Original Article

Evolutionary Psychology
July-September 2019: 1–12

DOI: 10.1177/1474704919863164
journals.sagepub.com/home/evp
SAGE

Honest Signals of Status: Facial and Bodily Dominance Are Related to Success in Physical but Not Nonphysical Competition

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Abstract

Recent studies suggest that both facial and bodily dominance promote high status positions and predict status-seeking behaviors such as aggression and social dominance. An evolutionarily relevant context in which associations between these dominance signals and status outcomes may be prevalent are face-to-face status contests. The present study examined whether facial and bodily dominance predicted success in dyadic competitions (one physical discipline, arm wrestling, and three nonphysical disciplines) in men ($N = 125$) in a controlled laboratory setting. Men's bodies and faces were independently rated for physical dominance, and associations of these ratings with contest outcomes as well as mediating and moderating variables (such as physical strength, body height, trait dominance, baseline and reactive testosterone) were examined. Both facial and bodily dominance positively predicted success in the physical discipline, mediated by physical strength, but not in the three nonphysical disciplines. Our findings demonstrate that facial and bodily physical dominance may be honest signals for men's formidability and hence status potential, at least in a physically competitive context.

Keywords

facial dominance, bodily dominance, social status, male competition, testosterone (T)

Date received: March 17, 2019; Accepted: June 13, 2019

Under the influence of intrasexual selection, nonhuman and human males developed formidable traits such as physical strength, fighting abilities, increased body height and behavioral tendencies such as risk-taking or aggressiveness, which are functional in competition and for displaying dominance (Cheng, Tracy, Ho, & Heinrich, 2016; see Puts, Bailey, & Reno, 2015 for a review). In intrasexually competitive contexts, it is crucial for rivals to perceive these signals accurately (Sell, Cosmides, et al., 2009). Thus, displays of dominance are fundamental for attaining higher social status, as the displayer ascends in the hierarchy if his opponent defers. In turn, higher status is expected to yield increased access to resources relevant for survival and reproduction, such as territory, food, and mates (Mehta, Lawless DesJardins, van Vugt, & Josephs, 2017). In small-scale societies, high status is allocated to dominant individuals by subordinates not only to avoid harm from them but also to gain potential benefits (e.g., in intergroup conflicts, von Rueden, Gurven, & Kaplan, 2008). This study aims at examining whether male dominant traits are related to outcomes of one physical and three nonphysical disciplines in a dyadic face-to-face competition, to elucidate whether cues to formidability are valid predictors of proxy measures of status acquisition.

Empirical evidence suggests that bodily characteristics, such as physical strength, upper body size, or body height, are effective predictors of men's fighting abilities (Sell, Hone, &

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Pound, 2012; Sell, Tooby, & Cosmides, 2009), high status, and leadership potential (Murray, 2014; for a review see Blaker & van Vugt, 2014), since leadership may require some dominance-related abilities (e.g., for punishing free riders, Lukaszewski, Simmons, Anderson, & Roney, 2016). For example, among the Tsimané, an Amazonian small-scale society, physically stronger individuals gained more social support and higher status than weaker individuals ($N = 57$, von Rueden et al., 2008). Also, taller candidates in the U.S. presidential elections received more popular votes than their opponents and were also more likely to be reelected ($N = 46$ elections, Stulp, Buunk, Verhulst, & Pollet, 2013). These examples indicate that men's bodily dominance is an influential characteristic regarding their potential for achieving and maintaining high status and leadership positions.

Besides bodily characteristics, facial appearance plays an important role in human status allocation, as it may reveal information about an individual's behavioral tendencies and dispositions (Mueller & Mazur, 1997). One aspect of facial appearance associated with high status and leadership is facial dominance, that is, masculine features such as strong jaws or a prominent chin. In contest competitions, men base the assessment of an opponent's formidability on facial appearance, including facial dominance (Sell, Cosmides, & Tooby, 2014; Sell, Cosmides, et al., 2009; Zilioli et al., 2015), which is thought to convey impressions of aggressiveness (Scott et al., 2014). Mueller and Mazur (1997) showed that facial dominance in male military cadets positively predicted their career success and reproductive success ($N = 337$). Furthermore, recent studies found facial dominance to be an important predictor of leader choice and higher pay reward in upper management (Fruhen, Watkins, & Jones, 2015; Little, 2014; Little, Burriss, Jones, & Roberts, 2007). An objective measure related to facial dominance is the facial width-to-height ratio (reviewed in Dixson, 2017). Differences in facial width-to-height ratio predicted aggressive behavior in male hockey players and in a laboratory task (2 samples, overall $N = 133$, Carré & McCormick, 2008), as well as men's observer-judged aggressiveness based on neutral facial photographs (2 studies, $N = 24$ stimuli photographs, overall $N = 47$ male and female observers, Carré, McCormick, & Mondloch, 2009). Thus, there is evidence that facial dominance may function as a signal for dominant and aggressive behavioral tendencies, which are important factors of men's status acquisition potential in some contexts.

With its various anabolic effects on the musculoskeletal system, including the development of body and muscle mass, the androgenic hormone testosterone (T) is thought to modulate the ontogeny of sexual dimorphism in several traits (Fink, Neave, & Seydel, 2007; Whitehouse et al., 2015) including facial dominance (Little et al., 2007; Marečková et al., 2011; Verdonck, Gaethofs, Carels, & de Zegher, 1999; for an overview see Poutvaara, 2014). According to the *immunocompetence handicap principle*, high T levels have immunosuppressive effects, which only high-quality individuals with good health may be able to withstand (for a review and commentary, see Folstad & Karter, 1992 and Wedekind & Folstad, 1994; for empirical evidence see Rantala, Vainikka, & Kortet, 2003). Accordingly, characteristics related to T levels like facial dominance may be cues to good physical condition. Furthermore, the *challenge hypothesis* (Archer, 2006; Wingfield, Hegner, Dufty, & Ball, 1990) highlights that T levels increase in reproductively relevant contexts such as intrasexual competition or mating opportunities, which in turn may lead to higher aggressiveness. While empirical data are inconsistent regarding an association between baseline T and aggression, a large body of evidence indicates that an acute T reactivity in the context of competition is related to aggressive behavior (Carré & Olmstead, 2015; reviewed in Carré & Archer, 2018) and increases in competitive personality states ($N = 124$, Kordsmeyer & Penke, 2019). In line with this, Pound, Penton-Voak, and Surridge (2009) found evidence for a link between facial dominance and T reactivity in men ($N = 57$) after having engaged in a competitive task, but no association with baseline T. The effects of T, however, are not restricted to physical characteristics. For example, Mehta and Josephs (2006) found T changes to predict motivation to compete again in male–male competitions among men who lost an initial competition ($N = 57$). In another similar study, increases in T (but not baseline T) predicted aggressive behavior in male losers of a dyadic competition ($n = 39$, Carré, Putnam, & McCormick, 2009).

As several studies indicated that T levels are positively related to aggression, dominance, and social status (Edwards, Wetzel, & Wyner, 2006; Olweus, Mattsson, Schalling, & Low, 1980; reviewed in Mazur & Booth, 1998), it might be plausible that leadership is also linked with T. van der Meij, Schaveling, and van Vugt (2016) investigated whether management position was associated with baseline T in men. Their results suggest that employees with higher baseline T levels had a more authoritarian leadership style, but this was only the case for nonmanagers (without any subordinates). This finding is in line with the *mismatch effect*, according to which individuals with high T who are also in a low status position are strongly motivated to use dominance in order to attain a higher hierarchical position (Josephs, Sellers, Newman, & Mehta, 2006). Findings of van der Meij and colleagues' (2016) field study ($N = 125$) and meta-analysis (overall $N = 1{,}103$), however, showed no relationship between leadership and baseline T, indicating that different biological mechanisms may underlie leadership and dominance. An alternative explanation for such null findings or weak associations with T would be that effects of T can be diminished by the inhibitory effects of the hormone cortisol as stated by the *dual-hormone hypothesis* (Mehta & Josephs, 2010). In support of this, the interaction of high T and low cortisol predicted high status positions and the number of subordinates in men (Sherman, Lerner, Josephs, Renshon, & Gross, 2016). To test this possibility, in our study, we included baseline T as a potential moderator and T reactivity as a mediator of associations of facial and bodily dominance with success in a physical competition. Moreover, baseline cortisol was investigated for effects in interaction with T levels, as usually interaction effects of T with baseline cortisol are investigated and reported in the literature (for a brief review see Mehta & Prasad, 2015).

While both facial and bodily dominance have been associated with traits and behavioral propensities related to high status like physical strength (Fink et al., 2007; Sell, Cosmides, et al., 2009), aggressiveness (Carré & McCormick, 2008; Sell et al., 2012), and fighting ability (Lukaszewski et al., 2016), there is a gap in the literature regarding effects on behavioral outcome measures of status contests such as success in direct male–male competitions, an important predictor of status acquisition in dominance-based hierarchies throughout human evolution (reviewed in van Vugt & Tybur, 2015). The present study aims at examining associations of men's facial and bodily dominance with the outcomes of dyadic face-to-face competitions not only in a physical discipline (arm wrestling) but also in three nonphysical disciplines (table pinball soccer, snatching game, and verbal fluency game, see below) in a controlled laboratory setting. The chosen disciplines each require different competencies. While arm wrestling mainly is a physical strength task, table soccer is an agility/reaction speed task, whereas the verbal fluency game requires fluid intelligence and the snatching game reaction speed and logical reasoning ability. Further, we examine potential mediating and moderating variables which are implicated in male–male competition and have been associated with physical dominance in the literature, such as physical strength, body height, baseline and reactive T (both also in interaction with baseline cortisol, Mehta & Josephs, 2010), and personality measures of dominance and competitiveness. We hypothesize that men with higher facial and bodily dominance win more often in the arm wrestling competition (but not in the three nonphysical disciplines), mediated by their physical strength and competition-induced T reactivity, and moderated by their baseline T, upper body size, self-reported trait dominance, and competitiveness.

Method

Participants

We recruited $N = 125$ male heterosexual young adults (mean age = 24.1 years, $SD = 3.3$, range 18–34) with no hormonal disorders (assessed with a standardized screening questionnaire, Schultheiss & Stanton, 2009). The sample size had sufficient power (>.80) to detect effect sizes of Pearson's $r > .24$ (Cohen, 1992). A total of 90.4% of the participants were students (of which only two were enrolled as psychology students). This sample was part of a larger study on associations between postcompetition T reactivity and personality state changes (see Kordsmeyer & Penke, 2019 for more information). All procedures received ethics approval from the local Psychology Ethics Committee (no. 111).

Stimuli and Ratings for Facial and Bodily Physical Dominance

Two photos were taken of each participant's face while standing in front of a white wall from a distance of 2 m, with the participant directly facing the camera (Canon EOS 350D) and asked to show a neutral facial expression. The more suitable of the two photos (in terms of neutral facial expression and head angle) was chosen for this rating study. The photos were presented on computer screens. A sample of $N = 11$ male raters (age: $M = 29.6$ years, $SD = 10.2$, range 19–54) rated $N = 124$ target men's faces (one photo was excluded due to issues with the photograph) for facial physical dominance (item: "How likely would this man win in a physical fight?") on an 11-point Likert-type scale (-5 = *extremely unlikely* to $+5$ = *extremely likely*). At first, raters saw a preview of the whole sample, with each picture displayed for 0.5 s, to provide the raters with a first impression of the target men's whole sample. Then each rater viewed the pictures in randomized order, one at a time and for as long as they wanted, directly followed by the item.

Ratings of target men's bodily dominance were based on 3-D body scans. Participants were scanned 3 times using the Vitus^{smart}XXL body scanner, running AnthroScan software (both Human Solutions GmbH, Kaiserslautern, Germany). 3-D body scans were converted into "beauty turn" videos (duration 8 s each), in which a body was turning around its vertical axis. Raters were instructed to watch the beauty turn until it had completed a full 360° turn, and the turns were repeated until the rater made a choice. After excluding 13 from overall 165 participants (full sample in Kordsmeyer & Penke, 2019) due to technical issues with the body scans, 152 3-D body scans (from which only 124 are relevant to this study, constituting the experimental group in Kordsmeyer & Penke, 2019) were divided into two equally large sets of 76 scans (62 for this study), and each set was rated by a group of 10 men (overall $N = 20$ male raters, $M = 23.1$ years, $SD = 3.1$, range 19–33) on a computer monitor in randomized order within each set. Beforehand, participants watched a preview with screenshots of the whole sample, with each beauty turn shown for 1 s, to provide a general impression about the range of different body statures in this study. Bodily physical dominance was rated using the item "How likely is it that this man would win a physical fight with another man?" on an 11-point Likert-type scale (ranging from -5 = *very unlikely* to $+5$ = *very likely*).

Video-Based Personality Ratings

Video recordings were taken of men's 1-min self-presentation, *pre* and *post* the dyadic competition (of which only pre videos are relevant to this study; overall, the sample comprised 158 men after excluding 7 from overall 165 participants due to technical problems with the video recordings; from these 158, 120 men engaged in the dyadic competition and were included in this study, i.e., most participants from the experimental group in Kordsmeyer & Penke, 2019). A target man was first told that the question he should answer during the video-recording would be, "What do you think right now, is great about yourself?" for which he could choose three out of eight life domains to talk about (Supplemental Table S1). Participants stood roughly 4 m from the camera to capture a full-body view. Since some target men exceeded the time limit, all videos were cut to a maximum length of 1 min. Observers were

$N = 400$ females ($M = 23.7$ years, $SD = 4.8$, range 16–56), all recruited via an online database, and ratings were conducted on computer screens using the software MediaLab v2014 (Empirisoft Corporation). Each rater viewed between 38 and 40 videos in randomized order, and each video was rated by 10 female observers. Personality states were rated using the German version of the Interpersonal Adjective List (IAL, Jacobs & Scholl, 2005; based on the interpersonal circumplex model of personality, Wiggins, 1982), of which only the facets "dominant" and "competitive" (PA and BC, Supplemental Figure S2; items like dominant, competitive, see Supplemental Table S2) are relevant to this study. Of the original eight items per facet, five were chosen for reasons of brevity (40 items total), and the 40 items were divided into 5-item groups, to reduce strain on our raters. Thus, each female observer rated the target men on one of the five items per facet (for each video 1 item of the dominance and competitiveness facets) on a 5-point Likert-type scale (1 = *disagree completely* to 5 = *agree completely*). Additionally, for each target man raters were asked to what degree they knew him on a 3-point scale (1 = *not at all*, 2 = *know him by sight*, 3 = *well*). Data points where a rater indicated to know a given target man well (= 3) were excluded from subsequent analyses.

Self-Reported Personality and Further Questionnaires

Using the IAL (Jacobs & Scholl, 2005), participants reported their personality states (of which once again only the dominance and competitiveness facets [PA, BC; Supplemental Figure S2] are relevant to this study) both pre and post the competition (only the pre ratings were used in this study), using the same five items per facets as for observer ratings. These scales were also used to measure personality traits (in the presession), only changing the instruction, to elicit a more general description of the men's personality. Internal consistency was satisfactory for all measures (Cronbach's α, IAL states pre: $\alpha = .67$–.86; IAL traits: $\alpha = .57$–.75, $N = 125$). In addition, IAL personality traits were reported by up to two informants (friends or family members) for each participant via an online questionnaire, from which dominance and competitiveness were used here (using all 8 items per facet; Cronbach's $\alpha = .66$–.84; $n = 119$). Finally, immediately after conclusion of the competition participants were asked to rate the female confederate's attractiveness (see below) using the items "I would find the female confederate attractive as a short-term partner (e.g., for a one-night stand)" and "I would find the female confederate attractive as a long-term partner (e.g., for a longer relationship)" on a 5-point Likert-type scale (ranging from 1 = *not at all* to 5 = *very much*). Both items were aggregated to a mean measure of confederate attractiveness.

Hormonal Measures

Participants were asked to refrain from drinking alcohol, exercising, taking recreational or nonprescribed clinical drugs on the day of the study, from ingesting caffeine (coffee, tea, coke) and sleeping 3 hr before, and from eating, drinking (except for water), smoking, or brushing teeth 1 hr before their scheduled appointment (e.g., Geniole, Busseri, & McCormick, 2013; Lopez, Hay, & Conklin, 2009). Participants provided at least 2 ml of saliva via unstimulated passive drool through a straw (Fiers et al., 2014; Schultheiss, Schiepe, & Rawolle, 2012). The samples were immediately transported to an ultralow temperature freezer (−80°C) and later shipped on dry ice to the Technical University of Dresden, where they were analyzed using chemiluminescence immuno assays with high sensitivity (IBL International, Hamburg, Germany). The intra- and inter-assay coefficients of variation for cortisol are below 8% and for T below 11%. Outliers were winsorized to 3 *SD*s ($n = 8$, in accordance with Mehta, Welker, Zilioli, & Carré, 2015). All T (baseline, first, and second postmeasures) and cortisol (baseline) measures appeared to be positively skewed and to violate the assumption of normality (Shapiro–Wilk test statistics < .94, *p*s < .001). Consequently, all four variables were log10 transformed (e.g., following Mehta et al., 2015). One participant had missing data for baseline T and cortisol, for whom we could not calculate T reactivity and the T × cortisol interaction (reducing sample size to $N = 124$ for these variables; for further details on hormonal measures see Kordsmeyer & Penke, 2019).

Procedure

To control for circadian variation in participants' T levels, all testing was conducted between 2 p.m. and 6 p.m. (Idris, Wan, Zhang, & Punyadeera, 2017; Schultheiss & Stanton, 2009). The study was divided into two parts, a presession and a main session, with the latter happening a few days after the former. During the presession, participants provided informed consent and personality traits were assessed, all led by a male experimenter. A first saliva sample was taken approximately 20 min after arriving at the lab, to get first measures of baseline T and cortisol levels. Further anthropometric measures were taken, including 3-D body scans (from which upper body size was measured as an aggregate of shoulder width, chest and upper arm girth, Price, Dunn, Hopkins, & Kang, 2012), body height (assessed with a stadiometer), and physical strength (mean of maximum handgrip of the dominant hand and upper body strength, each measured 3 times using a dynamometer; for further details on these measures see Kordsmeyer, Hunt, Puts, Ostner, & Penke, 2018).

The main session was divided into a pre- and a postpart, both involving hormonal measures (1 × pre, 2 × post), personality state assessments and 1-min video-recorded self-presentations (see above, and Supplemental Figure S1 for a time line). Between the pre- and post-parts, a dyadic competition under supervision of a physically attractive female confederate was held (the presence of whom was no central aspect of this study, however; the aim for this combination of these two manipulations was to collectively trigger a T response in the male participants), as outlined above. The prepart was led by a male experimenter and the postpart by the female confederate. Two randomly paired participants reported to the lab at a time. After filling out questionnaires, including the assessment of their personality states (see above), the first saliva sample for baseline T and cortisol measures and the first video recordings were taken. Next, the competition took place led by the female confederate, including four disciplines (administered in this order for all dyads): (1) a table pinball soccer game (best of nine goals), (2) a snatching game (where participants had to solve figural reasoning tasks, inferring which one of five objects did not match two objects on cards in shape or color and grasp the right object from the table quicker than the opponent, until one participant had won five rounds), (3) arm wrestling (best of three, alternating arms starting with the right arms), and (4) a turn-taking verbal fluency task (participants took turns naming words belonging to a certain category and starting with a specific letter, e.g., "occupations starting with *M*", best of three; for further details on the competition see Kordsmeyer & Penke, 2019). After the competition, two postsaliva samples were taken with a time lag of 15–20 min (as well as further measures not relevant to this study in between). Two samples were taken since it is not clear when exactly hormonal reactivity is highest and when changes are best detected in saliva. A delay of 15–20 min has been suggested for T responses (Casto & Edwards, 2016; Schultheiss et al., 2012). Finally, participants were debriefed about the study's objective.

Table 1. Descriptive Statistics for All Variables Measured.

Variable	*M*	*SD*	α
Rated facial physical dominance	0.39	1.50	.89
Rated bodily physical dominance	0.33	1.65	.91
Upper body strength (kg)	49.16	8.99	
Hand-grip strength (kg)	48.85	10.03	
Mean physical strength (kg)	49.00	7.93	
Body height (cm)	180.91	7.54	
Upper body size	0.01	0.92	
Baseline T (mean first and second presamples)	1.89	0.15	
T reactivity (first postsample)	0.17	0.32	
T reactivity (second postsample)	0.25	0.39	
Baseline cortisol (mean first and second presamples)	0.45	0.21	
Video-based observer-rated state dominance	3.19	0.63	.95
Video-based observer-rated state competitiveness	2.12	0.44	.90
Informant-reported trait dominance	3.53	0.60	
Informant-reported trait competitiveness	2.53	0.63	
Self-reported trait dominance	3.47	0.59	
Self-reported trait competitiveness	2.86	0.66	
Self-reported state dominance	3.34	0.57	
Self-reported state competitiveness	2.36	0.70	
Participant-rated attractiveness of female confederate	3.66	1.01	

Note. $N = 120$–125. α = interrater agreement (Cronbach's α).

Statistical Analyses

For T reactivity, percent changes from baseline levels (using the saliva sample obtained on the day of the main session) were determined for both postsamples separately. The difference of pre- and post-levels was divided by baseline T to get a percentage change from baseline levels (in accordance with Carré, Iselin, Welker, Hariri, & Dodge, 2014; Cook & Crewther, 2012; Roney, Mahler, & Maestripieri, 2003; van der Meij, Almela, Buunk, Fawcett, & Salvador, 2012). We analyzed mediating and moderating influences on any significant bivariate associations of facial and bodily physical dominance with arm wrestling outcome. The following potential mediator variables were considered, analyzed using structural equation modeling (*lavaan* package in R, Rosseel, 2012): physical strength, T reactivity (also in interaction with baseline cortisol as a mediated moderation), self-reported state dominance and competitiveness (pre the competition), as well as observer-rated state dominance and competitiveness (based on self-presentation videos). Moderating effects of the following variables were calculated by including cross-product terms in linear regression models (interaction with either facial or bodily dominance): self- and informant-reported trait dominance and competitiveness, baseline T (also in interaction with baseline cortisol as a three-way interaction), body height, and upper body size. Moreover, to investigate the robustness of our findings, we ran additional regression and mediation models controlling for opponents' facial and bodily physical dominance (within dyads) for analyses involving facial and bodily physical dominance, respectively, as well as controlling for participant-rated attractiveness of the female confederate. Finally, in linear regression models, we examined whether associations between facial and bodily dominance and competition outcome were stronger for the physical discipline (arm wrestling), compared to three nonphysical disciplines, by analyzing effects of the interaction between competition type (physical vs. nonphysical) and facial and bodily dominance (in separate models) on respective competition outcomes.

Analyses were performed using statistical software R (R Core Team, 2015), all questionnaires were administered using survey software formr.org (Arslan & Tata, 2017). Considering the dyadic nature of participants' interaction in the arm wrestling competition, we additionally analyzed actor and partner effects for binary competition outcomes, using the generalized estimating equations methodology for indistinguishable dyads (Loeys, Cook, Smet, Wietzker, & Buysse, 2014) in SPSS (Version 23), to control for a potential dependence among both contestants.

Data Availability

The data and analysis script associated with this research are available at osf.io/57vea.

Results

Preliminary Analyses

Descriptive statistics for all variables can be found in Table 1. Bivariate Pearson correlations of the main variables observer-perceived bodily and facial physical dominance, physical

Table 2. Bivariate Pearson Correlations Between All Main Variables and Competition Outcomes.

Bivariate Correlations	Won Full Competition	Won Arm Wrestling	Won Table Pinball	Won Snatching	Won Verbal Fluency
Observer-rated facial physical dominance	.09	.23*	−.05	−.01	.01
Observer-rated bodily physical dominance	.14	.24*	−.02	.04	.00
Mean physical strength	−.02	.32***	.05	−.05	−.12
Upper body strength	.04	.32***	.01	−.08	−.06
Hand-grip strength	−.07	.22*	.07	−.02	−.13
Baseline T (mean first and second presamples)	−.13	.03	−.07	.13	−.15
T reactivity (first postsample)	.09	.08	−.06	−.04	.05
T reactivity (second postsample)	.17	−.03	−.12	−.03	.24**
Self-reported trait dominance	.03	.20*	.05	−.06	−.09
Participant-rated attractiveness of female confederate	−.05	−.06	−.03	.08	−.01

Note. $N = 120–125$. *$p < .05$. **$p < .01$. ***$p < .001$. Baseline T = baseline testosterone; T reactivity = testosterone reactivity.

Table 3. Mediation Analyses for Associations of Facial and Bodily Physical Dominance With Winning the Arm Wrestling Competition.

	Rated Facial Physical Dominance				Rated Bodily Physical Dominance			
Mediator variable	Unst. est.	Stand. est.	*SE*	*p*	Unst. est.	Stand. est.	*SE*	*p*
Mean physical strength	.03	.09	.01	.01	.03	.09	.01	.01
T reactivity (first postsample)	.00	−.01	.01	.38	.00	.01	.00	.52
T reactivity (second postsample)	.00	.00	.00	.82	.00	.00	.00	.72
T Reactivity (first postsample) × Baseline cortisol	.00	.00	.00	.90	.00	−.01	.01	.75
T Reactivity (second postsample) × Baseline cortisol	−.01	−.01	.00	.57	.00	−.02	−.01	.39
Video-based observer-rated state dominance	.01	.03	.01	.34	.01	.03	.01	.44
Video-based observer-rated state competitiveness	.01	.03	.01	.35	.01	.03	.01	.46
Self-reported state dominance	.00	.01	.01	.48	.00	.01	.01	.62
Self-reported state competitiveness	.00	.00	.00	.90	.00	.00	.01	.99

Note. $N = 120–125$. Unst. est. = unstandardized coefficients; Stand. est. = standardized coefficients; T reactivity = testosterone reactivity; moderated mediation for T Reactivity × Baseline cortisol.

strength, self-reported trait dominance, baseline T (T), and T reactivity with the competition outcomes are depicted in Table 2.

Winning the arm wrestling competition, but not any of the other three nonphysical competitions, was correlated positively with both bodily and facial physical dominance, as well as physical strength and self-reported trait dominance (Table 2). The second T reactivity measure correlated positively with winning the verbal fluency task (Table 2). Applying a Benjamini–Hochberg correction for multiple testing (Benjamini & Hochberg, 1995) on the correlation matrix in Table 2, results remained virtually unchanged, except for the significance of the correlations of winning the arm wrestling competition with hand-grip strength (corrected $p = .07$) and trait dominance (corrected $p = .10$) fading (Supplemental Table S3). For both facial and bodily dominance, associations with competition outcomes were stronger for physical compared to nonphysical disciplines (cross-product terms, facial dominance: $\beta = .12$, $SE = .05$, $p = .02$; bodily dominance: $\beta = .12$, $SE = .05$, $p = .03$; Supplemental Table S4). Moreover, facial physical dominance correlated positively with baseline T ($r = .23$, $p < .05$), physical strength ($r = .32$, $p < .001$), and self-reported trait dominance ($r = .18$, $p < .05$; Supplemental Table S5). Bodily physical dominance correlated positively with physical strength ($r = .32$, $p < .001$) and trait dominance ($r = .28$, $p < .01$), and negatively with height ($r = -.22$, $p < .05$; Table S5).

Mediation and Moderation Analyses

Physical strength significantly mediated the relationship of both facial and bodily physical dominance with winning the arm wrestling discipline (Table 3; direct effect of facial/bodily dominance on outcome of arm wrestling: unstandardized coefficients = .05/.05, standardized coefficients = .15/.16, $SE = .03/.03$, $p = .09/.06$, on physical strength: unstandardized coefficients = 1.71/1.54, standardized coefficients = .32/.32, $SE = .47/.41$, $p < .001/< .001$). There was no mediation effect of T reactivity (also not in interaction with baseline cortisol), observer-rated or self-reported state dominance or competitiveness (Table 3).

No significant moderation effects were found for the relationship of bodily and facial physical dominance with winning the arm wrestling competition for any of the potential moderators (Table 4).

Robustness Checks

We examined whether the significant correlations and mediator effects were robust when controlling for opponents' bodily and

Table 4. Moderation Analyses for Associations of Facial and Bodily Physical Dominance With Winning the Arm Wrestling Competition.

	Rated Facial Physical Dominance				Rated Bodily Physical Dominance			
Moderator variable	Unst. est.	Stand. est.	*SE*	*p*	Unst. est.	Stand. est.	*SE*	*p*
Body height	.01	.02	.00	.10	.00	−.01	.00	.26
Upper body size	.04	.13	.03	.15	.03	.10	.03	.34
Baseline T	.13	.39	.24	.60	.17	.58	.20	.39
Baseline T × Baseline cortisol	−1.83	−5.48	1.24	.14	−1.13	−3.77	1.08	.30
Informant-reported trait dominance	−.02	−.05	.05	.76	−.02	−.05	.04	.72
Informant-reported trait competitiveness	−.01	−.03	.05	.81	.06	.19	.05	.22
Self-reported trait dominance	−.03	−.08	.05	.62	−.06	−.20	.05	.22
Self-reported trait competitiveness	.04	.12	.04	.37	.04	.14	.04	.32

Note. $N = 120$–125. Unst. est. = unstandardized coefficients; Stand. est. = standardized coefficients; Baseline T = baseline testosterone; Baseline T × Baseline C = interaction of baseline testosterone and baseline cortisol.

facial physical dominance (within dyads) and participant-rated attractiveness of female confederate. All results were virtually unchanged (see Supplemental Tables S6–S8).

Dyadic analyses revealed negative partner effects of facial physical dominance ($\beta = -.23$, $SE = .12$, $p = .050$) and bodily physical dominance ($\beta = -.26$, $SE = .11$, $p = .01$) on winning the arm wrestling competition, but no actor effects for facial or bodily physical dominance (both p's > .10). Thus, it can be concluded that winning the arm wrestling competition was influenced by opponents' facial and bodily physical dominance.

Discussion

This study demonstrated that men's facial and bodily physical dominance, as independently judged by naive observers, positively predicted winning a dyadic physical competition (arm wrestling) but not three nonphysical competition disciplines. Moderation analyses showed that associations of facial and bodily dominance with competition outcomes were stronger in physical relative to nonphysical disciplines. Furthermore, the effects of both facial and bodily physical dominance on success in arm wrestling were mediated by physical strength. Our findings support the role of facial and bodily dominance as signals for behavioral dominance, fighting abilities and hence potential for status acquisition (Sell, Cosmides, et al., 2009).

Our results suggest that there are contextual effects on the signaling quality of physical dominance, in that observer-rated physical dominance was associated with success in a physical but not in three nonphysical disciplines. This may explain earlier findings such as why facial or bodily physical dominance is correlated with leadership more strongly in a wartime than in a peacetime context (e.g., Re, DeBruine, Jones, & Perrett, 2013) and in small-scale societies (e.g., von Rueden, Gurven, Kaplan, & Stieglitz, 2014), or why physically dominant players accumulate more penalty points in team games (e.g., Carré & McCormick, 2008). Indeed, earlier studies suggested associations of facial dominance with awarded pay on a managerial level (Fruhen et al., 2015), men's career success and reproductive success (Mueller & Mazur, 1997), as well as a link of facial width-to-height ratio (as an objective proxy measure of facial dominance) with aggressive behavior in male hockey players (Carré & McCormick, 2008), physical and verbal aggression (Lefevre, Etchells, Howell, Clark, & Penton-Voak, 2014), and fighting ability (Zilioli et al., 2015; for meta-analyses see Geniole, Denson, Dixson, Carré, & McCormick, 2015 and Haselhuhn, Ormiston, & Wong, 2015). Our results extend these findings, in that we found associations between observer ratings of dominance for both faces and bodies and competition outcome in a controlled laboratory setting, which were mediated by physical strength. Moreover, we provide evidence for a link of facial and bodily dominance with physical strength, replicating earlier studies (Fink et al., 2007; Sell, Cosmides, et al., 2009; Windhager, Schaefer, & Fink, 2011).

The finding that facial and bodily dominance predicted success in a male–male physical competition suggests these traits may be shaped by intrasexual selection forces, in addition to intersexual selection (van Vugt & Tybur, 2015). However, when arguing that a trait has been shaped by sexual selection, it is required that the trait influences mating success besides being related to mechanisms of inter- or intra-sexual competition (Hill, Bailey, & Puts, 2017). On the one hand, facial and bodily dominance might have increased mating success for men because women preferred dominant individuals as they used these traits as cues to status, which granted resources and protection (van Vugt & Tybur, 2015). On the other hand, facially dominant individuals may have been avoided by competitors with less masculine faces and hence gained access to fitness-relevant resources (e.g., food and mates, Sell et al., 2012). Given the importance of adequate status assessment when engaging in intrasexual competition for resources (Sell, Cosmides, et al., 2009), our findings underline the significance of facial and bodily dominance as valid cues for physical strength and status (e.g., Fink et al., 2007; Windhager et al., 2011).

The associations of facial and bodily dominance with winning the physical competition discipline were mediated by physical strength. When analyzing both components of physical strength (handgrip and upper body strength) separately, a mediating effect was found for upper body, but not hand-grip strength. This provides further evidence that physical strength and especially upper body strength (rather than hand-grip strength, and other anthropometric traits such as height or upper body size) are influential factors of status and dominance (Sell et al., 2012; Sell, Tooby, & Cosmides, 2009). But what makes physical strength a crucial aspect of status potential? According to the *recalibrational theory of anger* (Sell, Tooby, & Cosmides, 2009), anger is the product of a neurocognitive mechanism shaped by evolutionary forces. Bargaining tactics are activated to recalibrate the valuation of an angry individual's interests in situations where the individual believes that his/her interests are not sufficiently valued by an opponent. Ancestrally, humans' bargaining power and the ability to inflict costs highly depended on their physical strength and fighting ability. Thus, anger was an effective way to gain status in intrasexual competition, especially for strong individuals with superior fighting abilities and hence increased bargaining power (Sell et al., 2012; but see von Borell, Kordsmeyer, Gerlach, & Penke, 2019 for a null association between physical strength and anger). In our study, we showed that physical strength may still be beneficial in male intrasexual contests contemporarily. Lukaszewski, Simmons, Anderson, and Roney (2016) found physical strength to predict within-group ratings of status, mediated by perceptions of greater leadership abilities of physically stronger men. This converges with Murray's finding (2014), who examined preferences for leaders with greater physical formidability (e.g., strength or height). These preferences were interpreted as evolutionary adaptations from human ancestral environments, in which individuals who followed powerful leaders were more likely to survive due to lower risk of harmful confrontations with rivals. In modern societies, leader preferences strongly depend on contextual factors (Laustsen & Petersen, 2015). Dominant faces, for example, were more likely to be preferred in times of war, while less-dominant faces were favored in peaceful contexts (van Vugt & Grabo, 2015). The associations of facial and bodily dominance with the arm wrestling outcome in our study imply that physically dominant men may indeed be more successful in physical competitions generally. Consequently, this means that preferences for facially and bodily dominant leaders in times of conflict may be adaptive.

Leadership evolved primarily for coordinating physical tasks such as group movement, coalitional aggression, and defense, whereas contemporary conflicts and status contests are less physical and aggressive (Li, van Vugt, & Colarelli, 2018). The fact that physical dominance signals are still associated with status and leadership in modern, large-scale societies (e.g., height, Stulp et al., 2013; facial maturity, Re et al., 2013) can be thought of as an evolutionary mismatch. According to the *evolutionary mismatch hypothesis* (Li et al., 2018; Schlaepfer, Runge, & Sherman, 2002), human psychology is adapted to past environments which markedly differ from modern contexts in some regard, creating a partial mismatch between evolved psychological mechanisms and the modern environment (but see Hagen, 2014 for claims that in some respects modern contexts are comparable to past environments). Our study's results are in line with the evolutionary mismatch hypothesis, in that physical dominance augmented success in physical but not nonphysical competition and that these characteristics may have predicted leadership and status acquisition more strongly in historical compared to modern contexts; contemporarily efficient leadership would require rather different skills such as social dominance or trustworthiness (von Rueden et al., 2014).

Earlier work suggested two different routes to status, dominance and prestige (e.g., Cheng, Tracy, Foulsham, Kingstone, & Henrich, 2013). Prestige is earned by individuals who possess outstanding abilities and skills such as verbal eloquence or intelligence, whereas dominance is based on threat displays and induction of fear (van Vugt & Tybur, 2015). Hence, in our study, winning the physical competition discipline would be more related to the dominance route because it requires physical strength, whereas winning the nonphysical disciplines indicated prestige because it presumably is augmented by skills like intelligence. Following this reasoning, our work suggests that facial and bodily dominance promote status-striving behaviors more via the dominance than the prestige route, as these traits predicted success in the physical but not in any of the three nonphysical competitions. This further implies that facial and bodily dominance may boost status positions in dominance-based but not in prestige-based hierarchies, which our findings are in line with. On the contrary, success in the three nonphysical disciplines should require skills such as reaction speed and fluid intelligence and predict status acquisition via the prestige rather than the dominance route. While this means that status acquisition may depend on the type of contest, in addition to contextual factors (e.g., wartime vs. peacetime, Re et al., 2013; small- vs. large-scale society, von Rueden & van Vugt, 2015), it is an exciting avenue for further research to investigate status-striving predicted by different competencies and mediated by prestige or dominance in different kinds of hierarchies (DesJardins, Srivastava, Küfner, & Back, 2015; van Vugt & Tybur, 2015). Moreover, further studies could differentially assess perceptions of facial and bodily social dominance alongside physical dominance and their effects on competition success in physical versus nonphysical disciplines (Watkins, 2018; Watkins, Jones, & DeBruine, 2010).

Previous studies also showed that T influences behaviors related to dominance and high status (Archer, 2006; Edwards et al., 2006; Mazur & Booth, 1998; Mehta & Josephs, 2010). In our study neither baseline T, nor T reactivity, nor their interactions with baseline cortisol (*dual-hormone hypothesis*, Mehta & Josephs, 2010) were associated with winning the arm wrestling competition. These findings may be false negatives due to our relatively small sample size, considering that correlations between T and aggression have been reported to be small (e.g., meta-analytic $r = .08$ for aggression, Archer, Graham-Kevan, & Davies, 2005). Nevertheless, we did find evidence for a link between facial dominance and baseline T, replicating earlier studies (Lefevre, Lewis, Perrett, & Penke, 2013; Roney, Hanson, Durante, & Maestripieri, 2006). Somewhat surprisingly, we detected a positive effect of T reactivity on winning one of the nonphysical competition disciplines (verbal fluency task), suggesting that T reactivity may enhance status acquisition via the prestige route (see Cheng, Kornienko, & Granger, 2018 for longitudinal evidence of an increase in prestige-based status predicting a rise in T levels, $n = 83$ men). Given these overly null results in our study and mixed findings in the literature (e.g., Carré, Ruddick, Moreau, & Bird, 2017), associations of T levels with dominant and aggressive behaviors require further investigation, including the consideration of mediator and moderator variables (e.g., Liening & Josephs, 2010).

Some limitations to our study need to be acknowledged. First, we used an exploratory approach that included many variables as potential mediators and moderators, increasing the likelihood of finding false positives. However, after applying a Benjamini-Hochberg correction for multiple testing to the bivariate correlations between the predictor, mediator and moderator variables and competition outcomes, most significant associations remained robust. Secondly, we only used a proxy of status acquisition (one physical and three nonphysical competition disciplines in a laboratory setting), and therefore, it remains elusive to what extent our findings generalize to other competitive interactions and more ecologically valid settings, as usually status is not allocated by such direct dyadic contests. Future work could assess effects of facial and bodily physical dominance on different status measures such as management position (van der Meij, Schaveling, & van Vugt, 2016), or prestige factors such as respect and group influence (Blaker & Van Vugt, 2014). Further research could explore status acquisition and leadership emergence predicted by facial and bodily dominance in longitudinal studies. Finally, all contest competitions were supervised by an attractive female confederate, which is assumed to influence men's T reactivity (e.g., van der Meij, Buunk, van de Sande, & Salvador, 2008). Future studies could benefit from having a male or less attractive female confederate leading dyads through the contest and investigate potentially divergent associations.

In conclusion, our study provides insights about the effects of men's facial and bodily physical dominance on the outcome of dyadic face-to-face competitions. Facial and bodily dominance seem to be honest signals of men's potential to gain status in terms of winning a physical competition but not three nonphysical competitions. One implication may be that humans contemporarily place too much weight on facial and bodily physical dominance when assessing competitive performance in status contests generally. Instead, for nonphysical competition, other characteristics such as intelligence may be more predictive of competition outcome. The associations of men's facial and bodily dominance with winning the physical competition discipline were partly explained by greater physical strength. This suggests a potential mechanism of status acquisition, in that men who appear as dominant are on average objectively stronger, leading them to succeed in face-to-face physical competitions, thus augmenting status acquisition.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Leibniz ScienceCampus Primate Cognition, Leibniz Association.

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Supplemental Material

The supplemental material is available in the online version of the article.

References

Archer, J. (2006). Testosterone and human aggression: An evaluation of the challenge hypothesis. *Neuroscience & Biobehavioral Reviews*, *30*, 319–345. doi:10.1016/j.neubiorev.2004.12.007

Archer, J., Graham-Kevan, N., & Davies, M. (2005). Testosterone and aggression: A reanalysis of Book, Starzyk, and Quinsey's (2001) study. *Aggression and Violent Behavior*, *10*, 241–261. doi:10.1016/j.avb.2004.01.001

Arslan, R. C., & Tata, C. S. (2017). formr.org survey software (version v0.16.12). doi:10.5281/zenodo.823627

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society Series B*, *57*, 289–300. doi:10.1111/j.2517-6161.1995.tb02031.x

Blaker, N. M., & van Vugt, M. (2014). The status-size hypothesis: How cues of physical size and social status influence each other. In J. T. Cheng, J. L. Tracy, & C. Anderson (Eds.), *The psychology of social status* (pp. 119–137). New York, NY: Springer. doi:10.1007/978-1-4939-0867-7_6

Carré, J. M., & Archer, J. (2018). Testosterone and human behavior: The role of individual and contextual variables. *Current Opinion in Psychology*, *19*, 149–153. doi:10.1016/j.copsyc.2017.03.021

Carré, J. M., Iselin, A. M. R., Welker, K. M., Hariri, A. R., & Dodge, K. A. (2014). Testosterone reactivity to provocation mediates the effect of early intervention on aggressive behavior. *Psychological Science*, *25*, 1140–1146. doi:10.1177/0956797614525642

Carré, J. M., & McCormick, C. M. (2008). In your face: Facial metrics predict aggressive behaviour in the laboratory and in varsity and professional hockey players. *Proceedings of the Royal Society of London B: Biological Sciences*, *275*, 2651–2656. doi:10.1098/rspb.2008.0873

Carré, J. M., McCormick, C. M., & Mondloch, C. J. (2009). Facial structure is a reliable cue of aggressive behavior. *Psychological Science*, *20*, 1194–1198. doi:10.1111/j.1467-9280.2009.02423.x

Carré, J. M., & Olmstead, N. A. (2015). Social neuroendocrinology of human aggression: Examining the role of competition-induced testosterone dynamics. *Neuroscience*, *286*, 171–186. doi:10.1016/j.neuroscience.2014.11.029

Carré, J. M., Putnam, S. L., & McCormick, C. M. (2009). Testosterone responses to competition predict future aggressive behaviour at a cost to reward in men. *Psychoneuroendocrinology*, *34*, 561–570. doi:10.1016/j.psyneuen.2008.10.018

Carré, J. M., Ruddick, E. L., Moreau, B. J., & Bird, B. M. (2017). Testosterone and human aggression. In P. Sturmey (Ed.), *The Wiley handbook of violence and aggression* (pp. 1–14). Hoboken, NJ: Wiley.

Casto, K. V., & Edwards, D. A. (2016). Testosterone, cortisol, and human competition. *Hormones and Behavior*, *82*, 21–37. doi:10.1016/j.yhbeh.2016.04.004

Cheng, J. T., Kornienko, O., & Granger, D. A. (2018). Prestige in a large-scale social group predicts longitudinal changes in testosterone. *Journal of Personality and Social Psychology*, *114*, 924–944. doi:10.1037/pspi0000126

Cheng, J. T., Tracy, J. L., Foulsham, T., Kingstone, A., & Henrich, J. (2013). Two ways to the top: Evidence that dominance and prestige are distinct yet viable avenues to social rank and influence. *Journal of Personality and Social Psychology*, *104*, 103–125. doi:10.1037/a0030398

Cheng, J. T., Tracy, J. L., Ho, S., & Heinrich, J. (2016). Listen, follow me: Dynamic vocal signals of dominance predict emergent social rank in humans. *Journal of Experimental Psychology*, *145*, 536–547. doi:10.1037/xge0000166

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*, 155–159. doi:10.1037/0033-2909.112.1.155

Cook, C. J., & Crewther, B. T. (2012). The effects of different pregame motivational interventions on athlete free hormonal state and subsequent performance in professional rugby union matches. *Physiology & Behavior*, *106*, 683–688. doi:10.1016/j.physbeh.2012.05.009

DesJardins, N. M. L., Srivastava, S., Küfner, A. C., & Back, M. D. (2015). Who attains status? Similarities and differences across social contexts. *Social Psychological and Personality Science*, *6*, 692–700. doi:10.1177/1948550615580171

Dixson, B. J. W. (2017). Facial width to height ratio and dominance. In T. K. Shackelford & V. A. Weekes-Shackelford (Eds.), *Encyclopedia of evolutionary psychological science* (pp. 1–4). Cham, Switzerland: Springer International. doi:10.1007/978-3-319-16999-6_1419-1

Edwards, D. A., Wetzel, K., & Wyner, D. R. (2006). Intercollegiate soccer: Saliva cortisol and testosterone are elevated during competition, and testosterone is related to status and social connectedness with teammates. *Physiology & Behavior*, *87*, 135–143. doi:10.1016/j.physbeh.2005.09.007

Fiers, T., Delanghe, J., T'Sjoen, G., van Caenegem, E., Wierckx, K., & Kaufman, J. M. (2014). A critical evaluation of salivary testosterone as a method for the assessment of serum testosterone. *Steroids*, *86*, 5–9. doi:10.1016/j.steroids.2014.04.013

Fink, B., Neave, N., & Seydel, H. (2007). Male facial appearance signals physical strength to women. *American Journal of Human Biology*, *19*, 82–87. doi:10.1002/ajhb.20583

Folstad, I., & Karter, A. J. (1992). Parasites, bright males, and the immunocompetence handicap. *The American Naturalist*, *139*, 603–622. doi:10.1086/285346

Fruhen, L. S., Watkins, C. D., & Jones, B. C. (2015). Perceptions of facial dominance, trustworthiness and attractiveness predict managerial pay awards in experimental tasks. *The Leadership Quarterly*, *26*, 1005–1016. doi:10.1016/j.leaqua.2015.07.001

Geniole, S. N., Busseri, M. A., & McCormick, C. M. (2013). Testosterone dynamics and psychopathic personality traits independently predict antagonistic behavior towards the perceived loser of a competitive interaction. *Hormones and Behavior*, *64*, 790–798. doi:10.1016/j.yhbeh.2013.09.005

Geniole, S., Denson, T., Dixson, B., Carré, J., & McCormick, C. (2015). Evidence from meta-analyses of the facial width-to-height ratio as an evolved cue of threat. *PLoS One, 10*, *e0132726*. doi:10.1371/journal.pone.0132726

Hagen, E. H. (2014). Invariant world, invariant mind. Evolutionary psychology and its critics. In D. M. Buss (Ed.), *Handbook of evolutionary psychology, Volume 1: Foundations* (2nd ed., pp. 136–160). Hoboken, NJ: Wiley.

Haselhuhn, M. P., Ormiston, M. E., & Wong, E. M. (2015). Men's facial width-to-height ratio predicts aggression: A meta-analysis. *PLoS One*, *10*, e0122637. doi:10.1371/journal.pone.0122637

Hill, A. K., Bailey, D. H., & Puts, D. A. (2017). Gorillas in our midst? Human sexual dimorphism and contest competition in men. In M. Tibayrenc & F. J. Ayala (Eds.), *On human nature: Biology, psychology, ethics, politics, and religion* (pp. 235–249). Cambridge, MA: Academic Press. doi:10.1016/B978-0-12-420190-3.00015-6

Idris, F. P., Wan, Y., Zhang, X., & Punyadeera, C. (2017). Within-day baseline variation in salivary biomarkers in healthy men. *OMICS: A Journal of Integrative Biology*, *21*, 74–80. doi:10.1089/omi.2016.0168

Jacobs, I., & Scholl, W. (2005). Interpersonale Adjektivliste (IAL). *Diagnostica*, *51*, 145–155. doi:10.1026/0012-1924.51.3.145

Josephs, R. A., Sellers, J. G., Newman, M. L., & Mehta, P. H. (2006). The mismatch effect: When testosterone and status are at odds. *Journal of Personality and Social Psychology*, *90*, 999–1013. doi:10.1037/0022-3514.90.6.999

Kordsmeyer, T. L., Hunt, J., Puts, D. A., Ostner, J., & Penke, L. (2018). The relative importance of intra- and intersexual selection on human male sexually dimorphic traits. *Evolution and Human Behavior*, *39*, 424–436. doi:10.1016/j.evolhumbehav.2018.03.008

Kordsmeyer, T. L., & Penke, L. (2019). Effects of male testosterone and its interaction with cortisol on self- and observer-rated personality states in a competitive mating context. *Journal of Research in Personality*, *78*, 76–92. doi:10.1016/j.jrp.2018.11.001

Laustsen, L., & Petersen, M. B. (2015). Winning faces vary by ideology: How nonverbal source cues influence election and communication success in politics. *Political Communication*, *33*, 188–211. doi:10.1080/10584609.2015.1050565

Lefevre, C. E., Etchells, P. J., Howell, E. C., Clark, A. P., & Penton-Voak, I. S. (2014). Facial width-to-height ratio predicts self-reported dominance and aggression in males and females, but a measure of masculinity does not. *Biology Letters*, *10*, 20140729. doi:10.1098/rsbl.2014.0729

Lefevre, C. E., Lewis, G. J., Perrett, D. I., & Penke, L. (2013). Telling facial metrics: Facial width is associated with testosterone levels in men. *Evolution and Human Behavior*, *34*, 273–279. doi:10.1016/j.evolhumbehav.2013.03.005

Li, N. P., van Vugt, M., & Colarelli, S. M. (2018). The evolutionary mismatch hypothesis: Implications for psychological science. *Current Directions in Psychological Science*, *27*, 38–44. doi:10.1177/0963721417731378

Liening, S. H., & Josephs, R. A. (2010). It is not just about testosterone: Physiological mediators and moderators of testosterone's behavioral effects. *Social and Personality Psychology Compass*, *4*, 982–994. doi:10.1111/j.1751-9004.2010.00316.x

Little, A. C. (2014). Facial appearance and leader choice in different contexts: Evidence for task contingent selection based on implicit and learned face-behaviour/face-ability associations. *The Leadership Quarterly*, *25*, 865–874. doi:10.1016/j.leaqua.2014.04.002

Little, A. C., Burriss, R. P., Jones, B. C., & Roberts, S. C. (2007). Facial appearance affects voting decisions. *Evolution and Human Behavior*, *28*, 18–27. doi:10.1016/j.evolhumbehav.2006.09.002

Loeys, T., Cook, W. L., Smet, O. de, Wietzker, A., & Buysse, A. (2014). The actor–partner interdependence model for categorical dyadic data: A user-friendly guide to GEE. *Personal Relationships*, *21*, 225–241. doi:10.1111/pere.12028

Lopez, H. H., Hay, A. C., & Conklin, P. H. (2009). Attractive men induce testosterone and cortisol release in women. *Hormones and Behavior*, *56*, 84–92. doi:10.1016/j.yhbeh.2009.03.004

Lukaszewski, A. W., Simmons, Z. L., Anderson, C., & Roney, J. R. (2016). The role of physical formidability in human social status allocation. *Journal of Personality and Social Psychology*, *110*, 385–406. doi:10.1037/pspi0000042

Marečková, K., Weinbrand, Z., Chakravarty, M. M., Lawrence, C., Aleong, R., Leonard, G., . . . Pausova, Z. (2011). Testosterone-mediated sex differences in the face shape during adolescence: Subjective impressions and objective features. *Hormones and Behavior*, *60*, 681–690. doi:10.1016/j.yhbeh.2011.09.004

Mazur, A., & Booth, A. (1998). Testosterone and dominance in men. *Behavioral and Brain Sciences*, *21*, 353–363. doi:10.1017/S0140525X98001228

Mehta, P. H., & Josephs, R. A. (2006). Testosterone change after losing predicts the decision to compete again. *Hormones and Behavior*, *50*, 684–692. doi:10.1016/j.yhbeh.2006.07.001

Mehta, P. H., & Josephs, R. A. (2010). Testosterone and cortisol jointly regulate dominance: Evidence for a dual-hormone hypothesis. *Hormones and Behavior*, *58*, 898–906. doi:10.1016/j.yhbeh.2010.08.020

Mehta, P. H., Lawless DesJardins, N. M., van Vugt, M., & Josephs, R. A. (2017). Hormonal underpinnings of status conflict: Testosterone and cortisol are related to decisions and satisfaction in the hawk-dove game. *Hormones and Behavior*, *92*, 141–154. doi:10.1016/j.yhbeh.2017.03.009

Mehta, P. H., & Prasad, S. (2015). The dual-hormone hypothesis: A brief review and future research agenda. *Current Opinion in Behavioral Sciences*, *3*, 163–168. doi:10.1016/j.cobeha.2015.04.008

Mehta, P. H., Welker, K. M., Zilioli, S., & Carré, J. M. (2015). Testosterone and cortisol jointly modulate risk-taking. *Psychoneuroendocrinology*, *56*, 88–99. doi:10.1016/j.psyneuen.2015.02.023

Mueller, U., & Mazur, A. (1997). Facial dominance in Homo sapiens as honest signaling of male quality. *Behavioral Ecology*, *8*, 569–579. doi:10.1093/beheco/8.5.569

Murray, G. R. (2014). Evolutionary preferences for physical formidability in leaders. *Politics and the Life Sciences*, *33*, 33–53. doi:10.2990/33_1_33

Olweus, D., Mattsson, Å., Schalling, D., & Low, H. (1980). Testosterone, aggression, physical, and personality dimensions in normal adolescent males. *Psychosomatic Medicine*, *42*, 253–269.

Pound, N., Penton-Voak, I. S., & Surridge, A. K. (2009). Testosterone responses to competition in men are related to facial masculinity. *Proceedings of the Royal Society of London B: Biological Sciences*, *276*, 153–159. doi:10.1098/rspb.2008.0990

Poutvaara, P. (2014). Facial appearance and leadership: An overview and challenges for new research. *The Leadership Quarterly*, *25*, 801–804. doi:10.1016/j.leaqua.2014.08.003

Price, M. E., Dunn, J., Hopkins, S., & Kang, J. (2012). Anthropometric correlates of human anger. *Evolution and Human Behavior*, *33*, 174–181. doi:10.1016/j.evolhumbehav.2011.08.004

Puts, D. A., Bailey, D. H., & Reno, P. L. (2015). Contest competition in men. In D. M. Buss (Ed.), *The handbook of evolutionary psychology, Volume 1: Foundations* (pp. 385–402). Hoboken, NJ: John Wiley.

R Core Team (2015). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from https://www.R-project.org

Rantala, M. J., Vainikka, A., & Kortet, R. (2003). The role of juvenile hormone in immune function and pheromone production trade-offs: A test of the immunocompetence handicap principle. *Proceedings of the Royal Society of London B: Biological Sciences*, *270*, 2257–2261. doi:10.1098/rspb.2003.2472

Re, D. E., DeBruine, L. M., Jones, B. C., & Perrett, D. I. (2013). Facial cues to perceived height influence leadership choices in simulated war and peace contexts. *Evolutionary Psychology*, *11*, 89–103. doi:10.1177/147470491301100109

Roney, J. R., Hanson, K. N., Durante, K. M., & Maestripieri, D. (2006). Reading men's faces: Women's mate attractiveness judgments track men's testosterone and interest in infants. *Proceedings of the Royal Society of London B: Biological Sciences*, *273*, 2169–2175.

Roney, J. R., Mahler, S. V., & Maestripieri, D. (2003). Behavioral and hormonal responses of men to brief interactions with women. *Evolution and Human Behavior*, *24*, 365–375. doi:10.1016/S1090-5138(03)00053-9

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*, 1–36. doi:10.18637/jss.v048.i02

Schlaepfer, M. A., Runge, M. C., & Sherman, P. W. (2002). Ecological and evolutionary traps. *Trends in Ecology & Evolution*, *17*, 474–480. doi:10.1016/S0169-5347(02)02580-6

Schultheiss, O. C., Schiepe, A., & Rawolle, M. (2012). Hormone assays. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), *Handbook of research methods in psychology, Volume 1: Foundations, planning, measures, and psychometrics* (pp. 489–500). Washington, DC: American Psychological Association. doi:10.1037/13619-000

Schultheiss, O. C., & Stanton, S. J. (2009). Assessment of salivary hormones. In E. Harmon-Jones & J. S. Beer (Eds.), *Methods in social neuroscience* (pp. 17–44). New York, NY: Guilford Press.

Scott, I. M., Clark, A. P., Josephson, S. C., Boyette, A. H., Cuthill, I. C., Fried, R. L., . . . Honey, P. L. (2014). Human preferences for sexually dimorphic faces may be evolutionarily novel.

Proceedings of the National Academy of Sciences, *111*, 14388–14393. doi:10.1073/pnas.1409643111

Sell, A., Cosmides, L., & Tooby, J. (2014). The human anger face evolved to enhance cues of strength. *Evolution and Human Behavior*, *35*, 425–429. doi:10.1016/j.evolhumbehav.2014.05.008

Sell, A, Cosmides, L, Tooby, J, Sznycer, D, von Rueden, C, & &Gurven, M (2009). Human adaptations for the visual assessment of strength and fighting ability from the body and face. *Proceedings of the Royal Society of London B: Biological Sciences*, *276*, 575–584. doi:10.1098/rspb.2008.1177

Sell, A., Hone, L. E., & Pound, N. (2012). The importance of physical strength to human males. *Human Nature*, *23*, 30–44. doi:10.1007/s12110-012-9131-2

Sell, A., Tooby, J., & Cosmides, L. (2009). Formidability and the logic of human anger. *Proceedings of the National Academy of Sciences*, *106*, 15073–15078. doi:10.1073/pnas.0904312106

Sherman, G. D., Lerner, J. S., Josephs, R. A., Renshon, J., & Gross, J. J. (2016). The interaction of testosterone and cortisol is associated with attained status in male executives. *Journal of Personality and Social Psychology*, *110*, 921–929. doi:10.1037/pspp0000063

Stulp, G., Buunk, A. P., Verhulst, S., & Pollet, T. V. (2013). Tall claims? Sense and nonsense about the importance of height of US presidents. *The Leadership Quarterly*, *24*, 159–171. doi:10.1016/j.leaqua.2012.09.002

van der Meij, L., Almela, M., Buunk, A. P., Fawcett, T. W., & Salvador, A. (2012). Men with elevated testosterone levels show more affiliative behaviours during interactions with women. *Proceedings of the Royal Society B: Biological Sciences*, *279*, 202–208. doi:10.1098/rspb.2011.0764

van der Meij, L., Buunk, A. P., van de Sande, J. P., & Salvador, A. (2008). The presence of a woman increases testosterone in aggressive dominant men. *Hormones and Behavior*, *54*, 640–644. doi:10.1016/j.yhbeh.2008.07.001

van der Meij, L., Schaveling, J., & van Vugt, M. (2016). Basal testosterone, leadership and dominance: A field study and meta-analysis. *Psychoneuroendocrinology*, *72*, 72–79. doi:10.1016/j.psyneuen.2016.06.005

van Vugt, M., & Grabo, A. E. (2015). The many faces of leadership: An evolutionary-psychology approach. *Current Directions in Psychological Science*, *24*, 484–489. doi:10.1177/0963721415601971

van Vugt, M., & Tybur, J. M. (2015). The Evolutionary foundations of hierarchy: Status, dominance, prestige, and leadership. In D. M. Buss (Ed.), *Handbook of evolutionary psychology, Volume 2: Integrations* (2nd ed., pp. 788–809). Hoboken, NJ: Wiley. doi:10.1002/9781119125563.evpsych232

Verdonck, A., Gaethofs, M., Carels, C., & de Zegher, F. (1999). Effect of low-dose testosterone treatment on craniofacial growth in boys with delayed puberty. *The European Journal of Orthodontics*, *21*, 137–143. doi:10.1093/ejo/21.2.137

von Borell, C. J., Kordsmeyer, T. L., Gerlach, T. M., & Penke, L. (2019). An integrative study of facultative personality calibration. *Evolution and Human Behavior*, *40*, 235–248. doi:10.1016/j.evolhumbehav.2019.01.002

von Rueden, C., Gurven, M., & Kaplan, H. (2008). The multiple dimensions of male social status in an Amazonian society. *Evolution and Human Behavior*, *29*, 402–415. doi:10.1016/j.evolhumbehav.2008.05.001

von Rueden, C., Gurven, M., Kaplan, H., & Stieglitz, J. (2014). Leadership in an egalitarian society. *Human Nature*, *25*, 538–566. doi:10.1007/s12110-014-9213-4

von Rueden, C., & Van Vugt, M. (2015). Leadership in small-scale societies: Some implications for theory, research, and practice. *The Leadership Quarterly*, *26*, 978–990. doi:10.1016/j.leaqua.2015.10.004

Watkins, C. D. (2018). Formidability and alliance politics in humans and nonhuman species. In C. Senior (Ed.), *The facial displays of leaders* (pp. 27–49). Cham, Switzerland: Palgrave Macmillan. doi:10.1007/978-3-319-94535-4_2

Watkins, C. D., Jones, B. C., & DeBruine, L. M. (2010). Individual differences in dominance perception: Dominant men are less sensitive to facial cues of male dominance. *Personality and Individual Differences*, *49*, 967–971. doi:10.1016/j.paid.2010.08.006

Wedekind, C., & Folstad, I. (1994). Adaptive or nonadaptive immunosuppression by sex hormones? *The American Naturalist*, *143*, 936–938. doi:10.1086/285641

Whitehouse, A. J., Gilani, S. Z., Shafait, F., Mian, A., Tan, D. W., Maybery, M. T., & Eastwood, P. (2015). Prenatal testosterone exposure is related to sexually dimorphic facial morphology in adulthood. *Proceedings of the Royal Society of London B: Biological Sciences*, *282*, 20151351. doi:10.1098/rspb.2015.1351

Wiggins, J. S. (1982). Circumplex models of interpersonal behavior in clinical psychology. In P. C. Kendall & J. N. Butcher (Eds.), *Handbook of research methods in clinical psychology* (pp. 183–221). New York, NY: Wiley.

Windhager, S., Schaefer, K., & Fink, B. (2011). Geometric morphometrics of male facial shape in relation to physical strength and perceived attractiveness, dominance, and masculinity. *American Journal of Human Biology*, *23*, 805–814. doi:10.1002/ajhb.21219

Wingfield, J. C., Hegner, R. E., Dufty, A. M. Jr., & Ball, G. F. (1990). The "challenge hypothesis": Theoretical implications for patterns of testosterone secretion, mating systems, and breeding strategies. *The American Naturalist*, *136*, 829–846. doi:10.1086/285134

Zilioli, S., Sell, A., Stirrat, M., Jagore, J., Vickerman, W., & Watson, N. (2015). Face of a fighter: Bizygomatic width as a cue of formidability. *Aggressive Behavior*, *41*, 322–330. doi:10.1002/ab.21544