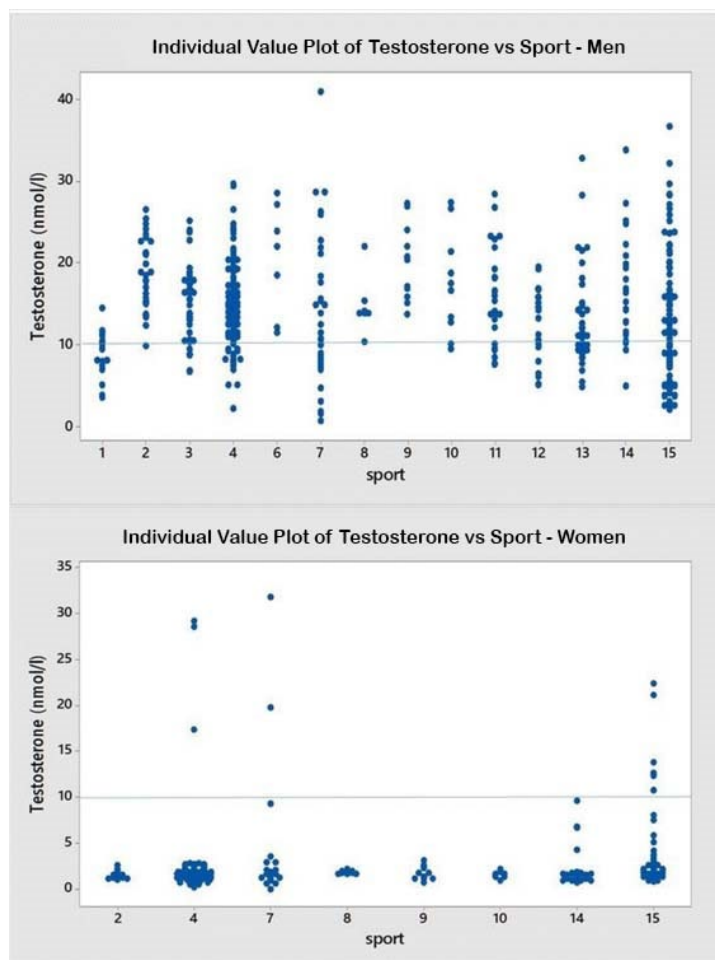




Testosterone Levels in Elite Athletes

HOW TO USE THIS RESOURCE

Show the following figure and caption to your students. The accompanying Student Handout provides space below the image caption for Observations, Notes, and Questions and space next to the “Background Information” for Big Ideas, Notes, and Questions. The “Interpreting the Graph” and “Discussion Questions” sections provide additional information and suggested questions that you can use to prompt student thinking, increase engagement, or guide a class discussion about the characteristics of the graph and what it shows.



Caption: Blood testosterone levels for 676 Olympic-level elite athletes. Individual athletes, represented by blue dots, are grouped by their biological sex (“Men” or “Women”) and sport (1-Powerlifting, 2-Basketball, 3-Soccer, 4-Swimming, 5-Marathon, 6-Canoeing, 7-Rowing, 8-Cross-Country Skiing, 9-Alpine Skiing, 10-Weight Lifting, 11-Judo, 12-Bandy, 13-Ice Hockey, 14-Handball, and 15-Track and Field). Blood samples were collected on a voluntary basis within two hours after the athletes had competed in their events. Sports missing from the plots did not have enough volunteers to be included in the study. None of the athletes were known to be intersex or to have used performance-enhancing drugs.

BACKGROUND INFORMATION

Testosterone is a hormone that is naturally produced by most vertebrates. In humans, blood testosterone levels typically range from about 0.5 to 2.5 nmol/L in women and 9 to 35 nmol/L in men. Scientists have investigated how testosterone affects a number of characteristics in both sexes, including sexual development and athletic

performance. Because some studies have shown that testosterone is associated with increased muscle mass and strength in men, some people have argued that athletes with higher testosterone levels have certain advantages over their competitors.

In 2012, the International Association of Athletics Federations (IAAF) and the International Olympic Committee (IOC) created controversial rules that banned anyone with testosterone levels above 10 nmol/L of blood from participating in women's sports events. These rules were based on the argument that individuals with higher levels of testosterone, which are more typical of those in men, would have an unfair advantage in women's events. In 2014, Indian sprinter Dutee Chand was found to have natural testosterone levels above the 10 nmol/L threshold. The IAAF banned her from competing in national women's track events. However, a court case determined that the existing scientific evidence did not justify the IAAF's rules. As a result, the court overturned the decision to ban Chand. Although the IAAF and the IOC have since changed some of their rules, the debate about regulating testosterone levels in competitive sports continues.

In a 2018 study, scientists examined the testosterone levels of Olympic-level elite athletes competing in national or international sports events. The scientists measured testosterone in blood samples from nearly 700 athletes to determine whether the levels varied among athletes who competed in different sports. The results were grouped according to the athletes' biological sexes and the sports they competed in. From these data, the scientists made several surprising observations about the athletes' natural testosterone levels. For example, several female athletes had testosterone levels above 10 nmol/L, the threshold that the IAAF had used to ban Dutee Chand from competing. In addition, many male athletes had testosterone levels below 10 nmol/L.

INTERPRETING THE GRAPH

In this figure, each dot represents the testosterone level (nmol/L of blood serum) of an individual Olympic-level athlete. Athletes are grouped by sport (represented by the numbered categories on the x-axis) and biological sex ("Men" in the top plot and "Women" in the bottom plot). In both plots, the reference line at 10 nmol/L represents the testosterone threshold previously used by the IAAF and the IOC to determine eligibility for competing in women's events. From 2012 to 2015, these organizations had banned certain athletes with testosterone levels above this threshold from competing in women's sports events.

The original goal of the scientists' study was to look for patterns in hormone levels that might correspond to an individual's performance in a particular sport. For example, the figure indicates that many male powerlifters (top plot, category 1) had testosterone levels below the 10 nmol/L threshold, significantly lower than the average testosterone levels of male athletes in other sports. It's equally possible that lower testosterone levels result from some aspect of powerlifting training or that men with lower testosterone levels have an advantage in powerlifting.

The figure also reveals some surprising patterns between the biological sexes. Male athletes had an unexpectedly broad range of testosterone levels. A high percentage (25.4%) of male athletes had testosterone levels below the 10 nmol/L threshold. A smaller percentage of the female athletes (4.8%) had testosterone levels above the 10 nmol/L threshold. Based solely on their testosterone levels, over a quarter of the male athletes in this study would have qualified to compete in women's events, and nearly 5% of the female athletes would have been excluded from competing in women's events.

Teacher Tip: Prompt your students to explain the parts of the graph as applicable:

- Graph type: Dot plot, where each dot represents an individual Olympic-level athlete

- X-axis: Sport (1-Powerlifting, 2-Basketball, 3-Soccer, 4-Swimming, 5-Marathon, 6-Canoeing, 7-Rowing, 8-Cross-Country Skiing, 9-Alpine Skiing, 10-Weight Lifting, 11-Judo, 12-Bandy, 13-Ice Hockey, 14-Handball, and 15-Track and Field). The sports missing from the plots did not have enough volunteers to be included in the study. One sport (5-Marathon) had only one volunteer and does not appear in either plot.
- Y-axis: Testosterone concentration in blood samples (nmol/L of blood serum)
- Reference line: The gray horizontal line in each plot designates a testosterone threshold of 10 nmol/L. From 2012 to 2015, this threshold was used by the IAAF and IOC to determine an athlete's eligibility for women's sports events.

DISCUSSION QUESTIONS

- What do you notice about the testosterone levels of athletes in different sports? Are the ranges of testosterone levels similar or different among sports?
- Could an athlete's testosterone levels affect which sport the athlete is most successful at? Or could certain testosterone levels result from training and competing in a particular sport? Which possibility do you think is more likely and why?
- How do the testosterone levels of athletes competing in the men's and women's events differ? What other differences do you notice between the two plots?
- What are the highest and lowest testosterone levels of athletes competing in men's events? In women's events?
- What is the average level of testosterone for athletes competing in men's events? In women's events? How did you estimate these numbers?
- Would you predict that members of the general population would have similar ranges in testosterone levels as these elite athletes? Why or why not?
- Does a threshold of 10 nmol/L of testosterone distinguish between male and female athletes? Support your claim with evidence from the figure.
- Would you predict that an unlabeled blood sample with 5 nmol/L of testosterone belongs to a male or female athlete? Use evidence from the figure to support your answer.
- Do you think that testosterone levels should be used to ban athletes from competing in women's events? Consider both scientific and ethical arguments in your answer.
- Although men's sports events are open to individuals with a wide range of testosterone levels, individuals with high testosterone levels have been banned from competing in women's events in the past. Why do you think these policies differ? Do you agree or disagree with the differences in these policies? Support your position with scientific or ethical arguments.
- Some people have argued that athletes should be allowed to compete in the events for whichever gender they were raised as, regardless of their testosterone levels. Do you agree or disagree with this opinion? Does your answer change if you consider transgender athletes who weren't raised as the gender they identify as?
- What biological criteria, if any, should be used to qualify an athlete to compete in men's or women's events?

DISCUSSION TIPS

- You may want to give your students some notice ahead of time that the class will be discussing topics related to biological sex and gender. Give students an opportunity to reach out to you with any concerns before the discussion.
- Consider engaging your students in a verbal agreement prior to or at the beginning of the class discussion. Remind them that discussing biological sex and gender can be challenging and

uncomfortable for some people. Different individuals may have had very different experiences, both affirming and hurtful, with biological sex and gender. Students should agree to keep these ideas in mind, be respectful of their peers, and carefully consider their words before speaking.

- Keep in mind that some students may have been diagnosed with low or high testosterone or DSD (differences in sexual development), or may be experiencing a changing or evolving gender identity. During the discussion, pay attention to the reactions of all your students. Depending on the responses, you may need to remind everyone of the agreement they made before the discussion or wrap up the discussion early.
- Some students might be tempted to label athletes with “atypical” levels of testosterone as transgender, intersex, or homosexual, even though these identities cannot be determined by testosterone levels. If needed, remind students that, although biological sex, gender, gender identity, gender expression, and sexual orientation may be related, they are independent of one another. You may ask your students to explore the [“Sex Verification Testing of Athletes”](#) Click & Learn to learn more about each of these terms.
- If needed, remind students that biological sex has been shown to be more complex than traditionally thought. It is determined by a combination of anatomy, chromosomes, hormones, genes, and gene expression and lies along a spectrum from typical biological men to typical biological women, including intersex conditions.

KEY TERMS

biological sex, ethics, hormone, hyperandrogenism, hypoandrogenism, sex verification testing

SOURCE

Figure 10 from:

Sönksen, Peter H., Richard I. G. Holt, Walailuck Böhning, Nishan Guha, David A. Cowan, Christiaan Bartlett, and Dankmar Böhning. "Why do endocrine profiles in elite athletes differ between sports?" *Clinical Diabetes and Endocrinology* 4, 3 (2018). <https://doi.org/10.1186/s40842-017-0050-3>.

CREDITS

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