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Distance Running as an Ideal Domain for Showing a Sex Difference in Competitiveness

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Abstract Men are over-represented in the arts, sciences, and sports. This has been hypothesized to reflect an evolved male predisposition for enduring competitiveness or long-term motivation to improve one's performance and "show-off." Evidence for this hypothesis is equivocal, however, because there are viable alternative explanations for men's dominance in most cultural display domains. Here, I argue that distance running is an ideal domain for addressing this issue. Distance running is ideal because it indicates enduring competitiveness, allows objective comparisons, and is accessible, acceptable, and popular for both men and women. I review recent studies and present new data showing that substantially more men than women run relatively fast in the U.S., that this sex difference in relative performance can be attributed, at least in part, to men's greater training motivation, and that this pattern has been stable for several decades. Distance running thus provides compelling evidence for an evolved male predisposition for enduring competitiveness. I conclude with suggestions regarding how variation in achievement motivation can be informed by considering how evolved predispositions interact with environmental and social conditions.

Keywords Motivation · Competition · Runners · Sex differences · Title IX

Introduction

Throughout recorded history, men have dominated expressive cultural domains such as athletics, painting, music, poetry, science, and technology (Battersby, 1989; Guttmann, 1991; Miller, 1999; Russ, 1983). Perhaps the most intuitive explanation for this pattern is that women have, in various ways, been excluded from these areas. Although this explanation undoubtedly has much validity (see below), it seems incomplete because the male dominance in expressive culture remains pronounced even in large contemporary societies where women have achieved substantial access to educational, political, and economic arenas. Domains where male dominance remains robust include chess: 99 % of grandmasters are men (Howard, 2005); jazz: 95 % of albums are recorded by men (Miller, 1999); and technological innovation: 92 % of patent applications are filed by men (Frietsch, Haller, Funken-Vrohlings, & Gruppa, 2009).

Evolutionists have hypothesized that this dominance can be largely understood as a manifestation of selection for male competitiveness. In particular, men's cultural displays evolved and, in general, presently function to "show off" or demonstrate a man's mental and behavioral talents relative to those of other men, and these displays thus serve as reliable indicators or signals of quality to potential mates, competitors, and allies (de Block & Dewitte, 2009; Hawkes & Bliege Bird, 2002; Kanazawa, 2003; Lombardo, 2012; Miller, 1999, 2000).

Although women may benefit by displaying their talents relative to those of other women, it is expected that they will be predisposed to do so in different ways than men, given the potential costs and benefits that would have prevailed during human evolutionary history (Campbell, 1999; Cashdan, 1996; Low, 1992). On the benefits side, high status may greatly increase a man's reproductive success but only modestly increase it for a woman (Betzig, 1986; Buss & Schmitt, 1993). On the costs side, because of her typically greater parental investment, a woman's reproductive success would be more compromised from physical harm incurred during direct competition and from neglecting crucial ecological tasks (Campbell, 1999; Taylor et al., 2000).

In addition, women's same-sex relationships with non-kin are thought to involve greater reciprocity and emotional intimacy

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than men's, meaning that they might be more disrupted by direct competition (Baumeister & Sommer, 1997; Geary, 2010). Thus, women are expected to compete more frequently through indirect means, such as gossiping (Bjorkqvist, 1994; Campbell, 1999; Maccoby, 1998). In addition, rather than competing chiefly for status, women are expected to more often compete for resources or attributions of attractiveness or sexual exclusiveness (Campbell, 1999; Cashdan, 1996; Fischer, 2004; Schmitt & Buss, 1996; but see Hrdy, 1999).

Three points should be emphasized about the hypothesis that cultural displays signal quality, at least the version advanced in this article. First, the hypothesis focuses on what can be termed "enduring competitiveness," defined here as motivation to engage in dedicated training for an extended period to improve one's performance or achieve expertise in a domain where one's performance can be compared readily with that of others. In the domains that have been studied in contemporary cultures, gaining such expertise typically requires something on the order of 10,000 h of training, nearly 3 h daily for 10 years (Ericsson, Krampe, & Tesch-Römer, 1993; Ericsson, Nandagopal, & Roring, 2009). Enduring competitiveness stands in contrast to social risk taking and competitiveness manifest in hypothetical situations or behavioral experiments (for reviews of sex differences, see Byrnes, Miller, & Schafer, 1999; Croson & Gneezy, 2009).

Second, the hypothesis is not that men have greater intrinsic talents than women—empirical studies collectively indicate modest or non-existent mean differences in most perceptual, motor, and cognitive abilities (Hyde, 2005; Spelke, 2005; see also Geary, 2010). Instead, the claim is that, on average, men have a substantially stronger motivation than women to compete for status and actively seek avenues for doing so. For men with a talent valued in their culture and the opportunity to develop it, cultural displays may be the preferred competitive route. For other men, however, competitiveness may engender socially destabilizing behavior, such as physical aggression or criminality (Kanazawa, 2003).

Third, the hypothesis focuses on long-term achievement in domains geared towards "showing off" in comparison to others in order to gain status. By contrast, sex differences in long-term achievement motivation may not occur (or may reverse) in domains more relevant to resource acquisition or its contemporary equivalents, such as school or job performance (see Ceci & Williams, 2010). This is consistent with previous work showing that males generally report stronger competitive orientations, whereas females report stronger work orientations (e.g., Gill, 1986; Spence & Helmreich, 1983).

The hypothesized sex difference in enduring competitiveness is vividly illustrated by patterns of yam growing in Melanesian societies, such as the Abelam (Bliege Bird & Smith, 2005). Although both men and women expend great effort in growing yams, women do so as part of a garden that produces food for household consumption. Men's yam growing, however, is primarily for display: it entails different yam varieties, different techniques, separate gardens, and much more labor per mass of yams produced; growing yams requires horticultural expertise, strength, and diligence; men's yams are prized according to their size, shape, and other qualities; and being a "big-yam" man is crucial for gaining status and political influence. Moreover, in many other societies, men's behavior in food production and acquisition tasks (e.g., hunting) seems to fit best into a competitive signaling framework (Bliege Bird & Smith, 2005; Hawkes & Bliege Bird, 2002).

Findings from large contemporary societies also support the hypothesis that men's displays function to signal quality (for a discussion of quality, see below). First, displays are most pronounced among relatively young men who are thought to be most highly motivated to compete for status and mates. This is obvious in athletics, but it is also holds in the arts (Miller, 1999, 2000) and science (Kanazawa, 2003). Second, marriage depresses male cultural achievement, consistent with the idea that effort channeled into cultural displays reflects mating effort (tennis: Farrelly & Nettle, 2007; science: Kanazawa, 2000). Third, men's creative activity in the visual arts and poetry is positively correlated with mating success (Nettle & Clegg, 2006), and athletic achievement for males is linked to both enhanced status (Chase & Dummer, 1992; Földesi, 2004; Sohi & Yusuff, 1987) and mating opportunities (e.g., Faurie, Pontier, & Raymond, 2004; Llaurens, Raymond, & Faurie, 2009). Finally, men employ cultural displays in situations consistent with the hypothesis: they are more creative in their writing when they have been romantically primed (Griskevicius, Cialdini, & Kenrick, 2006), attempt more challenging skateboarding tricks in the presence of an attractive female observer (Ronay & von Hippel, 2010), and use riskier chess strategies when playing against an attractive female opponent (Dreber, Gerdes, & Gränsmark, 2010).

Despite this evidence, the pattern noted above—male dominance in cultural displays—requires critical evaluation as a putative sex difference in enduring competitiveness. One alternative is that the male dominance could represent a persistent artifact of patriarchy (e.g., Battersby, 1989; Miller, 1999; Russ, 1983). For example, girls and women may receive less encouragement (Hyde & Kling, 2001), fewer resources (Xie & Shauman, 2003), or biased evaluations of their displays (Goldin & Rouse, 2000). Another possibility is that male dominance is greatly overstated because the domains that have been quantified mainly appeal to men.

Deaner (2006a; see also Deaner & Mitchell, 2011) suggested that distance running was an ideal cultural domain to test for an evolved male predisposition in enduring competitiveness and claimed to have provided strong evidence for it. Deaner showed that in the U.S. there are substantially more males than females that run fast relative to sex-specific world class performances, argued that this reflects, at least in part, a sex difference in enduring competitiveness, and provided evidence that the sex difference in relative performance has been stable for several decades despite apparently equal opportunities and incentives for male and female runners.

In the next section of this article, I expand on Deaner (2006a) by specifying six key criteria for an ideal domain for exploring sex differences in enduring competitiveness and show that distance running fulfills these criteria. Although this section serves primarily to support the claim that distance running is an ideal domain, it should also provide a framework for future work in other domains. In the sections after that, I make the argument that there is now compelling evidence from distance running for an evolved male predisposition for enduring competitiveness.

Criteria for an Ideal Domain

Distance running is an ideal display domain because, to an apparently greater degree than any other, many men and women, across settings, time periods, and cultures, can pursue the activity, and their objectively measured performance will indicate their enduring competitiveness and talent. The six criteria reviewed here make this case for distance running, but I stress two points. First, I do not claim that these criteria are necessary or sufficient for a domain to be suitable for assessing sex differences: a domain that does not meet all six criteria may provide insights; conversely, additional criteria for an ideal domain might still be identified.

Second, I do not claim that distance running is an ideal domain for assessing all aspects of the hypothesis that cultural displays signal quality. This hypothesis makes several predictions that do not concern or require sex differences (Bliege Bird & Smith, 2005; Hooper & Miller, 2008), and distance running may not be suitable for assessing them. Furthermore, the overall strength of this hypothesis will be largely dependent on its explanatory power across many domains, meaning that many should be probed.

Domain Allows Objective Comparisons

The first criterion for an ideal domain is that performance should permit objective comparisons between men and women across settings, time periods, and cultures. Most artistic and scientific fields, almost by definition, require some degree of creativity as a criterion for elite performance; this makes objective comparisons exceedingly difficult. Even when investigators measure total output (e.g., number of albums produced: Miller, 1999), valid comparisons may still be unachievable because one sex may produce fewer products but of higher quality (e.g., Long, 1992).

Individually played games and sports offer better prospects for objective comparisons, yet most suffer from major shortcomings. For example, chess has been suggested as a possible domain (Howard, 2005) because one can compare the number of males and females who achieve particular levels (e.g., grandmaster). Although there are objective methods determining achievement (e.g., Elo rating systems), there is no straightforward way to make cross-temporal or cross-cultural comparisons. Most measurements of sports achievement (e.g., tennis, gymnastics) are also only meaningful relative to the participating population. Furthermore, in most sports, males and females compete only against individuals of the same sex; this makes direct, objective comparisons of male and female achievement virtually impossible.

Nonetheless, there is a host of individual sports that are more promising because they are based on explicitly objective measures that can be easily compared across time periods and cultures. These include (1) time to complete a distance by running, swimming, skating or biking or (2) the distance or height achieved by jumping, vaulting or throwing an object. In these sports, males and females generally compete only against same-sex individuals, which is chiefly due to the fact that males have substantial physiological advantages (Cheuvront, Carter, Deruisseau, & Moffatt, 2005; Joyner, 1993; Shephard, 2000). It is possible, however, to make comparisons of males and females in terms of relative performance by quantifying the number of men and women who approach sex-specific world class performance standards (Deaner, 2006a). Using such standards is reasonable because, in running at least, they are quite stable and are thought to roughly approximate men's and women's performance limits (Cheuvront et al., 2005; Noakes, 2001; Sparling, O'Donnell, & Snow, 1998).

This relative performance approach could, in principle, be applied to any of the sports noted above. However, distance running is the best candidate because only it is known to fulfill the other criteria for an ideal domain (see below). In addition, running has a major advantage over other sports in that direct comparisons can be made across time periods and cultures. The reason is that equipment (e.g., shoes) and facilities (e.g., tracks) play a minor role in performance and there have been no recent training revolutions (Gotaas, 2009; Guttmann, 2004; Sears, 2001). Thus, the times recorded by the best runners in the 1970s and 1980s generally would be competitive with the best contemporary runners. For example, the times of the men's 1972 Olympic gold medalists for the 8 non-hurdling running events (100 m—marathon) are, on average, only 1.6 % slower than the corresponding bronze medal performances in 2008 Olympics (Athletics at the 1972, 2011; Athletics at the 2008, 2011). By contrast, swimmer Mark Spitz won seven gold medals in the 1972 Olympics, yet the performances from his four individual gold medal events, all of which set world records, are 6.9 % slower than the corresponding bronze medal performances from the 2008 Olympics (Swimming at the 1972, 2011; Swimming at the 2008, 2011).

Domain is a Meritocracy

A second criterion for an ideal domain is that it should be open to all who are interested in participating. In fact, sports may be appealing precisely because they are, at least in principle, meritocracies: all competitors in a given sport play by the same rules and champions succeed due to their own effort and talent (de Block & Dewitte, 2009; Lombardo, 2012; Miller, 2000). In practice, however, becoming a champion in many sports requires many advantages. First, proficiency often requires opportunities

for skill development during one's youth. Autobiographical accounts of champion tennis players, swimmers, figure skaters, and gymnasts stress substantial daily practice before the age of 10 (Agassi, 2009; Kwan & James, 1998; Phelps & Abrahamson, 2009; Retton, Karolyi, & Powers, 1986), and formal studies confirm the ubiquity of early training (Kalinowski, 1985; Law, Côté, & Ericsson, 2007; Monsaas, 1985). Second, proficiency in most sports requires access to equipment and environment: a swimmer must have access to a pool; a skier must have skis and snow. Largely for these reasons, in most sports, the vast majority of elite competitors emerge from particular cultures and socioeconomic classes (Guttmann, 2004).

Distance running, however, appears to be a true meritocracy. First, recent research indicates that achieving adult expertise in some sports does not require early specialized training, provided that other activities foster the development of transferable skills (Baker, Côté, & Abernethy, 2003). Running appears to exemplify this pattern: distance running "how to" books emphasize that specialization prior to puberty is not beneficial (Greene & Pate, 2004). Moreover, the biographies of elite runners indicate that they rarely began dedicated training before their teenage years, although most participated in other aerobically demanding sports, such as soccer, cycling or swimming (Sandrock, 1996; Young & Salmela, 2010).

Distance running is also a meritocracy because no special equipment or environment is required. Although many runners, both elite and non-elite, seem to benefit from training on groomed running trails, rubberized tracks, treadmills or other facilities, many of the world's best train only on whatever terrain is locally available. Similarly, although many runners apparently benefit from expensive running shoes, heart rate monitors, and other equipment, many elites train with nothing but inexpensive shoes and simple clothing. Demonstrating this are documented cases of champion runners racing without shoes or else doing almost all training without shoes and only wearing them in competition (e.g., Budd & Eley, 1989; Judah, 2009).

Domain is Popular

A third criterion for an ideal domain is that many individuals should show motivation to participate and excel. The greater the popularity of a domain, the more likely the patterns will generalize to the larger population.

It is challenging to assess the popularity of any sport across societies and history, but it is clear that distance running frequently has been popular. In recorded history, there are many cultures that put great stock in staging distance running races, including the Greeks who included a "long run" early in the original Olympics (Gotaas, 2009; Guttmann, 2004; Sears, 2001). In foraging societies, distance races frequently took a central role in community festivals (e.g., Bennett, 1935; Chapman, 1982; Pearsall, 1950).

Distance running is also popular in large modern societies. This is shown by the fact that distance running events have been featured in every rendition of the modern summer Olympics (1896–2008), something that is true of only eight other sports (Olympic Sports, 2011). Furthermore, mass participation distance races are regularly organized in many countries: there are 14 countries where distance races with at least 20,000 participants have occurred (List of Largest, 2011), and there are 37 countries where at least one marathon (42,195 m) has occurred annually since 1990 (List of Marathons, 2011).

The extent of mass participation is especially well-documented in the contemporary U.S.; there are over 10 million road race finishers per year (Running USA's State of the Sport 2010—Part III, 2010); 20 % of American adults report running at least once in the past 30 days, almost twice the frequency of any other sport (Ham, Kruger, & Tudor-Locke, 2009); and, in American high schools, over one million individuals compete in outdoor track and field, more than any other sport, and 440,000 girls and boys participate in cross country (National Federation of State High School Associations, 2010).

Domain is Appealing and Acceptable for Men and Women

A fourth criterion for an ideal domain is that it should be equally appealing and acceptable for men and women. To the extent this criterion is not met, interpreting sex differences becomes problematic. For example, the large sex difference in the proportion of elite chess players has been interpreted as reflecting sex differences in ability (Howard, 2005). However, this difference seems largely explicable by the fact that many more men play chess overall (Chabris & Glickman, 2006; but see de Bruin, Smits, Rikers, Henk, & Schmidt, 2008). In addition, the game's masculine stereotype may also depress female achievement (Chabris & Glickman, 2006; Maass, D'Ettole, & Cadinu, 2008).

Distance running may not fully meet the criterion of being equally popular and acceptable for men and women, but it comes close. Although distance running by females has been prohibited in many societies, girls and women have shown persistent interest (Gotaas, 2009; Guttmann, 1991; Kuscsik, 1977; Noakes, 2001; Sears, 2001). In the late twentieth century, many women in many nations began to participate, and women now comprise a large proportion of the world's distance runners. For example, in the 15 IAAF "gold-label" mass-participation marathons held in 2010 (in 11 countries), women comprised, on average, 23 % of finishers (Deaner, unpublished analysis; data and links from List of Marathons, 2011). Particularly good data are available from the contemporary U.S., and the patterns are striking: females comprise approximately 45 % of high school distance runners (National Federation of State High School Associations, 2010), 53 % of collegiate distance runners (NCAA Research, 2008), and 53 % of road race finishers (Statistics, n.d.).

A final point is that studies of sport stereotyping conducted in several nations have found that distance running is not considered a male-typical or female-typical sport; it is regarded as almost perfectly neutral (Colley, 1987; Koivula, 1995; Lauriola, Zelli,

Calcaterra, Cherubini, & Spinelli, 2004; Matteo, 1986). This suggests that stereotype threat almost certainly cannot explain male dominance in this domain.

Domain Indicates Enduring Competitiveness

A fifth criterion for an ideal domain is that elite performances should reveal enduring competitiveness, not merely talent. Enduring competitiveness was defined above as motivation to engage in dedicated training for an extended period to improve one's performance in a potentially competitive domain. Talent, by contrast, might be most easily viewed as genes that would facilitate excelling in a domain, although I define talent more broadly, as the ability to excel in a domain that is distinct from the contribution of enduring competitiveness. Thus, developmental events and exposures (e.g., nutritional stress, high altitude) contribute to talent.

The logic for the assumption that elite performances should depend on both talent and enduring competitiveness follows from costly signaling theory (Bliege Bird & Smith, 2005; Hawkes & Bliege Bird, 2002; Miller, 1999, 2000). In brief, if any quality-related display trait was preferentially chosen by mates (or other selectors), then competing individuals would undergo selection to best display the trait using any available mechanism (e.g., training), even if their actual quality was inferior to others'; thus, the only way a high quality individual could truly reveal their quality would be to utilize all potential mechanisms. An illustrative hypothetical example is weight lifting: if individuals competed to lift the heaviest weights, then an individual with low talent might achieve a decent performance through dedicated years of training at the gym; an individual of high talent might lift decently with little training; but an individual with high talent and dedicated training would lift best.

Based on this reasoning, we can expect that the most effective displays will usually require both enduring competitiveness and talent. Miller (2000) made this point by noting an exception that "proves the rule": the bewilderment and hostility shown by many to abstract art (e.g., a black canvas with one horizontal stripe) can be viewed as a display that fails to impress because it apparently does not require exceptional talent and effort. Psychologists have devoted considerable effort to identifying factors that lead to elite performance or expertise, and, as noted above, one of the most robust findings in this literature is that becoming a true expert in any domain requires years of dedicated training (Ericsson et al., 1993, 2009).

Despite these arguments, it is conceivable that there could be a domain where expertise can be achieved without enduring competitiveness and, obviously, such a domain would be a poor candidate for studying sex differences in this trait. However, distance running is not such a domain; on the contrary, the relation between distance running performance and training is exceptionally well-documented.

In considering the literature on distance running training, it should first be acknowledged that there is still vigorous debate about many issues. Nonetheless, there is consensus about some core principles, including that distance runners cannot approach their potential unless they maintain moderate to large training volumes (e.g., running 100–200 km/week for several years) (Berg, 2003; Midgley, McNaughton, & Jones, 2007; Noakes, 2001). Furthermore, training volume correlates with other aspects of dedicated training, such as the frequency of intensive sessions (Ogles & Masters, 2003; Slovic, 1977).

Thus, for a broad range of runners, training volume should be a useful gauge of overall dedication to training and, therefore, should be a good performance predictor. Indeed, training volume has been repeatedly shown to correlate strongly with distance running performance (Bale, Bradbury, & Colley, 1986; Bale, Rowell, & Colley, 1985; Hagan, Smith, & Gettman, 1981; McKelvie, Valliant, & Asu, 1985; Slovic, 1977). Also as expected, national and world class distance runners consistently report that they maintain training volumes in excess of 100 km/week (Karp, 2007; Tjelta & Enoksen, 2010). Finally, although biographies of elite distance runners often note that they showed unusual talent when they first began, none reach elite levels until they have trained consistently for years (Budd & Eley, 1989; Sandrock, 1996).

Domain Indicates Quality

A sixth criterion for an ideal domain is that performance in the domain should indicate an individual's quality to potential mates, competitors, or allies (de Block & Dewitte, 2009; Hawkes & Bliege Bird, 2002; Kanazawa, 2003; Lombardo, 2012; Miller, 1999, 2000). Quality could mean that choosing the displaying individual as a mate or ally provides greater net benefits than choosing others in the population. Similarly, quality could mean that avoiding competition with the displaying individual provides net benefits. Before considering quality, it is worth noting that a fundamental assumption of evolutionary signaling indicator frameworks is met for distance running: there is heritable variation in many of the physiological factors that underpin performance (reviewed by MacArthur & North, 2005).

The question of whether behavioral displays indicate quality has been considered most extensively in the context of a displaying male's mate quality (Andersson, 1994), and I will focus on that here, although it is also likely that distance running and other athletic displays indicate quality to a male's potential competitors or allies (Lombardo, 2012; Puts, 2010) or to a female's potential mates, competitors, or allies. Studies of male mate quality typically make a distinction, at least heuristically, as to whether the potential male is providing direct or indirect benefits (Cameron, Day, & Rowe, 2003; see also Kokko, Jennions, & Brooks, 2006). Direct benefits from a male include resources (e.g., food) and services (e.g., predator vigilance) directed to the mating female or her offspring (Kirkpatrick & Ryan, 1991). Indirect benefits refer to a male providing "good genes" to the female's potential offspring. "Good genes" would be ones that facilitate disease

resistance (Hamilton & Zuk, 1982) or otherwise promote developmental stability (Swaddle, 2003). "Good genes" may also be "good" relative to a specific, compatible female (e.g., MHC-heterozygosity; Ziegler, Kentenich, & Uchanska-Ziegier, 2005), although this possibility seems unlikely to be advertised in cultural displays, which are generally directed to broad audiences.

Distance running apparently provides direct benefits in some foraging societies that employ running-based meat acquisition techniques (e.g., Liebenberg, 2006; Lieberman, Bramble, Raichlen, & Shea, 2009). In sporting contexts, distance running prowess might also yield direct benefits. For example, at least 31 Kenyan or Ethiopian male distance runners have achieved lifetime winnings greater than $300,000 (Life-time, 2011), usually with only 3–10 years of professional running. This implies yearly earnings orders of magnitude greater than the median income for males in those nations (Countries and Economies, n.d.). Nonetheless, in many nations where distance running is popular, it is difficult to sustain an argument that elite distance running typically could provide substantial direct benefits. For example, it is believed that only a handful of male American marathoners earn more than $100,000/year in prize money, appearance fees, and endorsements, yet there were 104 men that achieved the 2004 Olympic Trials qualifying standard of 2:22:00, and performance at this level apparently entails running more than 150 km/week (Karp, 2007). For most men training at this level, it would seem that if their primary goal was to improve their mating prospects by acquiring resources, it would be more beneficial to put their efforts into more conventional careers. Supporting this are reports detailing financial sacrifices made by American runners (Lorge, 2010; Metzler, 2010; Stark, 2010).

It might still be argued, though, that men's elite distance running does predict direct benefits because excellence in this domain correlates with traits that typically lead to direct benefits in the context of long-term mating relationships. In particular, distance running performance is strongly associated with training volume and thus high levels of vigorous physical activity. Vigorous physical activity, in turn, correlates with reduced risk of chronic disease (e.g., Warburton, Nicol, & Bredin, 2006), improved executive functioning (e.g., Hillman, Erickson, & Kramer, 2008), and greater conscientiousness (e.g., de Bruijn, de Groot, van den Putte, & Rhodes, 2009). Furthermore, the health benefits of regular aerobic activity do not reach an asymptote at "recommended levels," such as 20 min per day (Warburton et al., 2006), and elite athletes show high levels of physical activity and good health outcomes decades after their competitive careers have ended (e.g., Backmand, Kujala, Sarna, & Kaprio, 2010).

With regard to indicating male mate quality indirectly, via "good genes," distance running has mixed support. First, it should be noted that there are no data addressing whether better male distance runners have healthier or more reproductively successful children, probably the most important "good genes" prediction. Nonetheless, such data may not exist for any male display in humans (Roberts & Little, 2008). Another "good genes" prediction is that female preference for the display or trait should increase when they are seeking short-term mating relationships and/or are in the potentially fertile phase of their ovulatory cycle. Evidence from humans supports this prediction for several male traits, especially those related to masculinity (e.g., height, voice, face shape, social dominance; reviewed in DeBruine et al., 2010). However, there is no evidence addressing it for distance running. In fact, Lombardo's (2012) overview suggests that females' short-term preference for mating with athletes is primarily directed to those excelling in masculine team sports.

Nevertheless, distance running has some support as an indicator of male quality via "good genes" because it correlates with other "good genes" traits. One is fluctuating asymmetry, a putative measure of developmental stability that has been frequently linked to sexually-selected displays and ornaments (Møller & Thornhill, 1998; Møller, Thornhill, & Gangestad, 2005). Although it is unclear whether the relation between athletic ability and fluctuating asymmetry will prove robust (Tomkinson, Popovic, & Martin, 2003), Manning and Pickup (1998) showed that among competitive male middle distance runners, faster runners had significantly more symmetrical nostrils and ears.

A second "good genes" trait is the ratio of the second to fourth digits (2D:4D), an apparent marker of prenatal exposure to testosterone (reviewed in McIntyre, 2006). Researchers have reported associations between 2D:4D and a wide variety traits (e.g., sexuality, cognition, morphology), although many apparent correlations turn out to be unreliable (Puts, McDaniel, Jordan, & Breedlove, 2008; Putz, Gaulin, Sporter, & McBurney, 2004). One exception is the negative correlation between athletic ability and 2D:4D; this relation is robust, and, of all the sports investigated so far, distance running shows the strongest ($r \sim .50$) and most consistent relation (Hönekopp & Schuster, 2010).

Relative Performance and Enduring Competitiveness

The previous section shows that distance running has many desirable characteristics of an ideal display domain. In this section, I consider the evidence of a sex difference in this domain, beginning with a review of self-reports of training. I then explain why relative performance, although indirect, is, in some respects, a superior training measure. I conclude by reviewing the evidence that relative performance is an unbiased measure of the sex difference in training.

Self-Report Measures

Perhaps the most straightforward way to assess runners' training is with self-reports (e.g., "How many miles [kilometers, days] do you typically run each week when training for a race?"). Self-reported training has been used in many studies of athletics, and there is good evidence for reliability (e.g., Young & Salmela, 2010). With respect to validity, self-reported training in distance

runners has been shown to correlate robustly with motivation (Masters, Ogles, & Jolton, 1993; Ogles & Masters, 2000, 2003; Ogles, Masters, & Richardson, 1995) and performance (Bale et al., 1985, 1986; Hagan et al., 1981; McKelvie et al., 1985; Slovic, 1977).

Most studies that measure self-reported training in distance runners were not designed to address sex differences in training and rarely mention them. Nonetheless, several report mean training volume separately for men and women, and these studies consistently indicate a sex difference (males run 74 % more, $n = 424$: Callen, 1983; males run 42 % more, $n = 2{,}552$: Clement, Taunton, Smart, & McNicol, 1981; males run 26 % more, $n = 610$: Ogles et al., 1995). These studies might seem unconvincing because they were conducted several decades ago. However, a 2009 survey of 11,00 runners (53 % female) indicated that mean male training volumes are 28 % larger than those of females (37 km vs. 47.5 km; Running USA's State of the Sport 2010—Part I, 2010). Even assuming that, for any given level of talent and training, men average 12 % faster running speeds (see Cheuvront et al., 2005; Noakes, 2001; Sparling et al., 1998), these studies still indicate that men spend 15 % more time training.

Another concern is that the sex difference in volume indicated by these studies is typically modest. It seems difficult to reconcile that two to four times as many men engage in dedicated training when the mean sex difference in training volume appears to be merely 15–20 %. The key to resolving this paradox begins with the recognition that only a small proportion of distance runners, at least in the U.S., train primarily for the goal of optimizing their timed performance. Instead, most individuals report being motivated to run races for a variety of non-competitive reasons (e.g., affiliation, weight concern, life meaning). In fact, Ogles and Masters (2003) developed a typology of marathoners based on their motivations and training and reported that only 17 % fit into the grouping "competitive achievers." Men were overrepresented in this group and other studies (Callen, 1983; Johnsgard, 1985) also indicate that, on average, male runners report greater competitive motivation.

Because the runners who maintain large training volumes are apparently rare, a sex difference in their occurrence may be difficult to detect. This is underscored by considering data from the Running USA survey where the mean training volume of female runners who train year round was only 37 km/week. If we suppose that 80 km/week is the minimal training needed to approach one's best performance in distance races and that competitive runners maintain this, and we suppose that all non-competitive runners in this sample maintained training volumes of 30 km/week, then competitive runners would be outnumbered by non-competitive ones by a ratio of 5:1. For males, the mean training volume was 47.5 km/week, and this would equate to a ratio of non-competitive runners (30 km/week) to competitive runners (80 km/week) of roughly 2:1, and, in fact, would be consistent with over twice as many males as females maintaining 80 km/week. In reality, the proportion of truly competitive, high volume runners may be substantially less than these estimates because fewer than 4 % of runners (under 40 years of age) in U.S. road races finish within 125 % of sex-specific world class standards, which may be a reasonable benchmark of dedicated training (Deaner, 2006b).

To better address whether there truly are more men engaged in dedicated training, it would be desirable to have detailed training and performance data from a very large sample of runners. Another possibility is to examine studies of elite runners' training. Although all elites are expected to maintain fairly high volumes, the larger number of relatively fast men (reviewed below) would suggest that some elite women might "get by" with less volume. Support for this idea comes from Karp (2007), who surveyed 93 qualifiers for the 2004 U.S. Olympic marathon trials; even in this select group, the men's weekly training distances were 25 % greater than the women's.

Relative Performance

To assess a sex difference in enduring competitiveness, Deaner (2006a, 2006b; Deaner & Mitchell, 2011) focused on performance, a correlate of training, rather than self-reports of training. This was done for three reasons. First, although runners' self-reported training generally seems reliable, biases are conceivable whereby men or women might systematically over- or under-report their training. Race performance data, by contrast, are objective. Second, as noted above, the sex difference in training dedication is only expected to be appreciable in the small proportion of runners who engage in dedicated training for extended periods. Thus, capturing this effect could be difficult unless study samples were very large. Third, many of the interesting questions about sex differences in this domain concern the behavior of populations from different societies or time periods. Obtaining large samples of valid, comparable self-report data from such populations generally would not be practical, whereas performance data are abundant.

It would be straightforward to compare populations of men and women in terms of absolute running performance (e.g., "How many men and how many women ran Marathon X in under 3 h?"). Such an approach would be unwarranted, though, because, for any given level of talent and training, males are expected to run substantially faster due to hormonally regulated differences in aerobic capacity, muscular strength, and body fat deposition (Cheuvront et al., 2005; Joyner, 1993; Shephard, 2000). This point is underscored by the fact that the very best female runners, no matter their training, do not approach the performances of their elite male counterparts.

Nonetheless, because sex differences in world class performance have stabilized at roughly 10–12 % across all distances (Cheuvront et al., 2005; Noakes, 2001; Sparling et al., 1998), sex-specific world class performances can be used as denominators in making relative comparisons between men and women. For example, if 20 men ran within 2 % of the male world record in a

given event during one particular year while 10 women ran within 2 % of the female world record that year, one could say that twice as many men ran relatively fast. Such a pattern would suggest that even if the total number of male and female distance runners is roughly equal, the pool of men engaged in dedicated training would be about twice the size of the pool of similarly engaged women. Of course, this approach assumes that the relation between training and sex-specific relative performance is highly similar in males and females, an issue that I address below.

Using this approach, Deaner (2006a, 2006b) demonstrated a highly robust sex difference: across all commonly contested distance events, in matched populations of elite, sub-elite, and recreational U.S. runners, two to four times as many men as women ran relatively fast in 2003.[1] Corroborating this is recent work by Frick (2011a, 2011b) showing a similar pattern in international elite distance running events occurring from 1973 to 2009. Although these are the first academic studies to demonstrate the sex difference in relative performance, there is much other evidence for the phenomenon. For example, for athletes of all nations, the 2008 Olympic "A" qualifying standard for the marathon was 2:15:00 for men (10:33, 8.4 % over the then-current men's world record) and 2:37:00 for women (21:35, 15.9 % over the then-current women's world record; The XXIX Olympic Games, 2008). Similar patterns can be observed in the U.S. where men's and women's participation is known to be equal (Qualifying Standards, n.d.-a, n.d.-b).

One concern with the relative performance approach is that female world class performances somehow might be "too fast" and thus provide biased baseline denominators. Indeed, several studies have speculated that some outstanding female performances, including world records, might be "too fast" because they were dependent on the use of illegal performance enhancing drugs. Although males may benefit from drugs, their gains may be smaller because they possess more endogenous testosterone (Seiler, De Koning, & Foster, 2007). Although concern about potentially biased denominators is reasonable, the sex difference in relative performance phenomenon cannot plausibly be explained from this perspective, at least not generally. One reason is that this perspective would imply that, for any given event, all of the best female performances, many of which occurred decades ago, were aided by drugs. For instance, if the 2008 U.S. Olympic Trials marathon women's qualifying standard of 2:47:00 was, like the male standard, 14.5 % slower than a hypothetical women's "drug free world record," it would mean that this world record "should be" 2:25:40 (rather than 2:15:25) and that all female performances faster than this, roughly 300 of them, were aided by drugs (All-Time Performances, 2010).

A second reason to reject the suggestion that the sex difference in relative performance phenomenon is only caused by biased world class performances is that there is strong evidence for the phenomenon that is entirely independent of these performances. Specifically, within any given population, the variability of the best male performances is consistently less than that of the comparable female performances (Deaner, 2006a; Frick, 2011a). Deaner (2006a) showed this in a few ways, but perhaps the most powerful was based on U.S. high school state championship 5K cross-country performances. The fastest 40 finishers were generally faster in states with more participants and these performances also fell closer together in states with more participants. The key point is that the regressions of variance on participants differed significantly for boys and girls and indicated that for a female population (i.e., state) to show similar variance to a male one, it required 2.3 times as many participants (Deaner, 2006a, Fig. 2b). In other words, although the number of boys and girls that run cross-country is similar in most states, the female populations "behave" as if fewer than half as many girls are engaged in highly dedicated training.

Alternative Explanations

Although a sex difference in enduring competitiveness seems to provide a satisfying explanation for the sex difference in relative performance, other explanations should be considered. One hypothesis is that, in some sense, it is "easier for males" to achieve a relatively fast performance. One version of this hypothesis is that females, on average, are less responsive to aerobic training. Contradicting this are studies showing that when fitness-matched males and females undertake controlled training programs, their physiological responses and performance gains are extremely similar (Dolgener, Kolkhorst, & Whitsett, 1994; Eddy, Sparks, & Adelizi, 1977; Skinner et al., 2001). A second version is that proportionally fewer females possess the biomechanical (e.g., skeletal) characteristics necessary for highly efficient running. If true, one might expect that females would be more variable than males in running related characteristics and untrained running speed. However, as is the case for most nonhuman species, it is boys and men who are more variable in morphology and behavior (Lehre, Lehre, Laake, & Danbolt, 2009). In fact, a meta-analysis of 20-m shuttle run performances, which included data from more than 400,000 untrained individuals, revealed that at every age from 6 to 19 years males were more variable (Olds, Tomkinson, Leger, & Cazorla, 2006).

Finally, the fundamental prediction of the "easier for males" hypothesis—that when men and women train similarly, men will generally run relatively faster—is not supported. A recent cross-sectional study (Deaner, Masters, Ogles, & LaCaille, 2011) assessed the relationship between training volume and relative marathon performance and found the relationships were extremely

[1] It would be desirable to estimate the size of the sex difference in relative performance in terms of a traditional effect size statistic, such as Cohen's *d*. No study has done this yet, although Deaner (2006b, Fig. 1) suggests the effect size is small to moderate. However, a modest overall population effect does not undermine the point that the sex difference can be large in the tail of distribution, and expressing the sex difference there as a ratio of male to female high achievers is reasonable (see Hedges & Nowell, 1995).

similar in men and women. Crucially, there was no indication that training volume underestimated female performance even after controlling for several relevant variables. Additional pertinent data were reported in Williams (1998) who found that the regression slopes for training volume and performance were highly similar in men and women. Moreover, the intercepts differed, on average, by 11.9 % (calculated from Williams' Figs. 1 and 2; data from runners under 40 years). For example, for individuals typically running 48–72 km/wk, men's and women's mean 10 km times differed by 12.0 %, and their mean marathon times differed by 8.5 %. The "easier for males" hypothesis predicts this sex difference should be substantially greater than 10–12 %, the typical difference in male and female world class running performances.

Another general kind of hypothesis acknowledges that women train less than men but holds that this is due to some kind of constraint, not because of a difference in motivation. One version of this "training constraint" hypothesis is that females are more susceptible to running injuries and so enjoy fewer opportunities to maintain high training volumes. Although there is a sex difference in injury rates for sports demanding explosive lateral movements (e.g., basketball and soccer) once running experience is controlled, male and female distance runners experience similar injury rates (Macera, 1992; van Gent et al., 2007; van Mechelen, 1992). Another version is that women cannot train consistently because they are constrained by pregnancy. Although this must be true in some cases, it fails as a general hypothesis because the sex difference in relative running performance is at least as strong in U.S. high school runners as it is in older populations. Thus, at least two-thirds of girls in U.S. high schools would need to be getting pregnant to account for the high school sex difference and the actual high school pregnancy rate is roughly 7 % (In Brief, 2011).

Yet other alternative hypotheses could be advanced. For example, if males are generally more motivated than females to participate and excel in sports, then, because their pool of competitors is larger, males might end up specializing in particular sports according to their talents to a greater degree than is true among female athletes. Thus, the sex difference in relative performance might reflect, at least partly, differential sorting rather than a difference in enduring competitiveness. This hypothesis is strengthened by recent studies indicating that a substantial sex difference in motivation to participate in sports is probably a cultural universal (Deaner & Smith, 2012), one that even holds in the contemporary U.S. (Deaner, Geary, Ham, & Kruger, 2011). Despite its plausibility, this hypothesis does not represent a strong alternative to the "show-off" hypothesis advanced in this article. This is because it still leaves unanswered why males are generally more motivated to participate and excel in sports. More importantly, this hypothesis cannot readily accommodate the findings that (1) training volume is known to be strongly associated with running performance, and the relations are highly similar, if not identical, in men and women and (2) men do, in fact, report greater competitive motivation and greater training volumes.

In sum, although more research should explore the possibility that relative running performance is a biased measure of enduring competitiveness, there is presently no evidence supporting the idea. By contrast, the case seems compelling that at least some of the sex difference in relative performance is due to a sex difference in enduring competitiveness.

Historical Stability in the U.S.

The previous section reviewed evidence for a robust sex difference in relative performance in U.S. distance runners and established that this difference is very likely to be due, at least in part, to more males being motivated to engage in dedicated training. Although these findings are consistent with the hypothesis of an evolved sex difference in enduring competitiveness, other explanations are possible. The clearest is that the sex difference might be ascribed to various sociocultural biases, such as male athletes receiving greater encouragement, opportunities, or rewards (Hogshead-Makar & Zimbalist, 2007; Messner, 2002).

Deaner (2006a) pointed out that the evolved predispositions hypothesis and what can be termed the "sociocultural conditions hypothesis" (e.g., Eagly & Wood, 1999) could be pitted against one another by examining the "historical experiment" that occurred in the U.S. for female sports (Hogshead-Makar & Zimbalist, 2007; Shulman & Bowen, 2001; Stevenson, 2007; Suggs, 2005; U.S. Department of Education, 2003). In particular, relatively few U.S. girls or women enjoyed athletic opportunities prior to the mid-1970s and, even when they could participate, they received fewer resources, such as coaching, equipment, and collegiate scholarships. However, due to a host of factors, including federal legislation (i.e., Title IX), the sex difference in high school and collegiate sports participation narrowed dramatically in the late 1970s and 1980s (National Federation of State High School Associations, 2010; NCAA Research, 2008; Stevenson, 2007; United States Commission on Civil Rights, 1980). Achievement-based incentives for females also increased substantially, including the awarding of athletic scholarships (NCAA Research, 2008; United States Commission on Civil Rights, 1980; Zimbalist, 1999) and the ceding of admissions advantages at non-scholarship-granting institutions (Bowen & Levin, 2003; Shulman & Bowen, 2001).

These changes extended across a broad range of sports, including cross-country and track and field. In fact, today, there are similar numbers of males and females running on high school and collegiate teams (National Federation of State High School Associations, 2010; NCAA Research, 2008) and participating in road races (Statistics, n.d.). Moreover, females compete for similar shares of prize money at professional track and field meets and road races (Prize Money, 2011), and female Division 1 and Division 2 collegiate runners actually receive 50 % more athletic-related aid than do their male counterparts (NCAA Research, 2008).

Deaner (2006a) argued that, given these changes, if the sociocultural conditions hypothesis holds, then the sex difference in the occurrence of relatively fast runners should be in the process of diminishing and should eventually disappear. By contrast, the evolved predispositions hypothesis predicts that, although there would be some initial response to such changes, the sex difference in relative performance should eventually stabilize at a point where there are substantially more males than females who run relatively fast. Deaner found that at high school, collegiate, and professional levels, there was a marked increase in the number of fast female runners in the 1970s and early 1980s. Nonetheless, in regressions exploring the last 20 or 25 years for which data were available (e.g., 1984–2003), there was no indication that the number of relatively fast U.S. female distance runners had increased.

To address this issue in non-elite runners, Deaner and Mitchell (2011) examined a sample of 342 road races that occurred between 1981 and 2006, most in or near Buffalo, NY. As female participation surged in the 1980s and 1990s, the difference in the absolute number of relatively fast men and women decreased. However, this difference was stable for races that occurred after 1993. After then, in any given race, even when male and female participation was equal, about three to four times as many men ran relatively fast. Collectively, these results strongly support the evolved predispositions hypothesis.

Frick's Challenge

Deaner's (2006a) conclusion of a stable sex difference in relative running performance was challenged by Frick (2011a). Frick analyzed, for nearly all widely-contested race distances, the top 200 performances in the world from 1973 to 2009. Frick showed that the sex difference in relative performance decreased substantially over this time period and claimed that this falsified Deaner's (2006a) evolved predisposition hypothesis. Frick concluded by saying, "over time competitiveness has increased among women to an extent that it is now very similar to that of men."

Frick's (2011a) conclusion, however, is not supported by his results. The key point is that evidence of a shrinking sex difference is, as Deaner (2006a) stressed, consistent with both the evolved predispositions and sociocultural conditions hypotheses. Strong evidence for sociocultural conditions hypotheses would be that the sex difference had completely disappeared. Although Frick implied that the sex difference in relative performance in his study was very small, the data contradict him. Frick's Fig. 5 showed that even in the last 10 years, relatively fast males outnumber relatively fast females by a ratio of approximately eight to one, roughly twice the difference found among elite U.S. runners (Deaner, 2006a). Moreover, this large difference appears to have stabilized since 1999. Thus, Frick's (2011a) data were not merely consistent with an evolved predispositions hypothesis; they actually support it.

Additional Tests of Historical Stability

Deaner (2006a) and Deaner and Mitchell's (2011) demonstration that the sex difference in relative performance is sizeable and stable in the U.S. clearly supports the evolved predispositions hypothesis. Nonetheless, this hypothesis should be tested further. One possibility is that although full convergence did not occur over this time period, it may eventually. Although it is impossible to look 20 or 40 years into the future, one can at least test for convergence in the past decade, from 2000 to 2010, and I have done so below. This period is especially suitable for study because American distance running has enjoyed a renaissance during this decade (Beverly, 2008; Burfoot, 2011; Robbins, 2009), and it is possible that this has been especially true for women.

To keep this study manageable in scope, I focused on Open (i.e., professional and all others) U.S. runners, a group for which yearly best performance lists have already been compiled. I considered all Olympic middle distance and distance events (800 m, 1500 m, 5000 m, 10000 m, marathon) and obtained data on the 25th best performer in each event for each year (data from Track & Field News Lists, n.d.; USA Top Marks Lists, n.d.). Deaner (2006a) showed that such a ranked performance did a good job estimating the number of fast runners within a population. Thus, the prediction of the evolved predispositions hypothesis is that the performance of the 25th best female performer will have remained stable over the decade, or if it did improve, will be matched by a similar improvement by males.

As shown in Table 1, performances for both males and females, in all five events, were negatively correlated with year, indicating an increase in the number of fast runners. Several of the correlations even reached significance despite the small sample size. These results clearly support the claim of resurgence in American distance running.

Of greater relevance is the difference between men's and women's performances. This did not show a consistent pattern: in the 800 m, 1500 m, and marathon, the percentage difference between men's and women's 25th ranked performance showed a negative correlation with year, indicating convergence, but the correlation was positive for the 5,000 and 10,000 m, and none of the correlations reached significance (Table 1). To increase statistical power, I repeated the test after combining all 55 events (5 events $\times$ 11 years). There was no significant change in percentage difference ($r = .08$), and the positive sign of the correlation indicates that the sex difference became slightly more pronounced, a pattern contradicting the sociocultural conditions hypothesis.

In addition, I revisited the claim of a sex difference in variability by calculating the mean percentage sex difference in absolute performance across the 55 events for the 25th ranked performer and 5th ranked performer; if there was no sex difference, the percentage difference should be the same. However, the difference among male and female 25th ranked performers was 16.0 % (SD = 0.01), substantially greater than the 14.1 %

(SD = 0.01), difference found for the 5th ranked performers in these events, $t(55) = 446, p < .0001$. This pattern confirms the sex difference in depth for elite U.S. runners: for men, it is more "crowded at the top."

The new evidence for a stable sex difference in relative performance in the U.S. strengthens the case for a male predisposition for enduring competitiveness. Although other interpretations for this stability warrant scrutiny, none seem compelling (reviewed in Deaner, 2006a). For instance, one might argue that early exposure to and participation in athletics is vital for distance running development, and boys still receive substantially more exposure. As reviewed above, though, one reason that distance running is an ideal domain is that the only apparent requirement is youth participation in aerobically-demanding activities, formally organized or not. It seems that many candidate activities are available to American girls. Soccer, for instance, is one of the most popular youth sports in the U.S., and girls comprise 40 % of participants (FIFA Big Count, 2007). Another possibility is that parents encourage their sons' more than their daughters' distance running. However, despite numerous studies, the evidence for differential parental encouragement for sons and daughters is modest and usually only found for sex-stereotyped activities (Lytton & Romney, 1991); distance running is not sex-stereotyped (Colley, 1987; Koivula, 1995; Lauriola et al., 2004; Matteo, 1986).

Discussion

Here, I have argued that distance running represents an ideal domain to test the evolved predisposition and sociocultural conditions hypotheses for men's historical dominance of the arts, sciences, and sports. Distance running is ideal because it indicates enduring competitiveness, allows objective comparisons and is accessible, acceptable, and popular for both men and women. These points apply especially well in the U.S. where distance running is equally popular for men and women, and the opportunities and incentives do not favor men. As reviewed, the data from the U.S. over the past four decades come down firmly on the side of the evolved predispositions hypothesis: more men engage in dedicated training; this is reflected in a sex difference in relative performance; and this sex difference in relative performance, although decreasing in the 1970s and 1980s, remains stable and sizeable.

Table 1 American male and female 25th best distance running performances, 2000–2010

Event (m)	Mean 2000–2010			Correlation with year		
	Female (s)	Male (s)	% Difference	Female	Male	% Difference
800	124.6	107.7	15.7	−.66*	−.79*	−.49
1,500	255.5	221.3	15.5	−.57	−.58	−.19
5,000	953.0	821.4	16.0	−.37	−.73*	.59
10,000	2020.7	1733.2	16.6	−.49	−.73*	.39
42,195	9728.0	8347.9	16.5	−.72*	−.63	−.12

* $p < .05$

A crucial question is whether future studies will reveal a sex difference in enduring competitiveness in other cultural display domains. As noted above, there are other sports where performances could be analyzed using a similar approach to that described here. Even clearer results may emerge by focusing on individuals' self-reported training and studies from the "deliberate practice" tradition may prove especially valuable. Researchers in this area have made great strides in specifying the kinds of training necessary for exceptional achievement, yet they have generally paid little attention to variation in training motivation (Chabris & Glickman, 2006; Ericsson et al., 2009). Nonetheless, some studies have assessed training practices separately by sex and differences sometimes emerge. For example, de Bruin et al. (2008) studied the development of chess ability in a cohort of highly promising Dutch youngsters: although males and females benefited similarly from various practice techniques, males engaged in 150 % more serious study alone, the technique that yields by far the greatest payoff.

Another important question is whether the sex difference in enduring competitiveness indicated in the U.S. will hold in other cultures, especially gender egalitarian ones. There are reasons to think it will. First, although sex differences in many traits vary widely, some sex differences, especially motivations and preferences, may be universally robust. One example is men's greater drive for sex, especially in short-term or uncommitted contexts (Baumeister, Catanese, & Vohs, 2001; Lippa, 2009; Schmitt, 2005). Another is women's relatively greater occupational preference to work with people rather than things (Lippa, 2010; see also Hansen, 1988; Su, Rounds, & Armstrong, 2009). Second, cross-cultural tests of purely sociocultural models (e.g., women's empowerment and related constructs explain all variation in sex differences: Eagly & Wood, 1999) generally fare poorly compared to those that specify how social conditions interact with evolved predispositions (Gangestad, Haselton, & Buss, 2006; Lippa, 2009, 2010; Schmitt, Realo, Voracek, & Allik, 2008).

One clear prediction of the present framework concerns "status vs. resources." In particular, males should be relatively more motivated to achieve in contexts where their talent allows them to compete for status (which often translates into resources and mates) whereas females will be relatively more likely to compete for resources. Thus, the sex difference in enduring competitiveness in a particular domain should be weaker in societies with greater performance-related material rewards. As noted in the section, "Domain Indicates Quality," the monetary payoffs for elite American distance running appear modest. By contrast, for elite runners from nations with fewer economic opportunities, the monetary payoffs for running well in world competitions and road races may be quite large, and the sex difference is thus predicted to be smaller there. Addressing this prediction could be complicated

by the fact that in such nations there may be external barriers to female sports achievement. More generally, cross-national assessments of the sex difference in relative performance must consider the extent to which the conditions that make distance running ideal for study in the U.S. (e.g., similar opportunities and incentives for men and women) hold in the nation(s) under consideration.

The "status vs. resources" prediction might also be addressed by examining different contexts within societies. One possibility is comparing the sex difference in relative performance for "Open" (i.e., all age) competitors with that of older, "masters" competitors. The popularity of competition for runners in their 40s, 50s, 60s, and 70s has burgeoned in recent decades, despite the fact that elite masters performances yield few tangible benefits (Ransdell, Vener, & Huberty, 2009). Thus, one can predict that the sex difference in relative performance and training dedication will be more pronounced among masters runners. Although this prediction has not been formally tested, the fact that the percentage sex difference in world records is substantially greater for masters runners than for Open runners (Ransdell et al., 2009; Tanaka & Seals, 2003) strongly suggests it will be upheld. Nonetheless, because older female competitors generally came of age when there were fewer sports opportunities for them, this pattern is open to alternative interpretations.

The ultimate benefit of studying sex differences in enduring competitiveness from an evolutionary perspective is not to support an essentialist position (e.g., "Men but not women are competitive. Period"). The payoff, instead, should be improved understanding of the various factors that affect long-term achievement motivation. This article has focused on the importance of sex, but it has also highlighted that motivation should be modulated by whether achievement in the domain yields status or resources and whether one perceives that they possess talent in the domain. An evolutionary framework may also suggest other relevant factors, such as an individual's prioritizing of mating or parenting (Farrelly & Nettle, 2007; Kanazawa, 2000).

Although achievement motivation has long been a central topic in psychology (e.g., Bandura, 1997; Deci & Ryan, 2000; Eccles & Wigfield, 2002), little work has addressed motivation for long-term achievement in cultural display domains. As noted above, this is true of research in the deliberate practice tradition. A similar neglect has characterized research addressing men's persistent over-representation in many scientific fields, especially the so-called "hard sciences" (Ceci, Williams, & Barnett, 2009). Much effort has been expended testing whether male over-representation is due to institutional barriers (e.g., various kinds of discrimination against women) or sex differences in intellectual abilities (e.g., mental rotation; male overrepresentation in the "right tail"). However, recent empirical studies find that both kinds of explanation have limited explanatory value (barriers: Ceci & Williams, 2011; Marsh, Jayasinghe, & Bond, 2011; abilities: Ceci et al., 2009; Spelke, 2005). Instead, men's dominance seems largely due to their motivation: on average, men are substantially more motivated to work with physical objects rather than people (Hansen, 1988; Lippa, 2010; Su et al., 2009) and men are more willing than women to prioritize the professional sphere (i.e., status-relevant) over the domestic one, especially when they have young children (Ferriman, Lubinski, & Benbow, 2009; Hakim, 2006; Mason & Goulden, 2004). As research better characterizes sex differences in motivation and how these interact with environmental and social conditions, it should be possible to craft policies to better achieve desirable outcomes, including policies that provide men and women genuinely equal opportunities to flourish (Ceci & Williams, 2010).

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References

Agassi, A. (2009). *Open: An autobiography*. New York: Knopf.

All-Time Performances. (2010). In *Association of Road Racing Statisticians*. Retrieved December 27, 2010, from http://www.arrs.net/AllTime/AL_Mara.htm.

Andersson, M. (1994). *Sexual selection*. Princeton, NJ: Princeton University Press.

Athletics at the 1972. (2011). In *Wikipedia*. Retrieved April 4, 2011, from http://en.wikipedia.org/wiki/Athletics_at_the_1972_Summer_Olympics.

Athletics at the 2008. (2011). In *Wikipedia*. Retrieved March 11, 2011, from http://en.wikipedia.org/wiki/Athletics_at_the_2008_Summer_Olympics.

Backmand, H., Kujala, U., Sarna, S., & Kaprio, J. (2010). Former athletes' health-related lifestyle behaviours and self-rated health in late adulthood. *International Journal of Sports Medicine, 31*, 751–758.

Baker, J., Côté, J., & Abernethy, B. (2003). Sport-specific practice and the development of expert decision-making in team ball sports. *Journal of Applied Sport Psychology, 15*, 12–25.

Bale, P., Bradbury, D., & Colley, E. (1986). Anthropometric and training variables related to 10 km running performance. *British Journal of Sports Medicine, 20*, 170–173.

Bale, P., Rowell, S., & Colley, E. (1985). Anthropometric and training characteristics of female marathon runners as determinants of distance running performance. *Journal of Sports Sciences, 3*, 115–126.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.

Battersby, C. (1989). *Gender and genius*. London: Women's Press.

Baumeister, R. F., Catanese, K. R., & Vohs, K. D. (2001). Is there a gender difference in strength of sex drive? Theoretical views, conceptual distinctions, and a review of relevant evidence. *Personality and Social Psychology Review, 5*, 242–273.

Baumeister, R. F., & Sommer, K. L. (1997). What do men want? Gender differences and two spheres of belongingness: Comment on Cross and Madson (1997). *Psychological Bulletin, 122*, 38–44.

Bennett, W. C. (1935). *The Tarahumara: An Indian tribe of northern Mexico*. Chicago: University of Chicago Press.

Berg, K. (2003). Endurance training and performance in runners: Research limitations and unanswered questions. *Sports Medicine, 33*, 59–73.

Betzig, L. L. (1986). *Despotism and differential reproduction: A Darwinian view of history*. New York: Aldine.

Beverly, J. (2008). Born at the right time: The renaissance in high school running. *Running Times, 360*, 37–40.

Bjorkqvist, K. (1994). Sex differences in physical, verbal, and indirect aggression: A review of recent research. *Sex Roles, 30*, 177–183.

Bliege Bird, R., & Smith, E. A. (2005). Signaling theory, strategic interaction, and symbolic capital. *Current Anthropology, 46*, 221–248.
Bowen, W. G., & Levin, S. A. (2003). *Reclaiming the game: College sports and educational values*. Princeton, NJ: Princeton University Press.
Budd, Z., & Eley, H. (1989). *Zola: Autobiography of Zola Budd*. London: Partridge Press.
Burfoot, A. (2011). The turning point. *Runner's World, 46*(1), 58–65.
Buss, D. M., & Schmitt, D. P. (1993). Sexual strategies theory: An evolutionary perspective on human mating. *Psychological Review, 100*, 204–232.
Byrnes, J. P., Miller, D. C., & Schafer, W. D. (1999). Gender differences in risk taking: A meta-analysis. *Psychological Bulletin, 125*, 367–383.
Callen, K. E. (1983). Mental and emotional aspects of long-distance running. *Psychosomatics, 24*, 133–151.
Cameron, E., Day, T., & Rowe, L. (2003). Sexual conflict and indirect benefits. *Journal of Evolutionary Biology, 16*, 1055–1060.
Campbell, A. (1999). Staying alive: Evolution, culture, and women's intrasexual aggression. *Behavioral and Brain Sciences, 22*, 203–252.
Cashdan, E. (1996). Women's mating strategies. *Evolutionary Anthropology, 5*, 134–143.
Ceci, S. J., & Williams, W. M. (2010). *The mathematics of sex: How biology and society conspire to limit talented women and girls*. New York: Oxford University Press.
Ceci, S. J., & Williams, W. M. (2011). Understanding current causes of women's underrepresentation in science. *Proceedings of the National academy of Sciences of the United States of America, 108*, 3157–3162.
Ceci, S. J., Williams, W. M., & Barnett, S. M. (2009). Women's underrepresentation in science: Sociocultural and biological considerations. *Psychological Bulletin, 135*, 218–261.
Chabris, C. F., & Glickman, M. E. (2006). Sex differences in intellectual performance. *Psychological Science, 17*, 1040–1046.
Chapman, A. (1982). *Drama and power in a hunting society: The Selk'nam of Tierra del Fuego*. New York: Cambridge University Press.
Chase, M. A., & Dummer, G. M. (1992). The role of sports as a social status determinant in children. *Research Quarterly for Exercise and Sport, 63*, 418–424.
Cheuvront, S. N., Carter, R., Deruisseau, K. C., & Moffatt, R. J. (2005). Running performance differences between men and women: An update. *Sports Medicine, 35*, 1017–1024.
Clement, D. B., Taunton, J. E., Smart, G. W., & McNicol, K. L. (1981). A survey of overuse running injuries. *The Physician and Sports Medicine, 9*, 47–58.
Colley, A. (1987). Attitudes to the female sex-role and sex-typing of physical activities. *International Journal of Sport Psychology, 18*, 19–29.
Countries and Economies. (n.d.). In *The World Bank*. Retrieved from http://data.worldbank.org/country. Accessed 4 May 2012.
Croson, R., & Gneezy, U. (2009). Gender differences in preferences. *Journal of Economic Literature, 47*, 448–474.
de Block, A., & Dewitte, S. (2009). Darwinism and the cultural evolution of sports. *Perspectives in Biology and Medicine, 52*, 1–16.
de Bruijn, G. J., de Groot, R., van den Putte, B., & Rhodes, R. (2009). Conscientiousness, extroversion, and action control: Comparing moderate and vigorous physical activity. *Journal of Sport & Exercise Psychology, 31*, 724–742.
de Bruin, A. B. H., Smits, N., Rikers, R. M. J. P., Henk, G., & Schmidt, H. G. (2008). Deliberate practice predicts performance over time in adolescent chess players and drop-outs: A linear mixed models analysis. *British Journal of Psychology, 99*, 473–497.
Deaner, R. O. (2006a). More males run fast: A stable sex difference in competitiveness in U.S. distance runners. *Evolution and Human Behavior, 27*, 63–84.
Deaner, R. O. (2006b). More males run relatively fast in U.S. road races: Further evidence of a sex difference in competitiveness. *Evolutionary Psychology, 4*, 303–314.
Deaner, R. O., Geary, D. C., Ham, S. A., & Kruger, J. (2011). *An evolved sex difference in the predisposition for physical competition: Males play sports much more than females even in the contemporary U.S.* (manuscript submitted).
Deaner, R. O., Masters, K. S., Ogles, B. M., & LaCaille, R. A. (2011b). Marathon performance as a predictor of competitiveness and training in men and women. *Journal of Sport Behavior, 34*, 325–342.
Deaner, R. O., & Mitchell, D. (2011). More men run relatively fast in U.S. road races, 1981–2006: A stable sex difference in non-elite runners. *Evolutionary Psychology, 9*, 600–621.
Deaner, R. O., & Smith, B. A. (2012). *Sex differences in sports across 50 societies*. Available at SSRN: http://ssrn.com/abstract=2009329. Accessed 4 May 2012.
DeBruine, L., Jones, B. C., Frederick, D. A., Haselton, M. G., Penton-Voak, I. S., & Perrett, D. I. (2010). Evidence for menstrual cycle shifts in women's preferences for masculinity: A response to Harris "Menstrual cycle and facial preferences reconsidered". *Evolutionary Psychology, 8*, 768–775.
Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 227–268.
Dolgener, F. A., Kolkhorst, F. W., & Whitsett, D. A. (1994). Long slow distance training in novice marathoners. *Research Quarterly for Exercise and Sport, 65*, 339–346.
Dreber, A., Gerdes, C., & Gränsmark, P. (2010). Beauty queens and battling knights: Risk taking and attractiveness in chess. *IZA DP No. 5314*.
Eagly, A. H., & Wood, W. (1999). The origins of sex differences in human behavior: Evolved dispositions versus social roles. *American Psychologist, 54*, 408–423.
Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*, 109–132.
Eddy, D. O., Sparks, K. L., & Adelizi, D. A. (1977). The effects of continuous and interval training in women and men. *European Journal of Applied Physiology, 37*, 83–92.
Ericsson, K. A., Krampe, R. Th., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363–406.
Ericsson, K. A., Nandagopal, K., & Roring, R. W. (2009). Toward a science of exceptional achievement: Attaining superior performance through deliberate practice. *Annals of the New York Academy of Sciences, 1172*, 199–217.
Farrelly, D., & Nettle, D. (2007). Marriage affects competitive performance in male tennis players. *Journal of Evolutionary Psychology, 5*, 141–148.
Faurie, C., Pontier, D., & Raymond, M. (2004). Student athletes claim to have more sexual partners than other students. *Evolution and Human Behavior, 25*, 1–8.
Ferriman, K., Lubinski, D., & Benbow, C. P. (2009). Work preferences, life values, and personal views of top math/science graduate students and the profoundly gifted: Developmental changes and gender differences during emerging adulthood and parenthood. *Journal of Personality and Social Psychology, 97*, 517–532.
FIFA Big Count. (2007). In *FIFA*. Retrieved May 31, 2007, from http://www.fifa.com/mm/document/fifafacts/bcoffsurv/bigcount.statspackage_7024.pdf. Accessed 4 May 2012.
Fischer, M. (2004). Female intrasexual competition decreases female facial attractiveness. *Proceedings of the Royal Society of London Biology Supplement, 271*, S283–S285.
Földesi, G. S. (2004). Social status and mobility of Hungarian elite athletes. *International Journal of the History of Sport, 21*, 710–726.
Frick, B. (2011a). Gender differences in competitiveness: Empirical evidence from professional distance running. *Labour Economics, 18*, 389–398.
Frick, B. (2011b). Gender differences in competitive orientations: Empirical evidence from ultramarathon running. *Journal of Sports Economics, 12*, 317–340.
Frietsch, R., Haller, I., Funken-Vrohlings, M., & Gruppa, H. (2009). Gender-specific patterns in patenting and publishing. *Research Policy, 38*, 590–599.

Gangestad, S. W., Haselton, M. G., & Buss, D. M. (2006). Evolutionary foundations of cultural variation: Evoked culture and mate preferences. *Psychological Inquiry, 17*, 75–95.
Geary, D. C. (2010). *Male, female: The evolution of human sex differences* (2nd ed.). Washington, DC: American Psychological Association.
Gill, D. L. (1986). Competitiveness among females and males in physical-activity classes. *Sex Roles, 15*, 233–247.
Goldin, C., & Rouse, C. (2000). Orchestrating impartiality: The impact of "blind" auditions on female musicians. *American Economic Review, 90*, 715–741.
Gotaas, T. (2009). *Running: A global history*. London: Reaktion Books.
Greene, L., & Pate, R. (2004). *Training for young distance runners* (2nd ed.). Champaign, IL: Human Kinetics.
Griskevicius, V., Cialdini, R. B., & Kenrick, D. T. (2006). Peacocks, Picasso, and parental investment: The effects of romantic motives on creativity. *Journal of Personality and Social Psychology, 91*, 63–76.
Guttmann, A. (1991). *Women's sports: A history*. New York: Columbia University Press.
Guttmann, A. (2004). *Sports: The first five millennia*. Amherst, MA: University of Massachusetts Press.
Hagan, R. D., Smith, M. G., & Gettman, L. R. (1981). Marathon performance in relation to maximal aerobic power and training indices. *Medicine and Science in Sports and Exercise, 13*, 185–189.
Hakim, C. (2006). Women, careers, and work–life preferences. *British Journal of Guidance and Counseling, 34*, 279–294.
Ham, S. A., Kruger, J., & Tudor-Locke, C. (2009). Participation by US adults in sports, exercise, and recreational physical activities. *Journal of Physical Activity & Health, 6*, 6–14.
Hamilton, W. D., & Zuk, M. (1982). Heritable true fitness and bright birds: A role for parasites. *Science, 218*, 384–387.
Hansen, J. C. (1988). Changing interests of women: Myth or reality? *Applied Psychology, 37*, 133–150.
Hawkes, K., & Bliege Bird, R. (2002). Showing off, handicap signaling, and the evolution of men's work. *Evolutionary Anthropology, 11*, 58–67.
Hedges, L. V., & Nowell, A. (1995). Sex-differences in mental test-scores, variability, and numbers of high-scoring individuals. *Science, 269*, 41–45.
Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience, 9*, 58–65.
Hogshead-Makar, N., & Zimbalist, A. (Eds.). (2007). *Equal play: Title IX and social change*. Philadelphia: Temple University Press.
Hönekopp, J., & Schuster, M. (2010). A meta-analysis on 2D:4D and athletic prowess: Substantial relationships but neither hand out-predicts the other. *Personality and Individual Differences, 48*, 4–10.
Hooper, P., & Miller, G. F. (2008). Mutual mate choice can drive ornament evolution even under perfect monogamy. *Adaptive Behavior, 16*, 53–70.
Howard, R. (2005). Are gender differences in high achievement disappearing? A test in one intellectual domain. *Journal of Biosocial Science, 37*, 371–380.
Hrdy, S. B. (1999). *The woman that never evolved*. Cambridge, MA: Harvard University Press. (Originally published 1981.)
Hyde, J. S. (2005). The gender similarities hypothesis. *American Psychologist, 60*, 581–592.
Hyde, J. S., & Kling, K. C. (2001). Women, motivation, and achievement. *Psychology of Women Quarterly, 25*, 364–378.
In Brief. (2011). In *Guttmacher Institute*. Retrieved January 2011, from http://www.guttmacher.org/pubs/FB-ATSRH.html.
Johnsgard, K. (1985). The motivation of the long distance runner: I. *Journal of Sports Medicine and Physical Fitness, 25*, 135–139.
Joyner, M. J. (1993). Physiological limiting factors and distance running: Influence of gender and age on record performances. *Exercise and Sport Sciences Reviews, 21*, 103–133.
Judah, T. (2009). *Bikila: Ethiopia's barefoot Olympian*. London: Reportage Press.
Kalinowski, A. G. (1985). The development of Olympic swimmers. In B. S. Bloom (Ed.), *Developing talent in young people* (pp. 139–192). New York: Ballantine.
Kanazawa, S. (2000). Scientific discoveries as cultural displays: A further test of Miller's courtship model. *Evolution and Human Behavior, 21*, 317–321.
Kanazawa, S. (2003). Why productivity fades with age: The crime–genius connection. *Journal of Research in Personality, 37*, 257–272.
Karp, J. R. (2007). Training characteristics of qualifiers for the US Olympic Marathon Trials. *International Journal of Sports Physiology and Performance, 2*, 72–92.
Kirkpatrick, M., & Ryan, M. (1991). The evolution of mating preferences and the paradox of the Lek. *Nature, 350*, 33–38.
Koivula, N. (1995). Ratings of gender appropriateness of sports participation: Effects of gender-based schematic processing. *Sex Roles, 33*, 543–557.
Kokko, H., Jennions, M. D., & Brooks, R. (2006). Unifying and testing models of sexual selection. *Annual Review of Ecology Evolution and Systematics, 37*, 43–66.
Kuscsik, N. (1977). The history of women's participation in the marathon. *Annals of the New York Academy of Sciences, 301*, 862–876.
Kwan, M., & James, L. M. (1998). *Michelle Kwan: My story-heart of a champion*. New York: Scholastic.
Lauriola, M., Zelli, A., Calcaterra, C., Cherubini, D., & Spinelli, D. (2004). Sport gender stereotypes in Italy. *International Journal of Sport Psychology, 35*, 189–206.
Law, M. P., Côté, J., & Ericsson, K. A. (2007). Characteristics of expert development in rhythmic gymnastics: A retrospective study. *International Journal of Sport and Exercise Psychology, 5*, 82–103.
Lehre, A. C., Lehre, K. P., Laake, P., & Danbolt, N. C. (2009). Greater intrasex phenotype variability in males than in females is a fundamental aspect of gender differences in humans. *Developmental Psychobiology, 51*, 198–206.
Liebenberg, L. (2006). Persistence hunting by modern hunter–gatherers. *Current Anthropology, 47*, 1017–1025.
Lieberman, D. E., Bramble, D. M., Raichlen, D. A., & Shea, J. J. (2009). Brains, brawn, and the evolution of human endurance running capabilities. In F. E. Grine & R. E. Leakey (Eds.), *The first humans: Origin and early evolution of the genus Homo* (pp. 77–92). New York: Springer.
Life-time. (2011). In *Association of Road Racing Statisticians*. Retrieved April 5, 2011, from http://www.arrs.net/PM_Life.htm.
Lippa, R. A. (2009). Sex differences in sex drive, sociosexuality, and height across 53 nations: Testing evolutionary and social structural theories. *Archives of Sexual Behavior, 38*, 631–651.
Lippa, R. A. (2010). Sex differences in personality traits and gender-related occupational preferences across 53 nations: Testing evolutionary and social-environmental theories. *Archives of Sexual Behavior, 39*, 619–636.
List of Largest. (2011). In *Wikipedia*. Retrieved February 4, 2011, from http://en.wikipedia.org/wiki/List_of_largest_running_events.
List of Marathons. (2011). In *Wikipedia*. Retrieved April 11, 2011, from http://en.wikipedia.org/wiki/List_of_marathons.
Llaurens, V., Raymond, M., & Faurie, C. (2009). Ritual fights and male reproductive success in a human population. *Journal of Evolutionary Biology, 22*, 1854–1859.
Lombardo, M. (2012). On the evolution of sport. *Evolutionary Psychology, 10*, 1–28.
Long, J. S. (1992). Measures of sex differences in scientific productivity. *Social Forces, 71*, 402–410.
Lorge, A. (2010). Working for the weekend: Elite runners in this year's National Marathon Championships who hold down day jobs. *Running Times, 381*, 45–51.
Low, B. S. (1992). Sex, coalitions, and politics in preindustrial societies. *Politics and the Life Sciences, 11*, 63–80.
Lytton, H., & Romney, D. M. (1991). Parents' differential socialization of boys and girls: A meta-analysis. *Psychological Bulletin, 109*, 267–296.
Maass, A., D'Ettole, C., & Cadinu, M. (2008). Checkmate? The role of gender stereotypes in the ultimate intellectual sport. *European Journal of Social Psychology, 38*, 231–245.
MacArthur, D. G., & North, K. N. (2005). Genes and human elite athletic performance. *Human Genetics, 116*, 331–339.

Maccoby, E. E. (1998). *The two sexes: Growing up apart, coming together*. Cambridge, MA: Belknap Press.
Macera, C. A. (1992). Lower extremity injuries in runners: Advances in prediction. *Sports Medicine, 13*, 50–57.
Manning, J. T., & Pickup, L. J. (1998). Symmetry and performance in middle distance runners. *International Journal of Sports Medicine, 19*, 205–209.
Marsh, H. W., Jayasinghe, U. W., & Bond, N. W. (2011). Gender differences in peer reviews of grant applications: A substantive-methodological synergy in support of the null hypothesis model. *Journal of Informetrics, 5*, 167–180.
Mason, M. A., & Goulden, M. (2004). Marriage and baby blues: Redefining gender equity in the academy. *Annals of the American Academy of Political and Social Science, 596*, 86–103.
Masters, K. S., Ogles, B. M., & Jolton, J. A. (1993). The development of an instrument to measure motivation for marathon running: The motivation of marathoners scales (MOMS). *Research Quarterly for Exercise and Sport, 64*, 134–143.
Matteo, S. (1986). The effect of sex and gender-schematic processing on sport participation. *Sex Roles, 15*, 417–432.
McIntyre, M. H. (2006). The use of digit ratios as markers for perinatal androgen action. *Reproductive Biology and Endocrinology*, *4*(10). Retrieved from http://www.rbej.com/content/pdf/1477-7827-4-10.pdf. Accessed 4 May 2012.
McKelvie, S. J., Valliant, P. M., & Asu, M. E. (1985). Physical training and personality factors as predictors of marathon time and training injury. *Perceptual and Motor Skills, 60*, 551–566.
Messner, M. A. (2002). *Taking the field: Women, men, and sports*. Minneapolis: University of Minnesota Press.
Metzler, B. (2010). On the verge: patience, progression put Brett Gotcher on the fast track after 2:10 debut marathon. *Running Times, 377*, 50–52.
Midgley, A. W., McNaughton, L. R., & Jones, A. M. (2007). Training to enhance the physiological determinants of long-distance running performance? Can valid recommendations be given to runners and coaches based on current scientific knowledge? *Sports Medicine, 37*, 857–880.
Miller, G. F. (1999). Sexual selection for cultural display. In R. Dunbar, C. Knight, & C. Power (Eds.), *The evolution of culture: An interdisciplinary view* (pp. 71–91). New Brunswick, NJ: Rutgers University Press.
Miller, G. F. (2000). *The mating mind: How sexual choice shaped the evolution of human nature*. New York: Doubleday.
Møller, A. P., & Thornhill, R. (1998). Bilateral symmetry and sexual selection: A meta-analysis. *American Naturalist, 151*, 174–192.
Møller, A. P., Thornhill, R., & Gangestad, S. W. (2005). Direct and indirect tests for publication bias: Asymmetry and sexual selection. *Animal Behaviour, 70*, 497–506.
Monsaas, J. A. (1985). Learning to be a world-class tennis player. In B. S. Bloom (Ed.), *Developing talent in young people* (pp. 211–269). New York: Ballantine.
National Federation of State High School Associations. (2010). *2009–10 High school athletics participation survey*. Indianapolis, IN: National Federation of State High School Associations.
NCAA Research. (2008). *Gender equity: 2005–06 NCAA gender-equity report*. Indianapolis, IN: National Collegiate Athletic Association.
Nettle, D., & Clegg, H. (2006). Schizotypy, creativity and mating success in humans. *Proceedings of the Royal Society of London, B: Biological Sciences, 273*, 611–615.
Noakes, T. (2001). *Lore of running* (4th ed.). Champaign, IL: Human Kinetics.
Ogles, B. M., & Masters, K. S. (2000). Older vs. younger adult male marathon runners: Participative motives and training habits. *Journal of Sport Behavior, 23*, 130–142.
Ogles, B. M., & Masters, K. S. (2003). A typology of marathon runners based on cluster analysis of motivations. *Journal of Sport Behavior, 26*, 69–85.
Ogles, B. M., Masters, K. S., & Richardson, S. A. (1995). Obligatory running and gender: An analysis of participative motives and training habits. *International Journal of Sports Psychology, 26*, 233–248.
Olds, T., Tomkinson, G., Leger, L., & Cazorla, G. (2006). Worldwide variation in the performance of children and adolescents: An analysis of 109 studies of the 20-m shuttle run test in 37 countries. *Journal of Sports Sciences, 24*, 1025–1038.
Olympic Sports. (2011). In *Wikipedia*. Retrieved April 7, 2011, from http://-en.wikipedia.org/wiki/Olympic_sports.
Pearsall, M. (1950). *Klamath childhood and education*. Berkeley: University of California Press.
Phelps, M., & Abrahamson, A. (2009). *No limits: The will to succeed*. New York: Free Press.
Prize Money. (2011). In *Association of Road Racing Statisticians*. Retrieved March 9, 2011, from http://www.arrs.net/PM_ByYr.htm.
Puts, D. A. (2010). Beauty and the beast: Mechanisms of sexual selection in humans. *Evolution and Human Behavior, 31*, 157–175.
Puts, D. A., McDaniel, M. A., Jordan, C. L., & Breedlove, S. M. (2008). Spatial ability and prenatal androgens: Meta-analyses of congenital adrenal hyperplasia and digit ratio (2D:4D) studies. *Archives of Sexual Behavior, 37*, 100–111.
Putz, D. A., Gaulin, S. J. C., Sporter, R. J., & McBurney, D. H. (2004). Sex hormones and finger length: What does 2D:4D indicate? *Evolution and Human Behavior, 25*, 182–199.
Qualifying Standards. (n.d.-a). In *USA Track & Field*. Retrieved from http://www.usatf.org/events/2008/olympictrials-marathon-men/entry/qualifyingstandards.asp. Accessed 4 May 2012.
Qualifying Standards. (n.d.-b). In *USA Track & Field*. Retrieved from http://www.usatf.org/events/2008/olympictrials-marathon-women/entry/qualifyingstandards.asp. Accessed 4 May 2012.
Ransdell, L. B., Vener, J., & Huberty, J. (2009). Masters athletes: An analysis of running, swimming and cycling performance by age and gender. *Journal of Exercise Science & Fitness, 7*, S61–S73.
Retton, M. L., Karolyi, B., & Powers, J. (1986). *Mary Lou: Creating an Olympic champion*. New York: Dell Publishing Company.
Robbins, L. (2009). Inspiration for a new crop of U.S. Runners. *New York Times*. Retrieved Nov 1, 2009, from http://www.nytimes.com/2009/11/02/sports/02robbins.html. Accessed 4 May 2012.
Roberts, S. C., & Little, A. C. (2008). Good genes, complementary genes and human mate preferences. *Genetica, 132*, 309–321.
Ronay, R., & von Hippel, W. (2010). The presence of an attractive woman elevates testosterone and physical risk taking in young men. *Social Psychological and Personality Science, 1*, 57–64.
Running USA's State of the Sport 2010—Part I. (2010). In *Running USA*. Retrieved April 11, 2010, from http://www.runningusa.org/node/57852.
Running USA's State of the Sport 2010–Part III. (2010). In *Running USA*. Retrieved August 4, 2010, from http://www.runningusa.org/node/57770#58551.
Russ, J. (1983). *How to suppress women's writing*. Austin, TX: University of Texas Press.
Sandrock, M. (1996). *Running with the legends: Training and racing insights from 21 great runners*. Champaign, IL: Human Kinetics.
Schmitt, D. P. (2005). Sociosexuality from Argentina to Zimbabwe: A 48-nation study of sex, culture, and strategies of human mating. *Behavioral and Brain Sciences, 28*, 247–311.
Schmitt, D. P., & Buss, D. M. (1996). Strategic self-promotion and competitor derogation: Sex and context effects on the perceived effectiveness of mate attraction tactics. *Journal of Personality and Social Psychology, 70*, 1185–1204.
Schmitt, D. P., Realo, A., Voracek, M., & Allik, J. (2008). Why can't a man be more like a woman? Sex differences in big five personality traits across 55 cultures. *Journal of Personality and Social Psychology, 94*, 168–182.
Sears, E. S. (2001). *Running through the ages*. London: McFarland & Company.
Seiler, S., De Koning, J. J., & Foster, C. (2007). The fall and rise of the gender difference in elite anaerobic performance 1952–2006. *Medicine and Science in Sports and Exercise, 39*, 534–540.

Shephard, R. J. (2000). Exercise and training in women: Part I. Influence of gender on exercise and training responses. *Canadian Journal of Applied Physiology, 25*, 19–34.

Shulman, J. L., & Bowen, W. G. (2001). *The game of life: College sports and educational values*. Princeton, NJ: Princeton University Press.

Skinner, J. S., Jaskolski, A, Jaskolska, A., Krasnoff, J., Gagnon, J., Leon, A. S., … Bouchard, C. (2001). Age, sex, race, initial fitness, and response to training: The HERITAGE Family Study. *Journal of Applied Physiology*, *90*, 1770–1776.

Slovic, P. (1977). Empirical study of training and performance in the marathon. *Research Quarterly, 48*, 769–777.

Sohi, A. S., & Yusuff, K. B. (1987). The socioeconomic status of elite Nigerian athletes in perspective of social stratification and mobility. *International Review for the Sociology of Sport, 22*, 295–303.

Sparling, P. B., O'Donnell, E. M., & Snow, T. K. (1998). The gender difference in distance running performance has plateaued: An analysis of world rankings from 1980 to 1996. *Medicine and Science in Sports and Exercise, 30*, 1725–1729.

Spelke, E. S. (2005). Sex differences in intrinsic aptitude for mathematics and science? A critical review. *American Psychologist, 62*, 950–958.

Spence, J. T., & Helmreich, R. L. (1983). Achievement-related motives and behaviors. In J. T. Spence (Ed.) *Achievement and achievement motives: Psychological and sociological approaches* (pp. 10–74). San Francisco: W. H. Freeman.

Stark, R. (2010). Holding out: Stephen Haas extends his running career with leap to the marathon. *Running Times, 377*, 46–47.

Statistics. (n.d.). In *Running USA*. Retrieved from http://www.runningusa.org/statistics. Accessed 4 May 2012.

Stevenson, B. (2007). Title IX and the evolution of high school sports. *Contemporary Economic Policy, 25*, 486–505.

Su, R., Rounds, J., & Armstrong, P. I. (2009). Men and things, women and people: A meta-analysis of sex differences in interests. *Psychological Bulletin, 135*, 859–884.

Suggs, W. (2005). *A place on the team: The triumph and tragedy of Title IX*. Princeton, NJ: Princeton University Press.

Swaddle, J. P. (2003). Fluctuating asymmetry, animal behavior, and evolution. *Advances in the Study of Behavior, 3*, 169–205.

Swimming at the 1972. (2011). *In Wikipedia*. Retrieved February 2, 2011, from http://en.wikipedia.org/wiki/Swimming_at_the_1972_Summer_Olympics.

Swimming at the 2008. (2011). *In Wikipedia*. Retrieved February 2, 2011, from http://en.wikipedia.org/wiki/Swimming_at_the_2008_Summer_Olympics.

Tanaka, H., & Seals, D. R. (2003). Invited Review: Dynamic exercise performance in masters athletes: Insight into the effects of primary human aging on physiological functional capacity. *Journal of Applied Physiology, 95*, 2152–2162.

Taylor, S. E., Klein, L. C., Lewis, B. P., Gruenewald, T. L., Gurung, R. A. R., & Updegraff, J. A. (2000). Biobehavioral responses to stress in females: Tend and befriend, not fight-or-flight. *Psychological Review, 107*, 411–429.

The XXIX Olympic Games. (2008). In *IAAF*. Retrieved February 5, 2008, from http://www.iaaf.org/oly08/standards/index.html.

Tjelta, L. I., & Enoksen, E. (2010). Training characteristics of male junior cross country and track runners on European top level. *International Journal of Sports Science & Coaching, 5*, 193–203.

Tomkinson, G. R., Popovic, N., & Martin, M. (2003). Bilateral symmetry and the competitive standard attained in elite and sub-elite sport. *Journal of Sports Sciences, 21*, 201–211.

Track & Field News Lists. (n.d.). In *Track & Field News*. Retrieved from http://www.trackandfieldnews.com/index.php/lists.

United States Commission on Civil Rights. (1980). *More hurdles to clear: Women and girls in competitive athletics* (Clearinghouse Publication Number 63). Washington, DC: Commission on Civil Rights.

USA Top Marks Lists. (n.d.). In *USA Track & Field*. Retrieved from http://www.usatf.org/Stats/Top-Marks-Lists.aspx. Accessed 4 May 2012.

U.S. Department of Education. (2003). *Open to all: Title IX at thirty*. Washington, DC: Department of Education, Secretary's Commission for Opportunity in Athletics.

van Gent, R. N., Siem, D., van Middelkoop, M., van Os, A. G., Bierma-Zeinstra, S. M. A., Koes, B. W., et al. (2007). Incidence and determinants of lower extremity running injuries in long distance runners: A systematic review. *British Journal of Sports Medicine, 41*, 469–480.

van Mechelen, W. (1992). Running injuries: A review of the epidemiological literature. *Sports Medicine, 14*, 320–355.

Warburton, D. E. R., Nicol, C. W., & Bredin, S. S. D. (2006). Health benefits of physical activity: The evidence. *Canadian Medical Association Journal, 174*, 801–809.

Williams, P. T. (1998). Relationships of heart disease risk factors to exercise quantity and intensity. *Archives of Internal Medicine, 158*, 237–245.

Xie, Y., & Shauman, K. A. (2003). *Women in science: Career processes and outcomes*. Cambridge, MA: Harvard University Press.

Young, B. W., & Salmela, J. H. (2010). Examination of practice activities related to the acquisition of elite performance in Canadian middle distance running. *International Journal of Sport Psychology, 41*, 73–90.

Ziegler, A., Kentenich, H., & Uchanska-Ziegier, B. (2005). Female choice and the MHC. *Trends in Immunology, 26*, 496–502.

Zimbalist, A. (1999). *Unpaid professionals: Commercialism and conflict in big-time college sports*. Princeton, NJ: Princeton University Press.