

Gender equality predicts female overrepresentation only in competitive domains where they have a relative advantage over males

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Abstract

Nature and nurture perspectives of the gender-equality paradox frequently talk past each other because they do not share underlying assumptions regarding which sex differences are inherent. We overcome this limitation by investigating the consequences of a sex difference both perspectives agree is inherent: physical size. We leveraged equestrian sports as a unique test case in which males and females compete together and in which smaller physical size provides a competitive advantage. Findings showed that gender equality is a stronger predictor of female representation in equestrian sports and that countries high in gender equality have the most extreme overrepresentation of female equestrians, compared with table tennis, judo, swimming, or sailing (total $n = 442,453$, 128+ countries in each sport). Furthermore, we show that the pattern of findings is inconsistent with the nurture perspective of the gender-equality paradox by simulating its assumptions using agent-based modeling and comparing these results to historical data of Olympic equestrians.

Keywords: sex differences, gender equality, competition, culture

Significance Statement

Debates over the “gender-equality paradox”—why sex differences often widen in more gender-equal societies—have remained unresolved because the competing nature and nurture explanations rest on different assumptions. This research overcomes that impasse by focusing on a gender difference both perspectives agree upon: physical size. Analyzing data from more than 440,000 competitors across 128+ countries in five competitive domains, we show that gender equality predicts female overrepresentation in equestrian sports in particular, where smaller stature confers a competitive advantage. Agent-based simulations and historical Olympic data further demonstrate that these patterns align with one explanation more than the other. The findings clarify the plausibility of different mechanisms behind the gender-equality paradox.

Introduction

How do gender differences manifest themselves across cultures? Building on evolutionary accounts regarding sexual selection and parental investment (1), a “nature” perspective has contended that certain sex differences are universal. Proponents of this perspective marshal evidence that there are universal differences in male vs. female mate preferences across 37 cultures (2). Meanwhile, a re-analysis of this data found that, while the gender differences were universal, their magnitude is smaller in more gender-equal countries (3). The findings of this re-analysis were interpreted as consistent with a “nurture” perspective, according to which the magnitude of gender differences is contingent

upon the level of gender equality in each culture (4, 5). A key prediction of proponents of this nurture perspective is that the magnitude of gender differences will be smaller in more gender-equal societies. The original formulations of the nature and nurture perspectives regarding the magnitude of gender differences across cultures proposed testable and falsifiable hypotheses. However, both perspectives were falsified by a diverse and independent set of findings demonstrating that gender differences are frequently larger in cultures higher in gender equality (falsifying the nurture perspective) and often do not even manifest themselves in cultures low in gender equality (falsifying the nature perspective; for a review, see 6). These findings have been referred to as the gender-equality paradox (GEP).

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Evolution of the nature and nurture perspectives

In light of these findings, proponents of each perspective have revised their predictions while maintaining their underlying assumptions. Proponents of the “revised nature” perspective maintain their assumption of evolved sex differences but have revised their theory to include a moderating role for the socio-ecological environment. According to this view, the set of findings comprising the GEP are driven by the greater freedom and lesser social constraint that allow people to pursue their inherent preferences in more gender-equal societies (7–9). In a competitive context where outcomes are measured by performance and success, this means that men and women sort themselves into domains where they enjoy a relative advantage. Meanwhile, proponents of the “revised nurture” perspective maintain their assumptions of socially constructed sex differences but have revised their theory to include two opposing psychological forces (10–12). First, the growth in gender equality throughout the 20th century (13) blurs differences between men and women in certain domains. Second, people have a tendency to think of gender in essentialist terms, whether due to cognitive processes (14) or motivational processes (15). Thus, gender equality activates the need to re-establish essentialist gender distinctions, leading to stronger gender stereotypes and consequently larger gender differences (16–20).

Notably, both revised perspectives posit an interaction between nature and nurture, but they diverge in what each construes as the nature component of that interaction. The revised nature perspective maintains that sex differences originate in evolved, biological differences between males and females, while acknowledging that socio-ecological conditions such as gender equality moderate the extent to which these innate differences are expressed. In contrast, the revised nurture perspective maintains that sex differences are socially constructed but incorporates a psychological nature element in the form of a widespread tendency to essentialize social categories such as gender. Thus, although both perspectives invoke nature–nurture interactions, they retain their original theoretical commitments regarding whether sex differences themselves are biologically inherent or socially constructed.

To date, each revised perspective has marshaled evidence in its favor, but each type of evidence rests on assumptions not shared by the other perspective. For instance, building on perspectives from evolutionary psychology on the challenges faced by males and females in the domains of mating and reproduction, Schwartz and Rubel-Lifschitz (9) hypothesized that men will value power more while women will value benevolence more, and these effects will be larger in more gender-equal countries. However, the nurture perspective does not share the underlying assumption about evolved sex differences regarding these values and can also interpret such findings in line with their own view. Meanwhile, under the revised nurture perspective, it has been suggested that the GEP can be explained by gender stereotypes, as demonstrated by findings that the stereotype linking math to men is stronger in more egalitarian countries (16). However, the revised nature perspective could interpret this correlational evidence in the reverse causal order, with stereotypes being the outcome, rather than the cause, of these gender differences.

An ideal test of the revised nature and nurture accounts would build on a gender difference that is mutually agreed upon by both perspectives. One gender difference acknowledged by proponents of the nurture account is that men are physically larger (21, 22). To the extent that this innate difference lends a competitive advantage to men or women in a given domain, the revised nature

perspective would contend that the representation of the advantaged gender in that domain should be greater in more gender-equal countries. Men and women typically do not compete against each other in competitive sports, but one exception is equestrianism (23). Equestrianism is unique in another aspect: since lighter equestrians pose less of a burden on the horse, there is a preference for jockeys who weigh less (24). Accordingly, women’s smaller physical stature gives them a competitive advantage over men (25). Thus, a prediction arising from the revised nature perspective is that the proportion of female equestrians will be greater in more gender-equal countries, and this association will be specific to equestrianism relative to other sports, where women’s stature does not confer them an advantage. Meanwhile, from the revised nurture perspective, there is little reason to expect that the proportion of female competitors will be different for equestrianism relative to other sports.

In study 1, we test these conflicting predictions by analyzing cross-country differences in the proportion of female competitors in equestrianism and three more sports in which athletes typically compete as individuals rather than on teams: swimming, table tennis, and judo. In addition, since equestrian is a more expensive sport than the others, we analyzed another sport with high expenses—sailing (26). These sports were selected as comparisons because they shared one of the aforementioned features with equestrian sports: athletes typically compete as individuals, or they are a high-expense sport. Many other sports may fall within these criteria. We disclose that no other data from any other sport has been collected or analyzed for the purpose of this investigation. In study 2A, we simulate the revised nurture perspective using agent-based modeling and investigate whether it is consistent with the findings of female representation in equestrianism over historical time in study 2B.

Study 1

Methods

Datasets

We scraped tables of sports competitors from the international federation websites of each sport. We included only competitors with data on gender, within legitimate age ranges (see below under “analyses”), and from countries with scores for gender equality. All data are freely accessible.

First, data on equestrian competitors were scraped from the website of the Fédération Equestre Internationale—International Equestrian Federation (<https://inside.fei.org/bios/Search/Biographies>) on 2023 June 12–14. A total of 148,469 competitors originated from 128 countries. Female competitors comprised 64.73% of all competitors, and the median of the percentage of female competitors in a country was 51.33%.

Second, data on table tennis competitors were scraped from the website of the International Table Tennis Federation (<https://ranking.ittf.com/#/players>) on 2023 December 9. A total of 21,376 competitors originated from 165 countries. Female competitors comprised 39.75% of all competitors, and the median of the percentage of female competitors in a country was 39.18%.

Third, data on judo competitors were scraped from the website of the International Judo Federation (<https://www.ijf.org/judoka>) on 2023 December 19. A total of 37,104 competitors originated from 167 countries. Female competitors comprised 33.76% of all competitors, and the median of the percentage of female competitors in a country was 33.33%.

Fourth, data on swimming competitors were scraped from the website of World Aquatics (<https://www.worldaquatics.com/>

athletes) on 2023 December 19. A total of 23,357 competitors originated from 169 countries. Female competitors comprised 49.51% of all competitors, and the median of the percentage of female competitors in a country was 45.58%.

Finally, data on sailing competitors were scraped from the website of World Sailing, the international governing body for the sport of sailing, on 2025 February 2 (<https://www.sailing.org/sailors/profiles/>). A total of 212,147 competitors originated from 164 countries. Female competitors comprised 19.32% of all competitors, and the median of the percentage of female competitors in a country was 18.99%. Critically, data on competitors' age were missing, and so the data were analyzed separately from the other datasets.

Gender-equality measures

We used two measures of country-level gender equality, which are frequently cited in the literature. The Global Gender Gap Index (GGGI) is developed by the World Economic Forum (27). It assesses how much women are behind men on 14 indicators related to politics, education, economy, and health. We used the most recently available data, from 2023, with scores for 146 countries ($M = 0.71$; $SD = 0.067$), with higher scores indicating greater gender equality. These ranged from Afghanistan being the least equal (0.405) to Iceland being the most equal (0.912).

The Gender Inequality Index (GII) is developed by the United Nations Development Programme (28). It is a composite index of inequality in three domains: labor market, reproductive health, and empowerment. We used the most recently available data, from 2021, with scores for 170 countries. We reverse-scored the scale, such that higher scores indicate greater gender equality ($M = 0.66$; $SD = 0.20$). These ranged from Yemen being the least equal (0.180) to Denmark being the most equal (0.987). The measures of gender equality were correlated ($r = 0.52$).

Country labels

In most instances, country names in the datasets of players matched country names in the indices of gender equality. However, some names were more difficult to match, particularly those referring to countries that splintered into smaller states. We excluded from the analyses participants whose country split into other countries, such as Yugoslavia or the Soviet Union. In addition, some of the datasets of players distinguish between England, Wales, and Scotland. Since both gender-equality indices refer to the United Kingdom without distinguishing between England, Wales, or Scotland, we coded all three names under the label "United Kingdom."

Analyses

When analyzing data, decisions made are often arbitrary and lack justification for choosing one alternative over another (29). To demonstrate our results are robust to these arbitrary decisions, we use multiverse-style analyses. These analyses help establish whether results are consistent across three decision points that needed to be made, including the country-level measure of gender equality, the age ranges of competitors, and when addressing differences in sample sizes of competitors between countries.

Gender equality

Gender equality has been assessed using various measures. As described earlier, we used two different measures of country-level gender equality.

Age ranges

One concern in comparing disparate datasets is their different inclusion criteria for active or inactive competitors. For instance, the swimming data contain competitors born in the 19th century, but the other datasets do not. Therefore, we adopted two alternative inclusion criteria. The first criterion was sport specific and reflected the age of active players for each sport in the Olympics. We used a database of Olympic athletes among competitors who participated in the Olympics from 1896 to 2016 to identify each sport's continuous age range (30). For instance, for swimming, the age of competitors was from 11 to 41, and every age in this range, as well as 46. Since the age range up to 46 is not continuous (no competitors were aged 42–45), we included only swimming competitors aged 11–41. The second criterion was identical across the sports and sought to capture the most common range of athletic performance. Specifically, in the database of Olympic athletes, we calculated the mean age across all competitors ($M = 25.78$) and the SD ($SD = 6.10$). We set the age range as one SD above or below the mean age: 19–31.

As we noted above, the dataset on sailing lacked athletes' ages and therefore was analyzed independently and without different sets of age ranges.

Differences in sample sizes

Our main measure is the proportion of female players in each country, and therefore, our unit of analysis is country. However, the number of competitors per country varied by more than three orders of magnitude for some sports. This means that results are more reliable in some countries than in others. We used two alternative criteria to address differences in sample sizes (31). First, we weighted countries in the regression by the total number of players in each country. This decreases the weight of countries with smaller sample sizes and increases the weight of countries with larger sample sizes. However, weighting may itself skew results by assigning more weight to a small subset of countries. Therefore, we used a second criterion in which we did not use weighting but selected an arbitrary cutoff of including countries with at least 50 competitors.

Results

Analyses were conducted separately for each sport. We calculated the number of female competitors relative to the total number of competitors in each country and regressed it on country-level gender equality. Results for the eight different multiverse-style analyses, as described earlier (two measures of gender equality, by two different methods for dealing with differing sample sizes, by two different age criteria), appear in Tables 1 and 2.

Results reveal little heterogeneity for the eight different analyses within each sport, but substantial heterogeneity between sports. Specifically, gender equality predicts a greater proportion of female competitors in equestrian sports. Meanwhile, gender equality does not predict the representation of female competitors in judo or table tennis. In swimming, greater gender equality predicts a higher proportion of female competitors in six of eight analyses. However, as illustrated in Fig. 1, the regression coefficients for swimming, as well as for judo and table tennis, are mostly outside the range of the correlations for equestrian sports. Figure 2 presents the associations in every sport for the GGGI, 19–31 age range, for countries with at least 50 competitors. Notably, the proportion of female equestrians in some of the most gender-unequal countries is only 1% (Pakistan), but in one of the most gender-equal countries, it reaches as high as 93% (Norway).

Table 1. Standardized regression coefficients for two measures of gender equality predicting the proportion of female competitors across two methods of dealing with differing sample sizes, for sport-specific age criteria.

	Age range	Measure	Sport-specific age criteria			
			Weighted		≥50 per country	
			β	95% CI	β	95% CI
Equestrianism	16–63	GGI	0.651	0.525, 0.777	0.710	0.561, 0.860
		GII	0.752	0.575, 0.930	0.534	0.355, 0.713
Table tennis	15–46	GGI	−0.038	−0.157, 0.080	0.101	−0.087, 0.289
		GII	0.092	−0.033, 0.217	0.064	−0.128, 0.255
Judo	14–40	GGI	0.097	−0.037, 0.231	0.153	−0.043, 0.349
		GII	0.113	−0.020, 0.247	−0.004	−0.204, 0.195
Swimming	11–41	GGI	0.239	0.128, 0.351	0.390	0.177, 0.602
		GII	0.214	0.089, 0.338	0.166	−0.053, 0.385

Table 2. Standardized regression coefficients for two measures of gender equality predicting the proportion of female competitors across two methods of dealing with differing sample sizes, for a common age criterion.

	Age range	Measure	Common age criterion			
			Weighted		≥50 per country	
			β	95% CI	β	95% CI
Equestrianism	19–31	GGI	0.601	0.482, 0.720	0.721	0.558, 0.885
		GII	0.700	0.525, 0.875	0.562	0.365, 0.759
Table tennis	19–31	GGI	−0.060	−0.162, 0.042	−0.041	−0.273, 0.191
		GII	0.043	−0.065, 0.152	0.139	−0.090, 0.369
Judo	19–31	GGI	0.064	−0.056, 0.184	0.169	−0.037, 0.376
		GII	0.048	−0.073, 0.169	−0.004	−0.215, 0.206
Swimming	19–31	GGI	0.253	0.146, 0.360	0.311	0.024, 0.597
		GII	0.208	0.086, 0.330	0.050	−0.231, 0.330

We argued that unique associations regarding the representation of females in equestrianism will be driven by the comparative advantage that females have in equestrianism, which they do not have in the other sports we examined. However, one concern about the comparison between equestrianism versus table tennis, judo, and swimming is that equestrian sports have higher expenses associated with them. This could lead to various confounds, such as competitors originating from higher socioeconomic classes across the world. We address this concern by analyzing data for another high-expense sport—sailing (26). Analyses on sailing distinguished between both types of gender equality and both methods of dealing with unequal sample sizes, but no data was available on sailing competitors' ages. Neither measure of gender equality predicted greater female representation for the weighted analyses (GGGI: $\beta = 0.010$, $P = 0.759$, 95% CI [−0.052, 0.071]; GII: $\beta = 0.008$, $P = 0.841$, 95% CI [−0.073, 0.089]). Likewise, neither measure of gender equality predicted greater female representation for the analyses with at least 50 competitors per country (GGGI: $\beta = 0.160$, $P = 0.166$, 95% CI [−0.067, 0.387]; GII: $\beta = 0.123$, $P = 0.262$, 95% CI [−0.094, 0.340]). Figure S1 presents the association between GGGI and female representation of sailors for countries with at least 50 competitors.

As a final check on the robustness of the results, we controlled for spatial dependencies in the data (32). The main pattern of findings was robust to these analyses (Table S1).

Discussion

Consistent with the revised nature perspective, gender equality predicted both greater representation and, notably, overrepresentation of female competitors in the sport in which they enjoy a relative advantage—equestrianism. Moreover, gender equality did not predict greater representation of female competitors in

other sports, except in swimming. Greater gender equality might loosen norms about modest female attire—norms that are at odds with a standard bathing suit (33)—that otherwise constrain access to swimming. Even so, the magnitude of the association between gender equality and female representation was still smaller in swimming than in equestrian sports.

The revised nurture perspective may argue that the finding for equestrianism is explained by the need to maintain gender essentialism in more gender-equal countries. However, the findings are inconsistent with this perspective for two reasons. First, the revised nurture perspective has no a priori basis for assuming that the need to maintain gender essentialism will be specific to equestrianism. Second, according to the revised nurture perspective, gender equality fosters gender-essentialist beliefs, which leads to the perception that a domain in which females (or males) happen to have a majority is a feminine (or masculine) domain. Thus, any domain with a majority of one gender should maintain and even increase that majority over time. For instance, if a certain domain is composed of 60% males and 40% females, an increase in gender-essentialist beliefs should lead that field to be perceived as masculine, which would then draw in more males and lead to the attrition of females. However, the representation of female equestrians in countries at the low end of gender equality is well below 50%, so the transition to countries with 90% females or more cannot be accounted for under this perspective. Nevertheless, data in study 1 are cross-sectional, which limits the ability to draw conclusions about processes unfolding over time. Study 2 addresses this concern.

Study 2

In study 2A, we simulate the revised nurture perspective over time using agent-based modeling to establish which trends are or are

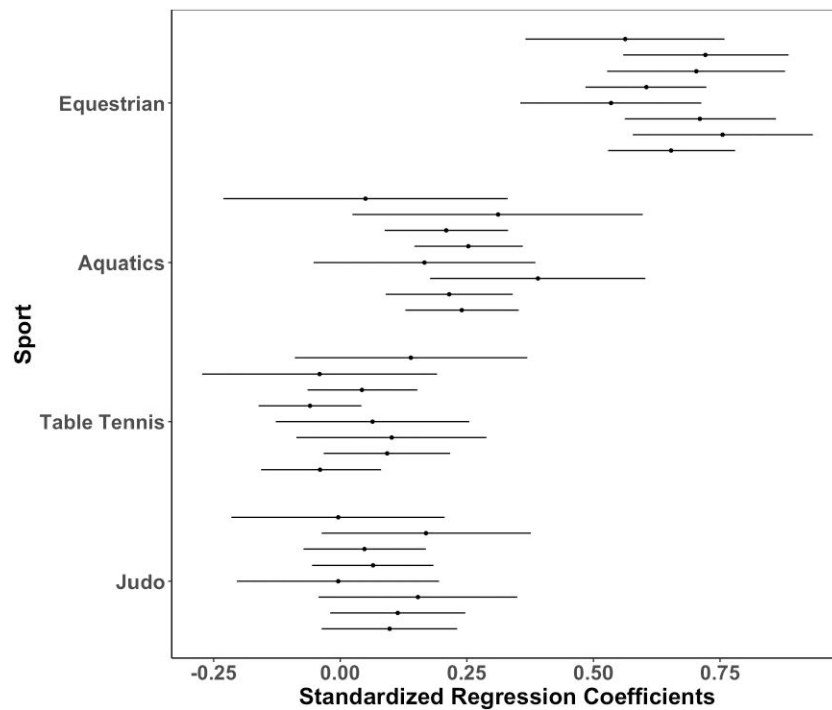


Fig. 1. Standardized regression coefficients for gender equality predicting the proportion of female competitors and 95% CIs for each analysis in each sport.

not commensurate with the revised nurture perspective. These simulations do not aim to capture the unique historical development of female participation in equestrianism per se, with the gradual removal of legal and cultural restrictions allowing them to participate in equestrianism (24, 25), but rather the essentialist feedback mechanism of the revised nurture perspective in general. Then, we investigate real trends in historical data on equestrianism in study 2B.

Study 2A

Methods

We created agents who have one of two values (corresponding to male and female). Agents could be active or inactive in nine different domains, corresponding to different fields of interest or pursuit (e.g. in sports: swimming, equestrianism, wrestling, or football; in higher education: hard science, math, or the humanities). At the initiation stage, each domain had a different level of representation of active agents from each sex, ranging from 10% female to 90% female. Then, successive iterations were played in which agents could become inactive in a domain where they are active or become active in a new domain where they were inactive. The rules for becoming active or inactive were based on the assumptions of the revised nurture perspective, allowing us to investigate what happens to the representation of males and females over time in domains with varying initial proportions of males and females according to the revised nurture perspective. The model was programmed in the NetLogo 6.4 environment.

Setup of the environment

We created a world in which half the agents were male and half the agents were female. The number of agents can be established by the user—in our analyses, we set the number of agents at 900, as in previous work (34). Agents occupy each of nine domains, and in each domain, they may be active or inactive. Domains differ in the proportion of active users of a given sex, varying from a

domain in which 90% of active agents are female (and 10% are male) to a domain in which 10% of active agents are female (and 90% are male), with the other seven domains varying in their representation of each sex in increments of 10% (i.e. 80, 70, 60, 50, 40, 30, and 20% female). In the main analysis, we report a simulation in which 40% of the agents are active in each domain and report supplemental analyses in which this is set to 50% or 30%. Thus, in the main analysis, the domain with 90% males has 360 active agents (40% of 900 agents), and of these, 324 are male (90% of 360) and 36 are female (10% of 360).

Actions

In each iteration, agents can undertake two actions in sequential order: first, they can become inactive in a domain in which they are active; then, they can become active in a domain in which they are inactive. Consistent with the revised nurture perspective, according to which people's gender-essentialist beliefs push them from domains that are viewed as typical of the other gender, agents are more likely to become inactive in a domain in which their sex is less represented. This probability (P) is given by the following equation:

$$P = X \times (1 - \text{percent-active-sex})^2,$$

where "percent-active-sex" is the percentage of players from one's sex who are active from among all the active players. The higher the proportion of one's sex in the given domain, the lower the likelihood that one leaves the domain. This value is squared to amplify the impact of being a part of the majority sex when one's sex is represented at higher levels. For instance, this reflects the greater likelihood that males will become inactive in a domain in which their representation has decreased from 20 to 10%, relative to a domain in which their representation has decreased from 40 to 30%, even though the linear difference is the same. X is a constant that is set to values below 1, which reduces the likelihood of leaving a domain, to account for other real-world factors that might

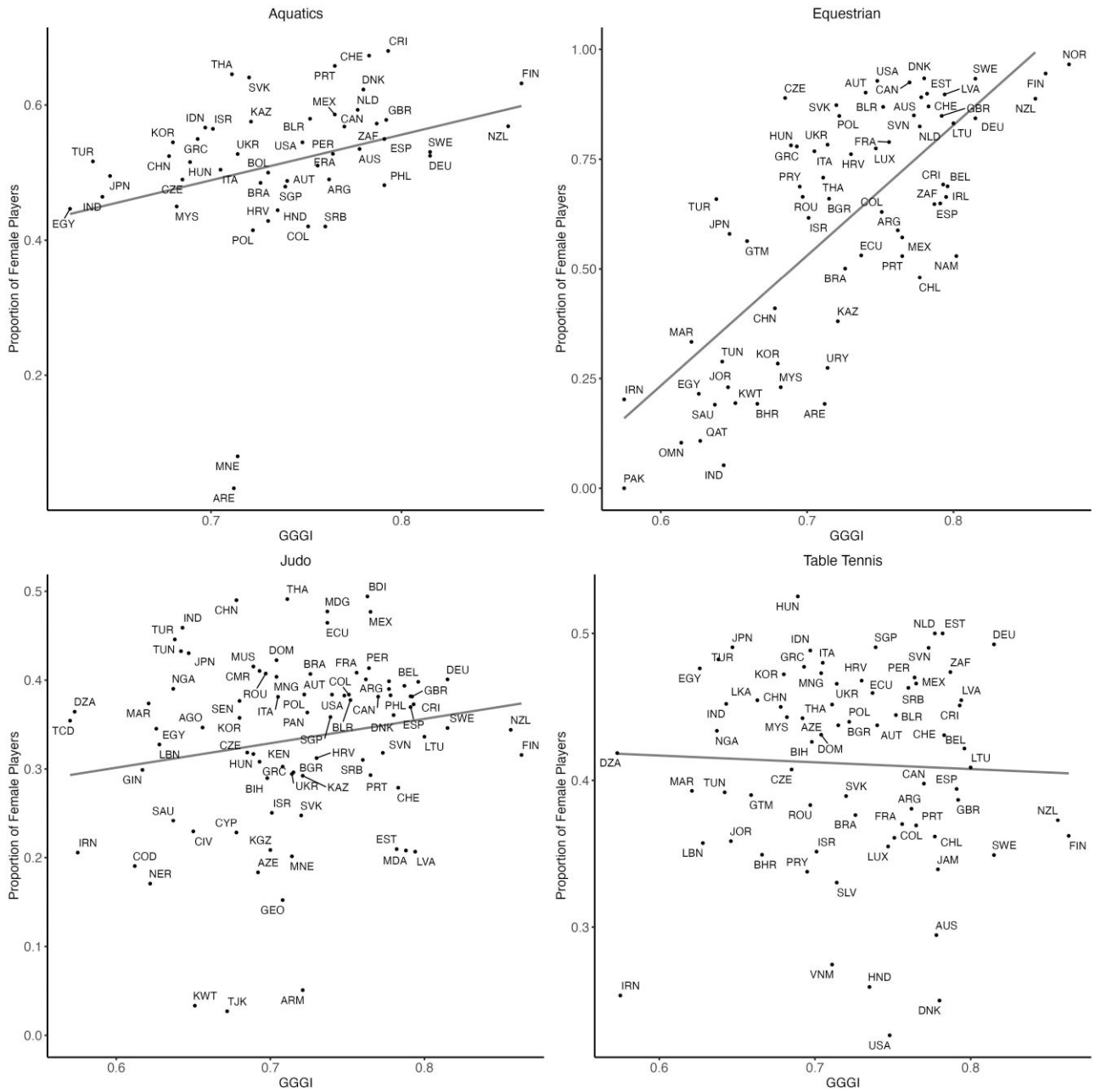


Fig. 2. Associations between the GGGI measure of gender equality and the proportion of female competitors among countries with at least 50 competitors, aged 19–31, for aquatics, equestrian sports, judo, and table tennis. AFG, Afghanistan; ALB, Albania; DZA, Algeria; AGO, Angola; ARG, Argentina; ARM, Armenia; AUS, Australia; AUT, Austria; AZE, Azerbaijan; BHS, Bahamas; BHR, Bahrain; BGD, Bangladesh; BRB, Barbados; BLR, Belarus; BEL, Belgium; BLZ, Belize; BEN, Benin; BTN, Bhutan; BOL, Bolivia; BIH, Bosnia and Herzegovina; BWA, Botswana; BRA, Brazil; BRN, Brunei Darussalam; BGR, Bulgaria; BFA, Burkina Faso; BDI, Burundi; CPV, Cabo Verde; KHM, Cambodia; CMR, Cameroon; CAN, Canada; CAF, Central African Republic; TCD, Chad; CHL, Chile; CHN, China; COL, Colombia; COM, Comoros; COG, Congo; CRI, Costa Rica; CIV, Cote d'Ivoire; HRV, Croatia; CUB, Cuba; CYP, Cyprus; CZE, Czechia; PRK, Democratic People's Republic of Korea; DNK, Denmark; DOM, Dominican Republic; COD, DR Congo; ECU, Ecuador; EGY, Egypt; SLV, El Salvador; EST, Estonia; SWZ, Eswatini; ETH, Ethiopia; FJI, Fiji; FIN, Finland; FRA, France; GAB, Gabon; GMB, Gambia; GEO, Georgia; DEU, Germany; GHA, Ghana; GRC, Greece; GTM, Guatemala; GIN, Guinea; GNB, Guinea-Bissau; GUY, Guyana; HTI, Haiti; HND, Honduras; HUN, Hungary; ISL, Iceland; IND, India; IDN, Indonesia; IRN, Iran; IRQ, Iraq; IRL, Ireland; ISR, Israel; ITA, Italy; JAM, Jamaica; JPN, Japan; JOR, Jordan; KAZ, Kazakhstan; KEN, Kenya; KWT, Kuwait; KGZ, Kyrgyzstan; LAO, Laos; LVA, Latvia; LBN, Lebanon; LSO, Lesotho; LBR, Liberia; LBY, Libya; LTU, Lithuania; LUX, Luxembourg; MDG, Madagascar; MWI, Malawi; MYS, Malaysia; MDV, Maldives; MLI, Mali; MLT, Malta; MRT, Mauritania; MUS, Mauritius; MEX, Mexico; MDA, Moldova; MNG, Mongolia; MNE, Montenegro; MAR, Morocco; MOZ, Mozambique; MMR, Myanmar; NAM, Namibia; NPL, Nepal; NLD, The Netherlands; NZL, New Zealand; NIC, Nicaragua; NER, Niger; NGA, Nigeria; MKD, North Macedonia; NOR, Norway; OMN, Oman; PAK, Pakistan; PAN, Panama; PNG, Papua New Guinea; PRY, Paraguay; PER, Peru; PHL, Philippines; POL, Poland; PRT, Portugal; QAT, Qatar; ROU, Romania; RUS, Russian Federation; RWA, Rwanda; LCA, Saint Lucia; VCT, Saint Vincent and the Grenadines; WSM, Samoa; SMR, San Marino; SAU, Saudi Arabia; SEN, Senegal; SRB, Serbia; SLE, Sierra Leone; SGP, Singapore; SVK, Slovakia; SVN, Slovenia; SLB, Solomon Islands; ZAF, South Africa; KOR, South Korea; ESP, Spain; LKA, Sri Lanka; SDN, Sudan; SUR, Suriname; SWE, Sweden; CHE, Switzerland; SYR, Syrian Arab Republic; TJK, Tajikistan; TZA, Tanzania; THA, Thailand; TLS, Timor-Leste; TGO, Togo; TON, Tonga; TTO, Trinidad and Tobago; TUN, Tunisia; TUR, Türkiye; TKM, Turkmenistan; UGA, Uganda; ARE, United Arab Emirates; GBR, United Kingdom; USA, United States; URY, Uruguay; UZB, Uzbekistan; VUT, Vanuatu; VEN, Venezuela (Bolivarian Republic of); VNM, Vietnam; YEM, Yemen; ZMB, Zambia; ZWE, Zimbabwe.

discourage leaving a domain (e.g. a personal affinity for the domain; costs of switching between domains). In the main analyses, X is set to 0.01, and supplemental analyses demonstrate our findings are robust to a higher value (0.05) or a lower value (0.002). For instance, with X at 0.01, in a domain where 80% of the active players are male, the likelihood that a given active male agent will leave this domain in a particular iteration is $0.01 \times (1 - 0.8)^2 = 0.0004$. Meanwhile, the likelihood that a given active female agent will leave this domain in a particular iteration is 0.0064, or 16 times more likely.

Following the action of becoming inactive in a domain, agents can then become active in a different domain. Consistent with the revised nurture perspective, according to which people's gender-essentialist beliefs pull them into domains in which their sex is more represented, agents are more likely to become active in domains in which their sex is more represented. Moreover, bearing in mind a reasonable assumption that when people leave a field of study or domain of interest, they are more likely to join another field of study or domain of interest, agents are more likely to become active as a function of the number of domains in which they have become inactive. Given that this assumption is not a central part of the revised nurture perspective, supplemental analyses were conducted without this assumption. Agents' probability (P) of becoming active in a domain in which they were inactive is given by the following equation:

$$P = X \times \text{percent-active-sex}^2 \times (\sqrt{\text{deactivated domains}}).$$

As before, percent-active-sex is the percentage of players from one's sex who are active among all the active players. The higher the proportion of one's sex in the given domain, the higher the likelihood that one joins the domain. As before, X is a constant that is set to values below 1, which reduces the likelihood of leaving a domain, to account for other real-world costs that might discourage joining a domain. In the main analyses, X is set to 0.01, and supplemental analyses demonstrate our findings are robust to a higher value (0.1) or a lower value (0.005). Finally, "deactivated domains" refers to the number of domains a given agent left in the same iteration. This is meant to capture a tendency to join new domains after having left other domains. As the number of domains an agent left increases, the likelihood of joining a new domain also increases. For instance, for X at 0.01 in a domain where 80% of the active players are male and the number of domains an agent left is 1, the likelihood a given male agent will join the domain is $0.01 \times 0.8^2 \times 1 = 0.0064$. Meanwhile, the likelihood that a given active female agent will leave this domain in a particular iteration is $0.01 \times 0.2^2 \times 1 = 0.0004$.

Results

In our main analyses, we ran the model on 500 iterations. Figure 3A presents the proportion of active male players in each of the nine domains across the 500 iterations. As can be seen, domains with >50% males at the initial stage became predominantly male by iteration 500. Meanwhile, domains with <50% males at the initial stage became predominantly female by iteration 500. Results were robust across various specifications, including whether the percentage of agents active was adjusted from 40 to 30% or 50% (Figs. S2 and S3), whether X was adjusted from 0.01 to 0.05 or 0.002 (Figs. S4 and S5), and whether the assumption that people are more likely to become active in a new field as a function of the number of fields in which they have become inactive is relaxed (Fig. S6).

The domain with an equal number of males and females at the initial stage broke toward becoming predominantly female, but it took the longest to develop this trend and could have just as likely broken the other direction. Indeed, in some of the supplemental analyses in this domain, sometimes it breaks toward being predominantly male.

Discussion

When simulating the assumptions of the revised nurture account using agent-based modeling, a clear trend emerged such that domains with an initial majority of one sex became composed predominantly of members of that sex. To the extent that the revised nurture perspective can explain the representation of males and females in a given domain over time, we would expect to see a pattern demonstrating that an initial majority for one sex becomes larger over time. In study 2B, we investigate whether this is indeed the case in equestrian sports.

Study 2B

In study 2B, we investigated the trend of female participation in equestrian sports over time. A key observation is that gender equality has increased largely monotonically throughout the 20th and 21st centuries (13, 27). Thus, trends over time serve as a proxy for increasing rates of gender equality and serve as a test of the predictions derived from the revised nurture perspective regarding the effect of gender equality on gender differences.

Methods

Dataset

We obtained a dataset of Olympic competitors from 1896 to 2016, scraped from www.sports-reference.com in May 2018 by an independent researcher and subsequently uploaded to the Kaggle database (30). This dataset includes 271,116 rows, where each row represents an athlete competing in a particular competition of a particular Olympics from the first Olympics in 1896 until the Olympics in Rio de Janeiro, Brazil, in 2016. For instance, an athlete competing in dressage, jumping, and vaulting competitions in the same Olympic competition would receive three separate rows in the dataset. Since we are interested in the representation of female (vs. male equestrian) competitors and not in the number of competitions they appeared in, we reduced such instances to one. Meanwhile, if a given competitor competed in more than one Olympics, they were listed in each Olympics they participated in. This left 187,297 unique competitors by Olympics. Of these, there were a total of 3,510 equestrian competitors by Olympics (20.5% female), on whom the analyses were performed.

Results

From the 1948 Olympics and earlier, there were only two female equestrians (vs. 675 male equestrians). Indeed, prior to 1952 women were not allowed to compete in any equestrian sports but were allowed to compete in all equestrian sports by 1964 (35). Consequently, we focus on the period of time beginning with the 1948 Olympics. Results show that the proportion of female equestrians was nil in 1948, below 10% in 1964, and has increased since (Fig. 3B). In the last year of the dataset, the proportion of female equestrians reached 37.5%.

Discussion

Longitudinal data on Olympian equestrians reveals that the proportion of female equestrians was nil before gradually rising until reaching close to 40%. This trend is directly opposed to the trends

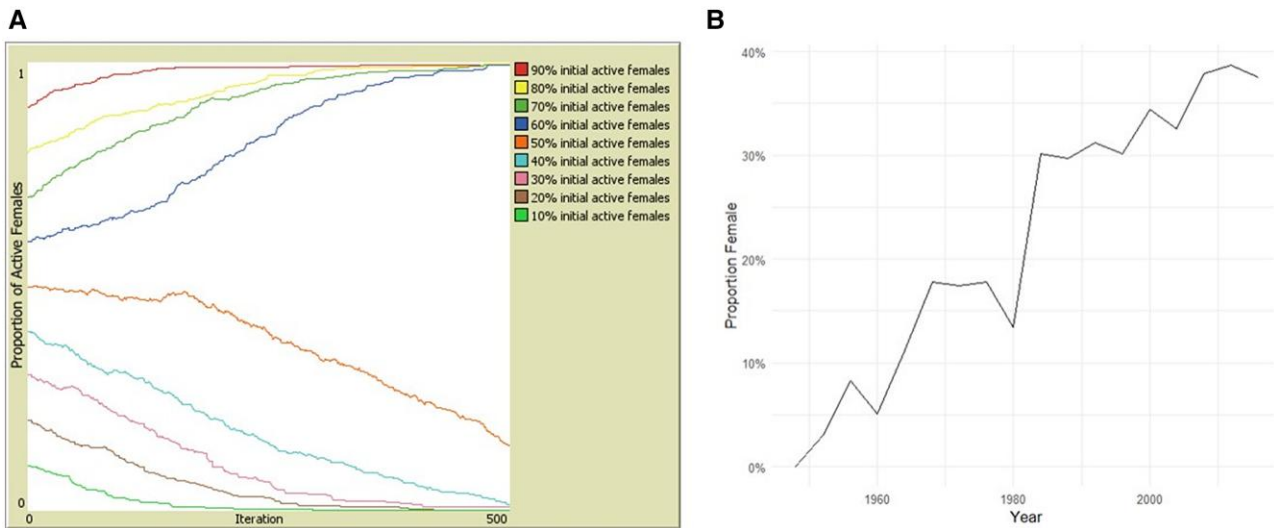


Fig. 3. Simulation of the proportion of females in domains varying in their initial representation of females based on the revised nurture perspective, study 2A (3A); proportion of female equestrian Olympic competitors per year, study 2B (3B).

expected from the revised nurture perspective simulated in study 2A, in which all domains with <50% females at the initial stage showed a decline in the proportion of females in subsequent iterations.

One important assumption of the agent-based model is that agents face continuous opportunities for entry and exit across domains under minimal formal constraints. This assumption is intentional: the goal of study 2A is not to reproduce the institutional history of equestrian sports, but rather to clarify the directional implications of the revised nurture perspective. As such, the simulations provide a benchmark for the patterns that should emerge if gender-essentialist dynamics alone are sufficient to explain long-run changes in gender representation. Meanwhile, the Olympic data reflect a historically realistic process in which constraints were first binding, whereby no competitions were open for female participation, and then progressively relaxed. Even so, the revised nurture perspective would still predict that domains initially dominated by men should remain male-typed or revert toward male dominance once female participation becomes possible.

General discussion

In study 1, higher gender equality predicted greater female representation in equestrian sports, compared with other individual sports (table tennis, judo, and swimming), as well as a fourth sport where, like equestrian sports, expenses are high (sailing). Moreover, a marked shift from female underrepresentation to female overrepresentation was observed when comparing the most gender-unequal countries to the most gender-equal countries. If the pattern of findings in equestrian sports were driven only by greater opportunity provided to women in more gender-equal countries, every sport should see notable effects of gender equality on female representation. Instead, these findings are consistent with the revised nature perspective by demonstrating that women are overrepresented only in a sport where they possess a competitive advantage. Conversely, these results challenge the revised nurture perspective on two accounts. First, the revised nurture perspective lacks an a priori rationale regarding why gender essentialism would drive female overrepresentation in equestrianism but not the other sports. Second, agent-based modeling

of the revised nurture perspective, in study 2A, revealed a pattern of findings which is inconsistent with an analysis of the actual historical trends of female representation among Olympic equestrian competitors, in study 2B. Specifically, whereas the agent-based modeling clarified the temporal dynamics of the revised nurture perspective under controlled assumptions, the historical Olympic data demonstrated that these predicted dynamics did not materialize in a real-world setting.

Limitations and future directions

The present investigation assumed a link between physical advantage and performance. Given the advantage for equestrians with a smaller physical stature, as is characteristic of women compared with men (24, 25), this presumably provides women a relative advantage in equestrian sports, which increases their participation in more gender-equal societies. However, the present analyses focus on representation and choice rather than performance outcomes per se. Importantly, existing evidence suggests that women do not consistently outperform men at the elite level in equestrian sports. For example, within British Eventing, which is a combination of three equestrian disciplines, men and women are equally represented at the top level even as women constitute the majority of participants, leading to the conclusion that “men are still outperforming women at the elite level” (35, p. 43). Nevertheless, to the extent that women constitute roughly half of the most elite competitors, this is an achievement unmatched in other competitive sports. One explanation for the gap between women’s relative advantage and their performance is that social, institutional, and historical barriers may constrain women’s performance at the highest levels, even in mixed-sex sports where formal rules permit equal competition (25). Future research integrating systematic cross-national performance data would be necessary to directly test whether gender differences in equestrian performance vary as a function of gender equality.

According to the revised nature perspective, greater gender equality provides a socio-ecological environment that allows women to exploit their relative advantage in equestrian sports given their lower weight relative to men. However, given recent findings showing that men are universally taller and heavier than women, but this gap increases with greater socioeconomic development (36), men might actually be less suited physically

for equestrian sports in more gender-equal and socioeconomically developed societies. While this is not commensurate with the entire set of findings given that in many societies men still outnumber women among equestrians, it may account for some of the overrepresentation of females, and underrepresentation of males, in the most gender-equal societies.

According to the revised nature perspective, the greater freedom and lesser social constraint of more gender-equal societies allow them to pursue their inherent preferences and exploit their relative advantages (7–9). However, the causal pathway between gender equality and female representation may have emergent properties that are more complex: as female representation increases with greater gender equality, women may come to be viewed as possessing an inherent trait (lower body size) that essentializes their position as naturally skilled and able equestrians, thus essentializing them (37; e.g. “women are natural riders”), which then leads to a positive feedback loop with even greater self-selection into that domain. While such processes are outside of the present investigation, they can be investigated in future work.

Are the present findings sufficient to rule out the revised nurture perspective as a viable explanation for the GEP? The GEP comprises numerous findings in varied domains, including personality traits (e.g. 8, and see 38, for a critique), values (9, 39, 40), cognitive abilities (41–43), personal and academic interests (16, 31, 44), clinical and subclinical outcomes (45, 46), and physical attributes (36). It is not unlikely that more than one mechanism accounts for such a diverse array of findings. Our contention, then, is more modest: we have identified a domain of human endeavor (competitive sports) that demonstrated a predictable and unique profile of associations with gender equality, and these findings are consistent with a priori predictions for one account of the GEP (the revised nature perspective) and inconsistent with a different account of the GEP (the revised nurture perspective). We interpret these findings as indicating that, at the very least, the revised nature perspective cannot be dismissed in future investigations of the GEP.

Most of the literature on the GEP has focused on cross-sectional data from numerous countries (8, 9, 16, 44). However, the proposed mechanisms, including the revised nature and the revised nurture perspectives, make clear and falsifiable claims regarding the historical development of the GEP. The present investigation addressed this by providing cross-sectional evidence (study 1), simulations of a mechanism across time (study 2A), and historical data (study 2B). Analyzing both cross-national data and cross-temporal data is critical to teasing apart various explanations for the GEP, yet such investigations are mostly absent from the literature (for an exception, see 47). Such an approach aligns with emerging perspectives in historical psychology, which emphasizes that psychological patterns should be evaluated as products of historically unfolding social change rather than as static cross-sectional regularities (48). Future work interested in teasing apart explanations for the GEP should seek to investigate the phenomenon both cross-nationally and cross-temporally.

Supplementary Material

Supplementary material is available at PNAS Nexus online.

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Author Contributions

Allon Vishkin (Conceptualization, Formal analysis, Visualization, Methodology, Writing—original draft), Rachel Krasner (Data curation, Formal analysis, Visualization), and Majd Wely (Data curation, Formal analysis, Visualization)

Data Availability

All data and scripts for all studies are publicly available on the Open Science Framework (OSF; https://osf.io/vrmyq/?view_only=f819b536617042598215d2039b65beca). The four datasets in study 1 are original and were scraped from international sporting federations, as described in the Methods section of study 1, and appear in the OSF repository. The dataset in study 2B was constructed by independent research (30), as described in the Methods section of study 2B. No studies were preregistered.

References

- Trivers RL. Parental investment and sexual selection. In: Campbell BG, editor. *Sexual selection and the descent of man: the Darwinian pivot*. 1972. p. 136–179.
- Buss DM. 1989. Sex differences in human mate preferences: evolutionary hypotheses tested in 37 cultures. *Behav Brain Sci*. 12(1): 1–14.
- Eagly AH, Wood W. 1999. The origins of sex differences in human behavior: evolved dispositions versus social roles. *Am Psychol*. 54(6):408–423.
- Eagly AH, Wood W. Social role theory. In: Van Lange P, Kruglanski A, Higgins ET, editors. *Handbook of theories of social psychology*. Sage, 2012. p. 458–476.
- Eagly AH, Wood W, Diekmann AB. Social role theory of sex differences and similarities: a current appraisal. In: Eckes T, Trautner HM, editors. *The developmental social psychology of gender*. Lawrence Erlbaum Associates Publishers, 2000. p. 123–174.
- Herlitz A, Hönig I, Hedebrant K. 2025. A systematic review and new analyses of the gender-equality paradox. *Perspect Psychol Sci*. 20:503–539.
- Schmitt DP. The evolution of culturally-variable sex differences: men and women are not always different, but when they are ... it appears not to result from patriarchy or sex role socialization. In: Shackelford TK, Hansen RD, editors. *The evolution of sexuality*. Springer, 2015. p. 221–256.
- Schmitt DP, Realo A, Voracek M, Allik J. 2009. “Why can’t a man be more like a woman? Sex differences in big five personality traits across 55 cultures”: correction to Schmitt et al. (2008). *J Pers Soc Psychol*. 96:118–118.
- Schwartz SH, Rubel-Lifschitz T. 2009. Cross-national variation in the size of sex differences in values: effects of gender equality. *J Pers Soc Psychol*. 97:171–185.
- Charles M, Bradley K. 2002. Equal but separate? A cross-national study of sex segregation in higher education. *Am Sociol Rev*. 67(4): 573–599.
- Charles M, Grusky DB. *Occupational ghettos: the worldwide segregation of women and men*. Stanford University Press, 2005.
- Knight CR, Brinton MC. 2017. One egalitarianism or several? Two decades of gender-role attitude change in Europe. *Am J Sociol*. 122(5):1485–1532.
- Inglehart R, Norris P. *Rising tide: gender equality and cultural change around the world*. Cambridge University Press, 2003.
- Gelman SA, Taylor MG. Development, gender essentialism in cognitive. In: Miller PH, Scholnik EK, editors. *Toward a feminist developmental psychology*. Taylor & Frances, 2000. p. 169–190.

- 15 Diesendruck G. 2021. A motivational perspective on the development of social essentialism. *Curr Dir Psychol Sci.* 30(1):76–81.
- 16 Breda T, Jouini E, Napp C, Thebault G. 2020. Gender stereotypes can explain the gender-equality paradox. *Proc Natl Acad Sci U S A.* 117(49):31063–31069.
- 17 Charles M, Bradley K. 2009. Indulging our gendered selves? Sex segregation by field of study in 44 countries. *Am J Sociol.* 114(4):924–976.
- 18 Napp C. 2023. Gender stereotypes embedded in natural language are stronger in more economically developed and individualistic countries. *PNAS Nexus.* 2(11):1–11.
- 19 Napp C, Breda T. 2022. The stereotype that girls lack talent: a worldwide investigation. *Sci Adv.* 8(10):1–12.
- 20 Vishkin A, Slepian ML, Galinsky AD. 2022. The gender-equality paradox and optimal distinctiveness: more gender-equal societies have more gendered names. *Soc Psychol Personal Sci.* 13(2):490–499.
- 21 Wood W, Eagly AH. 2002. A cross-cultural analysis of the behavior of women and men: implications for the origins of sex differences. *Psychol Bull.* 128(5):699–727.
- 22 Wood W, Eagly AH. Biosocial construction of sex differences and similarities in behavior. In: Olson JM, Zanna MP, editors. *Advances in experimental social psychology.* 1st ed. Elsevier Inc., 2012. p. 55–123.
- 23 Adelman M, Knijnik J. Introduction—women, men, and horses: looking at the equestrian world through a gender lens. In: Adelman M, Knijnik J, editors. *Gender and equestrian sport: riding around the world.* Springer, 2013. p. 1–14.
- 24 Hedenborg S, Hedenborg White M. From glamour to drudgery—changing gender patterns in the equine sector: a comparative study of Sweden and Great Britain in the twentieth century. In: Adelman M, Knijnik J, editors. *Gender and equestrian sport: riding around the World.* Springer, 2013. p. 15–36.
- 25 Butler D. Becoming ‘one of the lads’: women, horseracing and gender in the United Kingdom. In: Adelman M, Knijnik J, editors. *Gender and equestrian sport: riding around the World.* Springer, 2013. p. 55–72.
- 26 Buchan A. *How to sail on a budget.* Adlard Coles, 2011.
- 27 World Economic Forum. 2023. Global gender gap report 2023. https://www3.weforum.org/docs/WEF_GGGR_2023.pdf.
- 28 United Nations Development Programme. 2021. Gender Inequality Index (GII). 5 November 2023. <https://hdr.undp.org/data-center/thematic-composite-indices/gender-inequality-index#/indicies/GII>.
- 29 Del Giudice M, Gangestad SW. 2021. A traveler’s guide to the multiverse: promises, pitfalls, and a framework for the evaluation of analytic decisions. *Adv Methods Pract Psychol Sci.* 4(1):1–15.
- 30 Griffin RH. 2018. 120 years of Olympic history: Athletes and results [Data set]. Kaggle. <https://www.kaggle.com/datasets/heesoo37/120-years-of-olympic-history-athletes-and-results/>.
- 31 Vishkin A. 2022. Queen’s gambit declined: the gender-equality paradox in chess participation across 160 countries. *Psychol Sci.* 33(2):276–284.
- 32 Ebert T, Götz FM, Mewes L, Rentfrow PJ. 2023. Spatial analysis for psychologists: how to use individual-level data for research at the geographically aggregated level. *Psychol Methods.* 28(5):1100–1121.
- 33 Kabel AM. 2022. Modest swimwear, religiosity and aging: apparel and physical activity for women throughout the life course. *Anthropol Aging.* 43(1):35–48.
- 34 Muthukrishna M, Schaller M. 2020. Are collectivistic cultures more prone to rapid transformation? Computational models of cross-cultural differences, social network structure, dynamic social influence, and cultural change. *Pers Soc Psychol Rev.* 24:103–120.
- 35 Dashper KL. Beyond the binary: gender integration in British equestrian sport. In: Adelman M, Knijnik J, editors. *Gender and equestrian sport: riding around the World.* Springer, 2013. p. 37–53.
- 36 Giofrè D, Geary DC, Halsey LG. 2025. The sexy and formidable male body: men’s height and weight are condition-dependent, sexually selected traits. *Biol Lett.* 21:20240565.
- 37 Storage D, Charlesworth TES, Banaji MR, Cimpian A. 2020. Adults and children implicitly associate brilliance with men more than women. *J Exp Soc Psychol.* 90(June):104020.
- 38 Ilmarinen V, Lönnqvist J-E. 2024. Deconstructing the gender-equality paradox. *J Pers Soc Psychol.* 127:217–237.
- 39 Atari M, Lai MHC, Dehghani M. 2020. Sex differences in moral judgements across 67 countries. *Proc R Soc Lond B Biol Sci.* 287:20201201.
- 40 Moon JW, Tratner AE, McDonald MM. 2022. Men are less religious in more gender-equal countries. *Proc R Soc Lond B Biol Sci.* 289(February):20212474.
- 41 Asperholm M, Nagar S, Dekhtyar S, Herlitz A. 2019. The magnitude of sex differences in verbal episodic memory increases with social progress: data from 54 countries across 40 years. *PLoS One.* 14(4):e0214945.
- 42 Borgonovi F, Han SW, Greiff S. 2023. Gender differences in collaborative problem-solving skills in a cross-country perspective. *J Educ Psychol.* 115:747–766.
- 43 Weber D, Skirbekk V, Freund I, Herlitz A. 2014. The changing face of cognitive gender differences in Europe. *Proc Natl Acad Sci U S A.* 111(32):11673–11678.
- 44 Stoet G, Geary DC. 2018. The gender-equality paradox in science, technology, engineering, and mathematics education. *Psychol Sci.* 29(4):581–593.
- 45 Campbell OLK, Bann D, Patalay P. 2021. The gender gap in adolescent mental health: a cross-national investigation of 566,829 adolescents across 73 countries. *SSM Popul Health.* 13(December 2020):100742.
- 46 Stoet G, Bailey DH, Moore AM, Geary DC. 2016. Countries with higher levels of gender equality show larger national sex differences in mathematics anxiety and relatively lower parental mathematics valuation for girls. *PLoS One.* 11(4):e0153857.
- 47 Balducci M, Larose M, Stoet G, Geary DC. 2024. The gender-equality paradox in intraindividual academic strengths: a cross-temporal analysis. *Psychol Sci.* 35:1246.
- 48 Atari M, Henrich J. 2023. Historical psychology. *Curr Dir Psychol Sci.* 32(2):176–183.