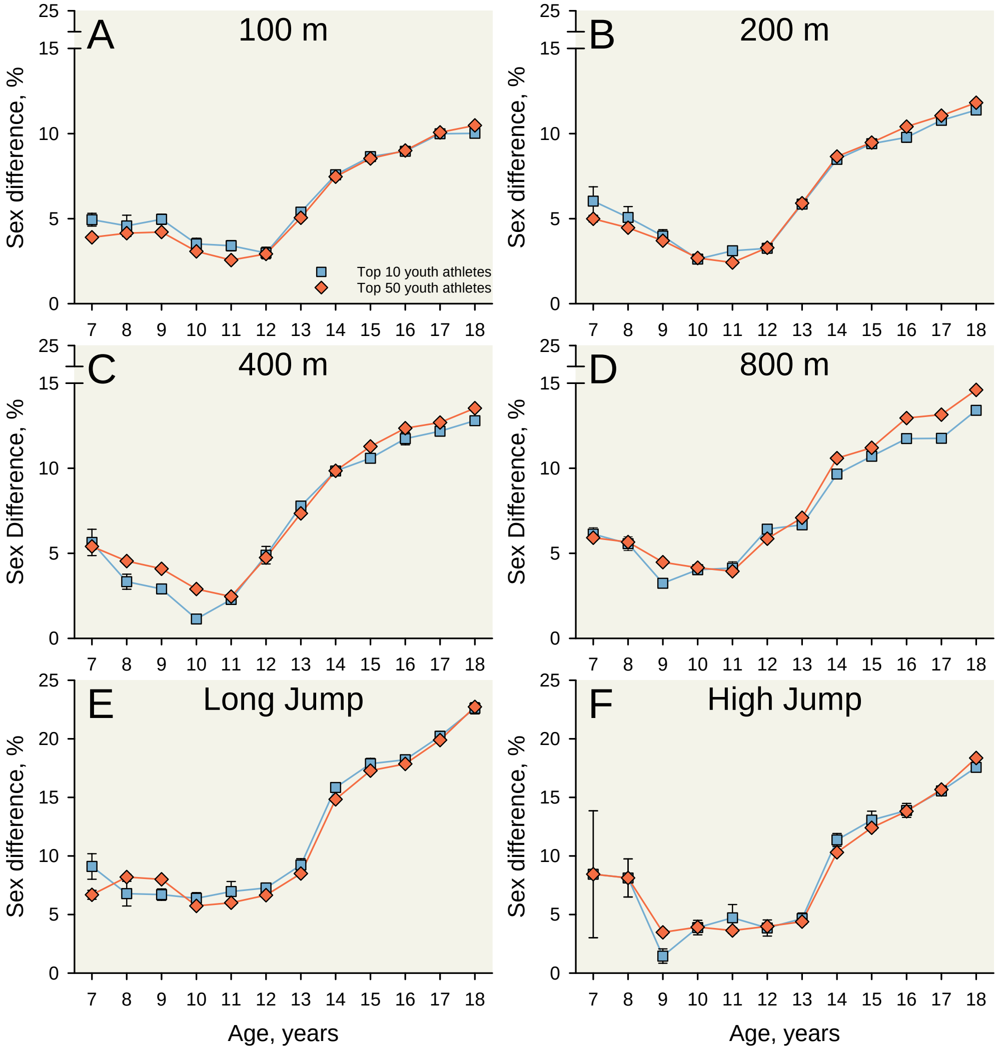

Figure 2. Age-related increase in sex differences in track and field performances of elite youth males and females. Scatter and line plots display the increase in sex difference in track and field performances across youth years among both the annual top 10 youth athletes (light blue

squares) and top 50 youth athletes (orange diamonds) for key track running events and field jumping events, including 100 m (A), 200 m (B), 400 m (C), 800 m (D), long jump (E), and high jump (F). Data represent an average across three years of competition (2019, 2021, 2022). Incomplete datasets are represented for high jump ages 7 years (*n* = 7 athletes) and 8 years (*n* = 17 athletes). Symbols represent group means and the error bars represent standard error.

Figure 3.

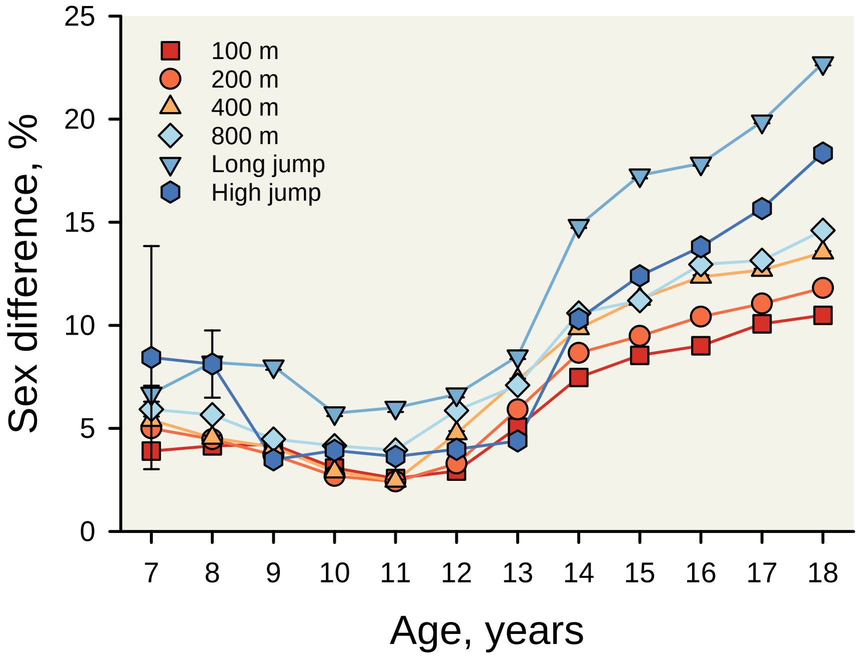

Figure 3. Age-related increase in sex differences in track and field performances of elite youth males and females, stratified by event. Scatter and line plots display the increase in sex difference in track and field performance across youth years stratified by track and field event, including, 100 m (red square), 200 m (orange circle), 400 m (light orange triangle), 800 m (light blue diamond), long jump (blue upside-down triangle), and high jump (blue hexagon). Data

represent an average across three years of competition (2019, 2012, 2022). Symbols represent group means and the error bars represent standard error.

Figure 4.

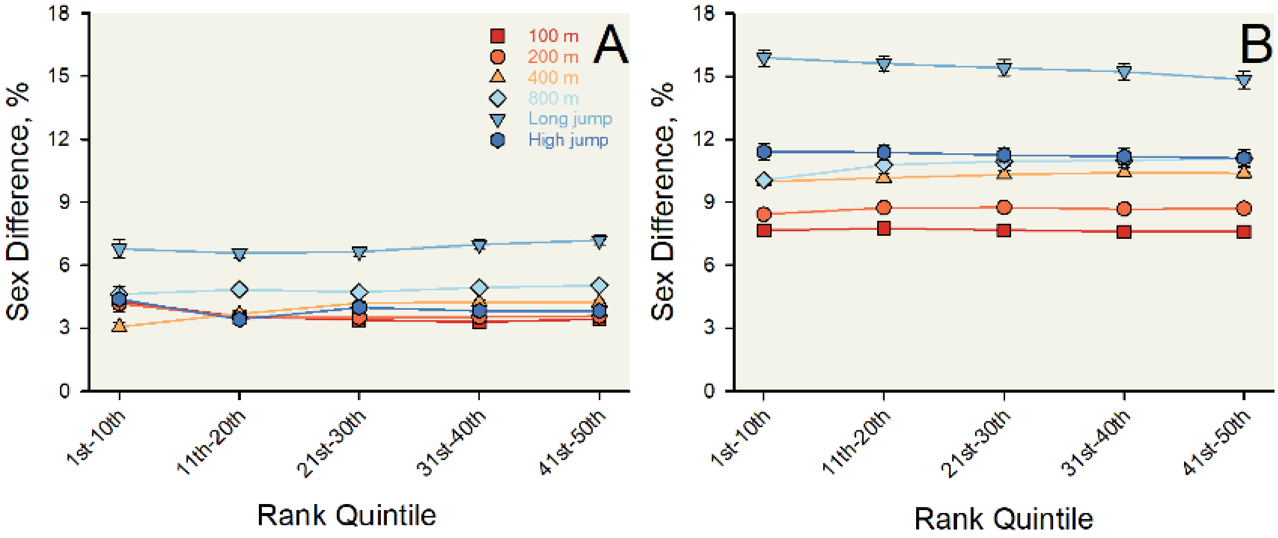

Figure 4. Rank-related sex differences in track and field performances of elite youth males and females. The scatter and line plots display the sex difference in track and field performances across rank quintile among 7- to 11-year-old (A) and 12- to 18-year old (B) elite athletes for track and field events, including, 100 m (red square), 200 m (orange circle), 400 m (light orange triangle), 800 m (light blue diamond), long jump (blue upside-down triangle), and high jump (blue hexagon). Data represent an amalgam of the top 50 athletes across three years of competition (2019, 2021, and 2022) and 5 one-year age groups (7 to 11 years), such that individual data points generally represent 150 athletes. Symbols represent group means and the error bars represent standard error.