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Winners, losers, and posers: The effect of power poses on testosterone and risk-taking following competition

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ABSTRACT

A contribution to a special issue on Hormones and Human Competition.
The effect of postural power displays (i.e. power poses) on hormone levels and decision-making has recently been challenged. While Carney et al. (2010) found that holding brief postural displays of power leads to increased testosterone, decreased cortisol and greater economic risk taking, this failed to replicate in a recent high-powered study (Ranehill et al. 2015). It has been put forward that subtle differences in social context may account for the differences in results. Power displays naturally occur within the context of competitions, as do changes in hormones, and researchers have yet to examine the effects of poses within this ecologically relevant context. Using a large sample of 247 male participants, natural winners and losers of a physical competition were randomly assigned to hold a low, neutral or high-power postural display. We found no main effect of pose type on testosterone, cortisol, risk or feelings of power. Winners assigned to a high-power pose had a relative, albeit small, rise in testosterone compared to winners who held neutral or low-power poses. For losers, we found little evidence that high-power poses lead to increased testosterone relative to those holding neutral or low-powered poses. If anything, the reverse was observed – losers had a reduction in testosterone after holding high-power poses. To the extent that changes in testosterone modulate social behaviors adaptively, it is possible that the relative reduction in testosterone observed in losers taking high-powered poses is designed to inhibit further "winner-like" behavior that could result in continued defeat and harm. Still, effects were small, multiple comparisons were made, and the results ran counter to our predictions. We thus treat these conclusions as preliminary.

1. Introduction

Social asymmetries in animals are often demarcated by physical and vocal displays that signal submission and dominance. In chimpanzees, our closest relatives, high-ranking males have erect hair, appear larger than their actual size (Nishida and Hiraiwa-Hasegawa, 1987) and engage in more agonistic encounters (e.g. charging displays) (Bygott, 1974; Muller, 2002). In contrast, subordinates pant-grunt (de Waal, 1982), lower their head and shoulders and avoid eye contact with their higher ranked counterparts (Goodall, 1986). These behaviors may also have a hormonal component since dominance rank and testosterone (T) are positively correlated in chimpanzees (Muller and Wrangham, 2004). Analogous behaviors are thought to exist in humans, especially following competitive interactions. Non-verbal expressions of victory often include an expansive posture and outstretched arms, while defeat is frequently followed by a contracted posture and lowered gaze (Tracy and Matsumoto, 2008). These expressions are culturally invariant and appear in blind and sighted individuals (Matsumoto and Willingham, 2009). While there is a long history of drawing parallels between dominance displays in other animals and emotional displays in humans (e.g., Darwin, 1872/2009), more recently, arguments of phylogenetic continuity have been made for displays of power and dominance (e.g., Weisfeld and Linkey, 1985) as well as the physiological systems that underlie them (e.g., Carney et al., 2010).

Drawing from the theory of embodiment – the idea that bodily movements can influence cognition, motivation and emotion – a number of researchers have examined whether bodily expressions of power in humans, manifested as either expanded or contracted postures, have discernable effects on the psychology, physiology and behavior of their bearers. While a growing number of studies have demonstrated that expansive bodily postures (i.e., power posing) results in increased feelings of power (Carney et al., 2010; Fischer et al., 2011; Huang et al., 2011; Park et al., 2013; Ranehill et al., 2015), its effects on hormones, and risk-taking behavior remain controversial. In a sample of 42 participants randomly assigned to hold either high or low power poses, Carney et al. (2010), found that individuals who took high power poses had increased T, decreased cortisol (C) and were more risk seeking in monetary gambles. However, a conceptual replication involving a considerably larger sample of 200 individuals failed to find an effect of

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power posing on T, C, economic risk-taking as well as a behavioral measure of competitiveness (Ranehill et al. 2015). Some have labeled Carney et al.'s (2010) original study as an "exercise in noise mining",[1] and thus likely a false positive result that should not be expected to replicate. The original study was, indeed, statistically underpowered to detect any effect of power poses hormones and behavior (Simmons and Simonsohn, 2015). Still, others have argued that subtle methodological differences that exist between Carney et al. (2010) and Ranehill et al. (2015) could have accounted for this failure to replicate, including differences in instruction method, participant pool and the time of day the study was conducted (see Carney et al., 2015 for complete list).[2] While it could be argued that meaningful effects should generalize despite slight methodological variations, the original authors have also argued that differences could also be due to the fact that the replication was not situated in a "social context" (Carney et al., 2015).

Social context may be particularly important given that power displays are likely to have evolved for their communicatory effect, and hormones themselves affect and are affected by social behaviors. In the original study participants were asked to form impressions of faces on a screen while holding the different poses. While this task was initially described as a "filler task" by Carney et al. (2010), the authors argue that it may have been necessary to produce the effect. That said, it should be noted that significant, albeit weaker, effects have been obtained in studies conducted in non-social contexts (Cesario and McDonald, 2013). Nevertheless, given the theorized importance of social context on power posing, we decided to study its effect within a competitive context – a context that 1) has greater ecological validity for power posing, 2) has established hormonal correlates, and 3) is anchored in an evolutionary framework. We believe that an evolutionary framework is conducive for understanding *why* a relationship between postural displays and hormones/behavior might exist in the first place, *if* it exists at all.

"The Challenge Hypothesis" (Wingfield et al., 1990; Archer, 2006) and "The Biosocial Model of Status" (Mazur and Booth, 1998) are two influential and complementary theoretical models that help to explain the dynamic relationship between T, the end product of the hypothalamus-pituitary-gonadal (HPG) axis, and the social behavior of males in a number of species. According to "The Challenge Hypothesis," T should encourage resource and mate-seeking behaviors in organisms – including those behaviors associated with aggression and competition – when it is beneficial for the organism. Likewise, the "Biosocial Model of Status" posits that T motivates competitive behaviors that serve to increase status. This model further predicts that changes in status impact T concentrations such that winners of competitive interactions experience a relative rise in T compared to losers. This differential response to wins and losses primarily occurs in men (Bateup et al., 2002; Casto and Edwards, 2016a, 2016b), and applies to physical competitions, such as tennis (Booth et al., 1989) and wrestling (Elias, 1981), non-physical competitions, such as chess (Mazur et al., 1992) and political elections (Apicella and Cesarini, 2011; Stanton et al., 2009). While not all studies demonstrate a significant winner-loser effect, meta-analytic evidence suggests that winners generally have higher T than losers (Archer, 2006; Geniole et al., 2016). Moreover, this characteristic hormonal response is thought to modulate behavior adaptively (Oliveira, 2004) – declining levels of T in losers may promote withdrawal from these activities, possibly to prevent further loss and harm, while elevated levels in winners may serve to encourage further status seeking opportunities and ultimately, greater reproductive opportunities (Mazur and Booth, 1998). Indeed, studies have found that transient changes in T following competition affects men's aggressiveness (Carré and Olmstead, 2015; Carré et al., 2009), willingness to compete (Mehta and Josephs, 2006), economic risk taking (Apicella et al., 2014) and investment in a team (Apicella and Cesarini, 2011). While both hypotheses have garnered support for the role of T on a broad range of competitive and status-enhancing activities, including economic risk-taking in humans (for reviews, Apicella et al., 2015; Archer, 2006; Oliveira et al., 2009; Stanton and Schultheiss, 2009), other non-androgenic hormones, namely C, have recently been implicated in status-seeking behaviors and may help to explain some of the null results obtained for the winner-loser effect (for review, Hamilton et al., 2015).

Cortisol is a glucocorticoid – the end product of the hypothalamic-pituitary-adrenal axis (HPA) – known for its metabolic and energy mobilization processes. Within minutes of a threat increases in circulating C are observed. C causes glucose to become more concentrated in the bloodstream by stimulating gluconeogenesis (i.e. the conversion of proteins to glucose) and down-regulating insulin-mediated glucose uptake (Lundgren et al., 2004). This temporary mobilization of glucose provides muscles with the energy needed for fight or flight responses (Sapolsky, 1992b) that may be necessary during dominance contests or competitions. Perhaps then unsurprisingly, many athletes experience a rise in both C and T with competition (e.g. Casto et al., 2014; Edwards et al., 2006; Hamilton et al., 2009; Suay et al. 1999) though there is little evidence for a link between baseline C and self-selection into competitive environments (Apicella et al., 2011). Also, in many low-ranking animals, glucocorticoids are generally elevated, possibly due to psychosocial stress (Sapolsky, 2005), although the reverse has also been observed. This reversal in hormones and status may occur when dominance hierarchies are unstable (Sapolsky, 1983, 1992a) and/or when the energetic costs of maintaining high status are great (Gesquiere et al. 2011; Muller and Wrangham, 2004).

Not only is there a complex reciprocal interplay between C, T and the social environment, but they may interact with each other as well. Cortisol has inhibitory effects on HPG function and similarly, T inhibits HPA function (Viau, 2002). Moreover, baseline levels of T may affect how individuals react hormonally and behaviorally to wins and losses. For instance, Mehta et al. (2008) find that only men with high basal T experience changes in C as a result of winning or losing. More recently, it has been hypothesized that *only* when C is low, should T promote dominance and status seeking behaviors (Mehta and Josephs, 2010; see Hamilton et al., 2015 for review). This new view is called the dual-hormone hypothesis.

The current study examines the effects of postural displays on both T and C, and their interaction, within the context of a physical competition. To do this, natural winners and losers of a physical competition were randomly assigned to hold low, neutral or high power poses to examine if body posture influences power, risk taking, and physiology differently following a victory or a defeat. In other words, we ask whether postural displays can affect how people experience wins and losses. If a competitor walks away from a loss with their shoulders lifted and head held high, versus shoulders slumped and head lowered, does this affect how they experience the defeat? We focus on the post-competition context since both postural and hormone changes naturally occur following competitive interactions.

2. Method

2.1. Participants

We recruited $N = 258$ male participants from an urban mid-Atlantic university population, including students and staff, using a web-based subject pool. Prior to hormone assays, we excluded eleven participants who used psychotropic medications or steroids. The final sample was $n = 247$ male participants with a mean age of $M = 22.0$ ($SD = 5.6$) years old. We exclusively studied men since measurement of T in women can be particularly problematic (Welker et al., 2016). A majority

[1] Andrew Gelman, a statistician at Columbia University, has written extensively on power posing on his blog and has referred to the original study as an exercise in noise mining. http://andrewgelman.com/2016/10/22/30294/

[2] Since the acceptance of this paper one of the authors of Cuddy et al. (2010) has publicly disavowed the effect though another author maintains its veracity. This will be further addressed in the discussion.

Fig. 1. Reenactment of tug-o-war game played by participants.

of the sample identified as White, $n = 114$, but also included participants who identified as Asian or Pacific Islander, $n = 77$, Black, $n = 31$, Hispanic, $n = 15$, and Other, $n = 9$. One participant did not provide sufficient saliva sample for baseline C levels and was not included in relevant analyses.

2.2. Procedure

The study was a 2 (Competition outcome: winner or loser) × 3 (Power pose: low, neutral or high) between-subjects design; competition outcome was not randomly assigned and instead was determined by an actual competition, and we randomly assigned participants to a pose condition. Participants were told the study was about the role of biology in decision-making and were instructed not to eat or drink any liquids an hour before coming in for their scheduled session. Each session had four to ten participants, and three research assistants oversaw all sessions; the sessions were conducted throughout the day, with starting times from 9:00 to 18:00. After consenting to the study, participants provided the first saliva sample overseen by a male[3] research assistant. Following saliva collection, participants were randomly assigned to an opponent to compete in three rounds of tug-of-war (see Fig. 1). At the end of the third round the research assistant declared a winner and a loser. After the competition, participants then held a low, neutral, or high power pose for 63 s, and then held another version of the same pose type for an additional minute. Participants then waited 15 min after the pose before providing a second saliva sample. During the wait, participants completed a survey that included demographics and questions about power, control and comfort level while holding the poses, taken from Carney et al. (2010), After the second saliva sample was collected participants completed a task measuring economic risk-taking. Finally, anthropometric measures were taken and participants were debriefed and paid a show-up fee of 15 USD, plus any additional earnings. During debriefing, ten participants said they were aware of previous research on posture and hormones and correctly guessed the hypothesis; excluding the participants did not change the results so they were included in the results. All procedures were approved by the University of Pennsylvania's Office of Regulatory Affairs.

2.3. Tug-o-war

After participants provided the first saliva sample, they were randomly paired to compete against each other in a game of tug-o-war. The participants were led to another area of the lab out of view from the original station. Once there, a male[4] research assistant instructed the participants on how to play tug-o-war and the conditions for winning and losing. Participants faced each other at 8 ft (2.4 m) apart and used an 11 ft, 10 in. (3.6 m) long, 1.5 in. (3.8 cm) nylon tug-o-war rope to pull their opponent 3 ft (.9 m) over a win line; all distances were marked with color-coded tape and explained to the participants prior to play. All participants wore fitness gloves with padded palms to protect their hands. Participants played three rounds under the supervision of the research assistant. At the end of the third round, the participant who won the most rounds was declared the winner: "Congratulations, you are the winner of this competition. Based on this measure, you are stronger than your opponent." The other participant was declared the loser: "I am sorry, but you are the loser of this competition. Based on this measure, you are weaker than your opponent." The competition typically lasted less than 5 min. We used a physical competition instead of a cognitive task (e.g., Mehta et al., 2008; Zilioli & Watson, 2014) to better simulate the dominance competitions across the animal kingdom in which the winner-loser effect is well established. We used a natural competition instead of a rigged one with randomly assigned winners and losers because the Penn Laboratory for Experimental Evolutionary Psychology adhered to a no deception policy.

2.4. Power poses

After the tug-o-war competition, participants were led to a third section of the lab for the postural pose manipulation overseen by a female[5] research assistant. Because of this set-up, the research assistant overseeing the power poses was blind to the competition outcome though they may have made correct assumptions about the winner based on the body size of the participants. Each participant sat at a computer station out of view of the other participants and was randomly assigned to the

[3] For 31 participants, this RA was a female. While participants were randomized to pose-type, excluding these 31 participants did not change the results and so are included in all analyses.

[4] For 11 participants, this RA was a female. Similar to the above footnote, excluding these participants did not change the results and are included in all analyses.

[5] For 20 participants, this RA was a male. Excluding these participants did not change the results and they are included in all the analyses.

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Table 1
Mean testosterone (T), cortisol (C), and risk taking by experimental group.

	n	Baseline T (pg/mL)	Change in T (pg/mL)	Baseline C (μg/dL)	Change in C (μg/dL)	Risk taking score
Winner						
High power	43	171.41 (79.27)	9.22 (43.90)	0.233 (0.226)	0.027 (0.120)	4.5 (1.2)
Neutral	43	162.44 (88.05)	−0.14 (48.16)	0.171 (0.122)	0.019 (0.074)	4.4 (1.2)
Low power	38	155.96 (64.98)	−3.50 (41.55)	0.204 (0.135)	0.000 (0.096)	4.2 (1.1)
Loser						
High power	40	174.43 (70.47)	−12.84 (45.03)	0.254 (0.171)	−0.010 (0.152)	4.3 (1.2)
Neutral	44	150.10 (58.25)	−7.91 (42.04)	0.198 (0.123)	0.017 (0.208)	4.2 (1.3)
Low Power	39	163.37 (52.61)	8.09 (45.96)	0.271 (0.226)	0.002 (0.145)	4.1 (1.2)

Note. Values for hormones are non-transformed salivary levels. Standard deviations are in parentheses.

high power, low power, or neutral power pose condition by the computer. The computer provided instructions on how to hold the pose; the research assistant confirmed that the participant was holding the pose correctly before letting the participant continue and then moved out of sight from the participant. Participants held a sitting or standing version of the pose for 63 s and then switched to the alternative version for another 63 s, again after the research assistant confirmed they were holding the pose correctly. The high and low power poses were taken from Carney et al. (2010). For the neutral standing pose, participants stood with their feet slightly apart, but no further than their shoulders, and with their arms resting against their sides. For the neutral sitting pose, participants placed their feet flat on the floor shoulder-width apart, sat up straight, and kept their arms on the arm rest.

We used the same filler task used by Carney et al. (2010) which they later (Carney et al. 2015) hypothesized could have been an important methodological omission in the replication by Ranehill et al. (2015), thus lending to a lack of an effect. While holding each pose, participants viewed nine faces (obtained from Carney, personal communication), for 7 s each and were instructed to “form an impression” of the person in each photo – for a total time holding the pose of 63 s.[6] This was repeated for the next version of the pose with a different set of nine faces.

3. Measures

3.1. Hormonal assays

Saliva samples were collected via passive drool into 2 ml cryovials. Immediately after collection, the samples were stored in a freezer at −20 °C. After data collection, all samples were shipped in dry ice via UPS overnight delivery to Salimetrics, LLC, Carlsbad, CA. Saliva samples were assayed for T and C in duplicate using an enzyme immunoassay.[7] Both tests use 25 μl of sample per determination. The test for T had a lower limit sensitivity of 1 pg/ml and an average inter-assay coefficient of variation of 9.8%. The intra-assay coefficient of variation was 5.2% for the entire sample. The test for C had a lower limit sensitivity of 0.007 μg/dl and an average inter-assay coefficient of variation of 6.6%. The intra-assay coefficient of variation was 5.1% for the entire sample.

3.2. Risk preferences

Financial risk preferences were measured using a variant of a multiple price list (MPL), one of the most commonly employed ways to elicit risk preferences in economics (for review see Charness et al., 2013). Participants were asked to make ten pairwise choices between receiving a certain amount of money and a lottery. These choices were presented in a table containing ten rows. The same lottery, which was a 50/50 gamble to win 10 USD or nothing, was offered in each row, but the safe option increased in each row from 1 USD to 10 USD, in increments of 1 USD. Participants were told that one of their ten decisions would be chosen and realized as payment. This ensured that each decision was incentivized. The number of risky decisions chosen was used as the participant's risk preference score, with a lower number indicating greater risk aversion. In our task, a risk-averse individual would trade off some expected gain for increase certainty, preferring perhaps a certain amount of $2 or $3, over a chance to win $10. A risk-loving individual might prefer the lottery over a certain amount of $8. We could have extended our rows to include safe amounts higher than the amount that could be won in the lottery (i.e. $10), but individuals with such extreme preferences are rare (Dohmen et al., 2011). Our risk task is similar to what many use in the economics literature, e.g. Dohmen et al. (2011), and it is also an extended version of the risk task used by Carney et al. who also offer participants a choice between one safe option of $2 and a 50/50 lottery to win $4 or $0. However, the main difference is Carney et al. had their participants make only a single decision where the safe option and the lottery have the same expected payoff. Thus our task provides a more fine-grained measure of an individual's risk preferences.

3.3. Anthropometric measurements

Anthropometric measures, including height, weight, body fat percent, muscle mass, and hand grip strength were collected as possible control variables. Participants were weighed using a Tanita BC-533 InnerScan Body Composition Monitor, which provided measurements for weight, body fat percent, and lean muscle mass. Participants provided estimates of their height. Grip strength was measured using a Baseline Smedley Digital Hand Dynamometer.

4. Results

The distributions for T and C levels were nonnormal, so the data were transformed using a two-step process prior to any analysis. In this process, the data were percentile ranked to produce a uniform distribution, which was then used as the probability to calculate a *z*-score using the inverse error function to produce a normal distribution (Templeton, 2011). Changes in hormone levels were calculated by regressing the transformed post-manipulation levels on to the transformed baseline levels and saving the unstandardized residuals. Table 1 presents the descriptive statistics for the raw values of T and C, as well as the risk score, for each experimental group.

4.1. What predicts winning?

Competition outcome was not randomly assigned but instead determined by a natural competition. As such, we first determined the best predictors of winning the competition to identify controls to use in our analyses. We started with the assumption that physical size and strength are major contributors to winning at tug-o-war. Indeed, winners had a greater height, weight, muscle mass, body fat percent, and grip strength than their opponents, $ts > 2.55$, $df = 123$, $ps < 0.05$.

[6] Poses were held for 63 s, as opposed to a minute, because the software used did not allow us to limit the amount of time they looked at each picture by fractions of a second.

[7] A recent paper suggests immunoassays are not as accurate as other methods, in particular mass spectrometry (Welker et al., 2016). However, we use the immunoassay method because it is the method used in most studies, including Carney et al. (2010).

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When entered in a logistic regression predicting competition outcome, only muscle mass, $b = 0.09$, $SE = 0.05$, $z = 1.89$, $p = 0.059$, and grip strength, $b = 0.02$, $SE = 0.01$, $z = 1.85$, $p = 0.065$, were marginally significant. Muscle mass and grip strength were moderately correlated, $r = 0.48$, $p < 0.001$, so we calculated a composite strength score from their mean values after being standardized. When entered in logistic regression with height, weight, and body fat percent, it was a significant predictor of winning, $b = 0.62$, $SE = 0.27$, $z = 2.28$, $p = 0.022$, and remained the only significant predictor, all other $ps > 0.28$.

We also examined if baseline T and C predicted competition outcome. In a logistic regression with baseline T and C, higher levels of C predicted a loss, $b = -0.53$, $SE = 0.19$, $z = -2.84$, $p = 0.004$, whereas there was a marginally significant positive correlation between baseline T and victory, $b = 0.32$, $SE = 0.18$, $z = 1.78$, $p = 0.074$. When entered in a logistic regression with the strength composite score, C remained significant, $b = -0.48$, $SE = 0.20$, $z = -2.44$, $p = 0.014$, T became significant, $b = 0.39$, $SE = 0.19$, $z = 2.06$, $p = 0.039$, and strength remained significant as well, $b = 0.84$, $SE = 0.17$, $z = 5.06$, $p < 0.001$. We conduct all of our analyses with and without strength, baseline hormone levels, age, and time of day as controls.

4.2. Competition, poses, and power

Self-perceived power was analyzed in a 2 (Competition outcome: Winner or Loser) × 3 (Power pose: Low, Neutral, or High) between-subjects ANOVA. There was no effect of competition outcome, $F(1, 240) = 1.13$, $p = 0.290$, or power pose, $F(2, 240) = 0.30$, $p = 0.740$, and the interaction was nonsignificant, $F(2, 240) = 0.46$, $p = 0.634$ (see Fig. 2A). The results remain nonsignificant when controlling for strength, baseline hormone levels, time of day, and age, $ps > 0.29$.

4.3. Competition, poses, and economic risk

Economic risk taking was analyzed in a 2 (Competition outcome: Winner or Loser) × 3 (Power pose: Low, Neutral, or High) between-subjects ANOVA. There was no effect of competition outcome, $F(1, 241) = 0.96$, $p = 0.328$, or power pose, $F(2, 241) = 0.98$, $p = 0.377$, and the interaction was nonsignificant, $F(2, 241) = 0.16$, $p = 0.850$ (see Fig. 2B). The results remain nonsignificant when controlling for strength, baseline hormone levels, time of day, and age, $ps > 0.31$.

4.4. Competition, poses, and hormones

Change in T was analyzed in a 2 (Competition outcome: Winner or Loser) × 3 (Power pose: Low, Neutral, or High) between-subjects ANOVA. There was a significant interaction, $F(2, 241) = 3.24$, $p = 0.041$, partial $\eta^2 = 0.03$ (see Fig. 2C). This remains significant after controlling for strength, baseline hormone levels, time of day, and age, $F(2, 236) = 3.61$, $p = 0.029$, partial $\eta^2 = 0.03$, and when also controlling for the interactions between pose, strength, and baseline hormone levels, $F(2, 230) = 3.60$, $p = 0.029$, partial $\eta^2 = 0.03$. This interaction is not predicted by power pose theory. There was no main effect of competition outcome, $F(1, 241) = 1.49$, $p = 0.224$, or power pose, $F(2, 241) = 0.65$, $p = 0.525$; these remained nonsignificant after controlling for strength, baseline hormone levels, time of day, and age, $ps > 0.22$. Probing the interaction, we examined the difference in power pose effects between competition outcomes by testing the simplified 2 × 2

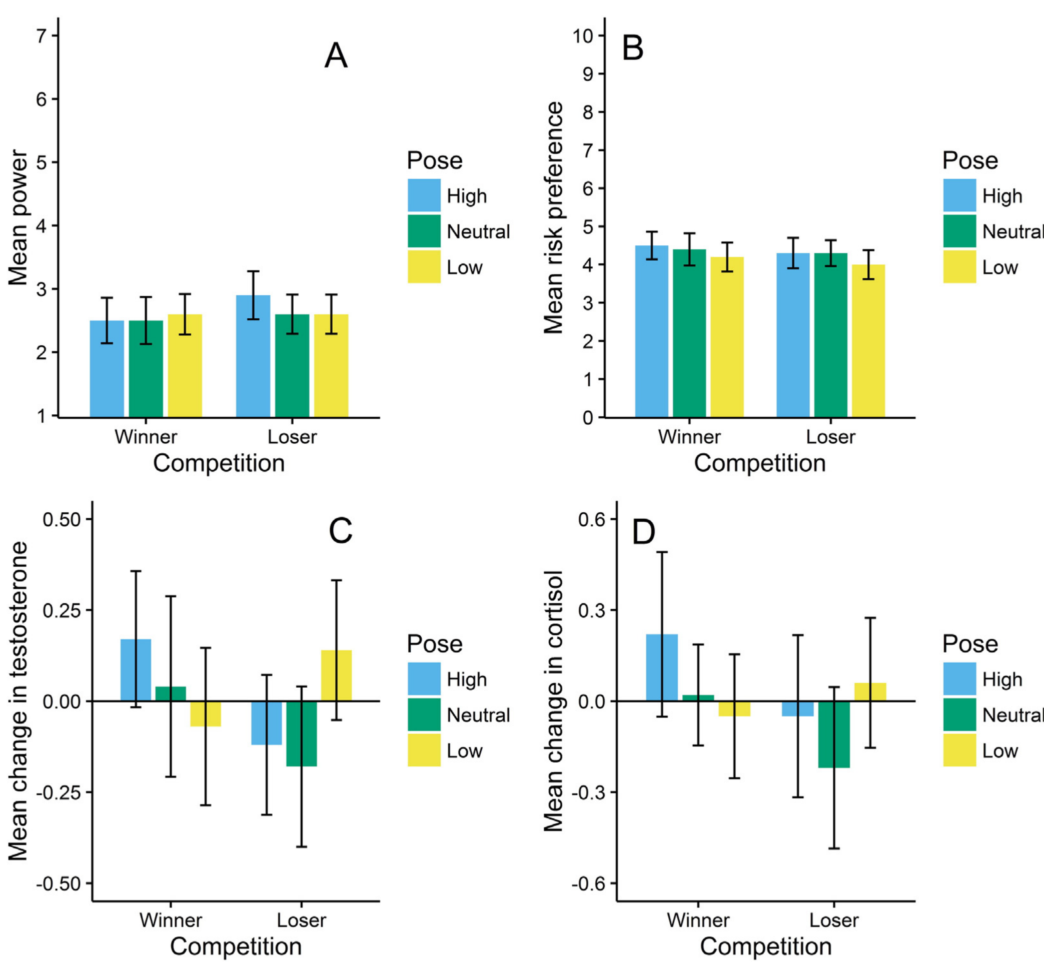

Fig. 2. Mean (A) self-perceived power, (B) risk-taking score, (C) residual change in testosterone, and (D) residual change in cortisol by condition. Error bars are 95% confidence intervals.

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interaction between competition and power poses, excluding neutral poses. There was a significant interaction, $F(1, 156) = 6.65$, $p = 0.011$, partial $\eta^2 = 0.04$; participants who held poses congruent with their competition outcome, such as winners holding high power poses or losers holding low-power poses, had an increase in T, whereas participants who held poses incongruent with their competition outcome, such as losers holding high power poses, had a decrease in T. We then examined mean differences between pose conditions within each competition outcome. There was no effect of power pose for winners, $F(2, 121) = 1.14$, $p = 0.324$, while there was some evidence of an effect of power pose for losers, $F(2, 120) = 2.91$, $p = 0.058$, partial $\eta^2 = 0.05$. A post-hoc Tukey test showed some evidence that losers who held a low power pose had a marginally significant increase in T relative to losers who held a neutral pose, $p = 0.064$; no other differences were significant, $ps > 0.16$.

Change in C was analyzed in a 2 (Competition outcome: Winner or Loser) × 3 (Power pose: Low, Neutral, or High) between-subjects ANOVA. There was no main effect of competition outcome, $F(1, 241) = 2.22$, $p = 0.137$, or power pose, $F(2, 241) = 1.28$, $p = 0.280$, and the interaction was nonsignificant, $F(2, 241) = 1.54$, $p = 0.216$ (see Fig. 2D). These effects remained nonsignificant after controlling for strength, the hormone composite, time of day, and age, $ps > 0.13$.

4.5. Exploratory analyses: hormones and economic risk taking

We conducted a number of exploratory analyses – many of which were requested by reviewers. Previous research found that hormone levels, and in particular T, sometimes influence economic risk-taking, although the results are mixed (see Apicella et al., 2015, for a review). Different models of this relationship have been proposed and tested. The simplest model is that risk-taking increases linearly with baseline T (Apicella et al., 2008). Others though have found that the relationship between risk-taking and T is quadratic, with moderate levels of T being associated with greater risk-taking (Stanton et al., 2011). Still others have found that the relationship between T and risk-taking depends on the level of C, with a positive relationship between T and risk-taking with unknown outcomes for individuals with low C (Mehta et al., 2015).[8] Finally, other research indicates that change in T may also predict risk-taking, with increases in T being associated with more risk-taking (Apicella et al., 2014). Though it was not the central aim of this research, we conducted exploratory analyses testing these different models of hormones and economic risk taking.

Testing the simple baseline model, risk-taking was regressed on baseline T and C separately and together, with and without age, time of day, and strength as controls. In the full model with both hormones and the controls, T was nonsignificant, $b = -0.03$, $SE = 0.10$, $t(241) = 0.09$, $p = 0.927$, and so was C, $b = 0.01$, $SE = 0.10$, $t(241) = -0.29$, $p = 0.775$. The coefficients were nonsignificant in the simpler models.

Testing the quadratic model, risk-taking was regressed on T-squared and baseline T and C-squared and baseline C, in the same and separate models, with and without age, time of day, and strength as controls. In the full model, T-squared was nonsignificant, $b = 0.04$, $SE = 0.04$, $t(239) = 0.97$, $p = 0.331$, as was C-squared, $b = -0.00$, $SE = 0.04$, $t(239) = -0.04$, $p = 0.965$. The coefficients were nonsignificant in the simpler models.

Testing the reactivity model, risk-taking was regressed on the change in T and change in C, separately and together, with and without age, time of day, and strength as controls. In the full model, change in T was nonsignificant, $b = -0.05$, $SE = 0.14$, $t(240) = -0.39$, $p = 0.698$, as was the change in C, $b = 0.12$, $SE = 0.13$, $t(240) = 0.94$, $p = 0.348$. The coefficients were nonsignificant in the simpler models.

Testing the dual-hormone model, risk-taking was regressed on the interaction between T and C, with and without age, time of day, and strength as controls. In the full model, the interaction was nonsignificant, $b = 0.05$, $SE = 0.07$, $t(239) = 0.74$, $p = 0.463$, as well as baseline T, $b = -0.04$, $SE = 0.10$, $t(239) = -0.42$, $p = 0.675$, and baseline C, $b = 0.01$, $SE = 0.10$, $t(239) = 0.10$, $p = 0.919$. The coefficients were nonsignificant in the simpler models.

We further tested each of the models with competition outcome, poses, and their interaction with hormone levels. This resulted in dozens of regression models, some with nearly a dozen coefficients, dramatically increasing our experimentwise error rate. Only one set of models, the dual-hormone model interacting with competition outcome, neared significance; however, we highlight it here—with the caveat that this analysis was completely exploratory—because it highlights future areas of research, and it is in line with previous findings of competition outcomes moderating the interactive effects of C and T in dominance behavior (Mehta & Josephs, 2010). Risk-taking was regressed on the three-way interaction between baseline C, baseline T, and competition outcome, along with the simpler components of the interaction. There was a marginally significant three-way interaction without controls, $b = -0.27$, $SE = 0.15$, $t(239) = -1.86$, $p = 0.064$. The three-way interaction was statistically significant when including age, time of day, and strength as controls (see Table 2), and remained significant, $b = -0.32$, $SE = 0.15$, $t(233) = -2.13$, $p = 0.035$, when controlling for the three-way interaction between T, C, and strength to control for the fact that stronger individuals were more likely to be winners. We decomposed the interaction by examining the two-way interaction between T and C for winners and losers separately. The interaction was marginally significant for losers, $b = 0.20$, $SE = 0.11$, $t(119) = 1.81$, $p = 0.072$. When C was low, there was a trending negative association between T and risk, $b = -0.30$, $SE = 0.18$, $t(119) = -1.70$, $p = 0.092$, and when C was high, there was a nonsignificant positive association between T and risk, $b = 0.12$, $SE = 0.23$, $t(119) = 0.55$, $p = 0.582$. For winners, the two-way interaction was nonsignificant, $b = -0.07$, $SE = 0.09$, $t(120) = -0.75$, $p = 0.457$, and none of the simple slopes are significant. However, examining Fig. 3 suggests winners show the opposite pattern from losers, with risk-taking increasing with T when C is low, though again, this is nonsignificant. Again, we stress that these additional tests were exploratory, as requested by reviewers, multiple tests were conducted, and many of the tests are only marginally significant.

5. Discussion

Carney et al.'s (2010) borrowed aphorism, "fake it till' you make it" – the idea that a relatively simple body hack can change your hormones and behavior – has enjoyed mass appeal. A 2012 TEDGlobal talk highlighting the findings and delivered by co-author Amy Cuddy, who stated that these "tiny tweaks can lead to big changes", has been viewed over 27 million times, generated mass interest in the phenomenon of

Table 2
OLS regression model testing dual-hormone hypothesis on risk.

	b	*SE*	*t* (236)	*p*
Cortisol	0.02	0.13	0.18	0.521
Testosterone	−0.11	0.16	−0.64	0.521
Competition	0.30	0.18	1.61	0.109
Cortisol by testosterone	0.23	0.11	2.02	0.045*
Cortisol by competition	−0.05	0.21	−0.23	0.819
Testosterone by competition	0.14	0.21	0.68	0.498
Cortisol by testosterone by competition	−0.29	0.14	−2.05	0.042*

Notes. Regression model includes age, time of day, and strength as controls.
* p < .05.

[8] The Balloon Analogue Risk Task (BART), where participants attempt to maximally inflate a balloon for a reward without popping it, was used in this study. This is commonly described as a measure of risk propensity. We prefer to describe this as a measure of ambiguity aversion since risk, at least in economics, refers to situations where probabilities are known. In the BART task, participants do not know when the balloon will pop.

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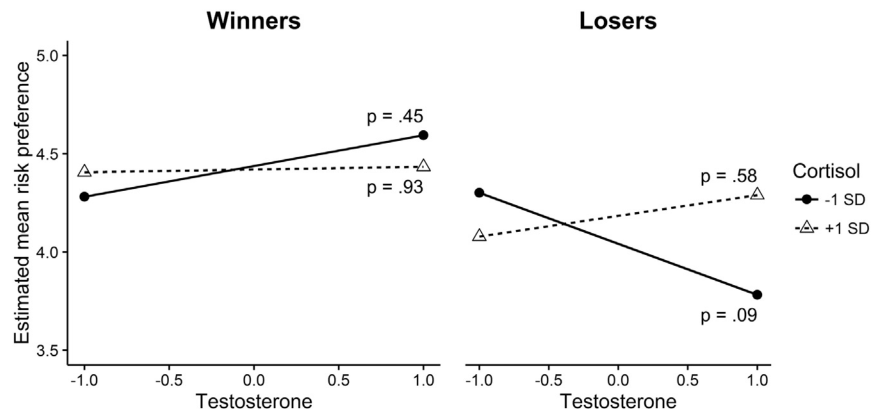

Fig. 3. Economic risk preference as a function of baseline cortisol and testosterone for winners and losers. Plotted points are conditional low and high values of testosterone and cortisol.

power posing[9] and a book deal for Cuddy. At the same time, skepticism about the phenomenon grew among academics leading to increased research effort and money devoted to studying the phenomenon, including the current study which took over two years to complete. Most recently, and since submission of the current publication, two of the authors of Carney et al. (2010) have publicly disagreed about whether the effects of power posing are in fact real. On September 25th 2016, Carney posted a document on her website which included an admission of unintentional p-hacking and disavowing the reported effects of power posing. A few days later, Cuddy defended power posing, especially its effects on feelings of power, in a statement issued through her publisher. In the current study, with a sample six times larger than Carney et al. (2010) we find no main effect of pose type on T, C, economic risk-taking or feelings of power.

The original findings are striking. Carney et al. (2010) report that a 2-minute pose manipulation (low or high) can lead to sizable changes in T, C, economic risk-taking and feelings of power. For instance, they found that holding a simple expansive posture for as little as 2 min led to a 20% increase in T. This amount of time is similar to how long it might take a person to hang up a curtain, yet this change is similar to the magnitude of change that occurs diurnally. Testosterone decreases about 20–25% in young men from early morning to late afternoon (Brambilla et al., 2009). In contrast, we found that winners holding a high-power pose had a small increase (10.6%) in T and for losers the reverse was observed with a high-power pose resulting in a decrease (3.6%) in T. Winners holding a low-power pose also had a small increase (1.1%) in T and losers holding a low-power pose also had an increase (7.7%) in T. We also find that levels of C, risk-taking and feelings of power were unaffected by pose type. Similar to Ranehill et al. (2015), our results call into question whether one can "fake it till' they make it" by holding expansive or contractive power poses. If anything, our results suggest that if you are a "loser" it could potentially hurt, but urge skepticism until the result can be replicated in a high powered study.

The methods employed in our study were similar to Carney et al. (2010) in a number of ways. Our participants 1) were also recruited from a large urban university, located about 100 miles south of the original study site,[10] 2) held the same poses and for the same amount of time 3) engaged in the same filler task where participants were asked to view and form impressions of nine faces and 4) were not told explicitly told the purpose of the study. It should be noted that Carney et al. (2015) listed these particular study characteristics as possible reasons for the failed conceptual replication by Ranehill et al. (2015). Unlike Carney et al. (2015), our sample was nearly six times larger, took place in an ecologically and socially relevant context (i.e. a competition) and employed a more continuous measure of economic risk-taking.

As described in the methods, participants were not randomly assigned to a competition outcome. Though we attempted to control for features that predicted competition outcomes, such as strength and baseline hormone levels, no causal conclusion can be reached about competition outcome. Future work could address this by rigging competitions to randomly assign participants to either victory or defeat. Participants were, however, randomly assigned to hold low, neutral, or high power poses, and we can conclude from the study design that the causal effect of poses—if any—potentially differs between contexts, though other studies are necessary to establish whether it is competition outcomes or other variables that cause the context effect.

While we did not reveal the purpose of the study to participants we also did not deceive participants by providing an elaborate cover story as was the case for Carney et al. (2010). Given the widespread popularity of power posing it is possible that this deception was necessary in order to generate an effect. That said, the vast majority of our participants did not guess the purpose of the study and excluding those participants that did, did not change the results. If it is the case that conscious awareness of power poses and their hypothesized effects can reduce or eliminate the pose's influence, then this too calls into question the usefulness of the behavior in everyday life. Thus the advice given to the general public – to hold power poses before high stakes events – is likely wrong.

Difference in cover story may also explain why we failed to replicate a main effect of post-type on feelings of power, the finding which Cuddy most strongly defends and Ranehill et al. (2015) also replicates. Though Ranehill et al. (2015) did not reveal any specific predictions about the relationship between poses and behavior to participants, they did clearly state to participants that the study was examining the effect of such poses on behavior. We simply told participants the study was on the role of biology in decision-making, which may not have cued our participants on to the pose manipulation, avoiding a possible demand effect. Future studies could use measures of implicit power to further avoid demand characteristics. That said, careful attention to the supplementary material for Ranehill et al. (2015) show that the effect on feelings of power was only present for men. Moreover, a very recent study examining the effect of power poses on feelings of power found that expansive poses led to decreased feelings of power (Garrison et al., 2016). It could thus very well be the case that the feelings of power results in both Carney et al. (2010) and Ranehill et al. (2015) are false positives.

[9] Comparing July 2012 to December 2015 on Google Trends suggest that the number of Google searches for "Amy Cuddy" multiplied by 29. Similarly, the number of searches for "power pose" was 296% higher in December 2015 compared to July 2012. One of the current authors (C. Apicella), even promoted the findings in an online video released by National Geographic's popular show *Brain Games*.

[10] Of course, the original study included men and women. However, there was no indication of a sex difference in the effect. If anything, by restricting our sample to men, we reduce the variability in hormone levels and risk-taking, reducing error and increasing our chances of finding the effect.

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5.1. Why did losers holding high power poses experience a decrease in T?

While we found no main effect of pose type on T, C, risk or feelings of power, we unexpectedly found that losers who held high power poses experienced a relatively greater decrease in T compared to losers who assumed neutral or low power poses. While this may be a false-positive and thus requires further replication, we do speculate on these findings. It has been hypothesized that T works as a physiological modulator of behavior in males allowing them to respond adaptively to changing social environments (Oliveira, 2004). For instance, it is thought that the rise in T that is observed in winners of competitions works to motivate future competitive and risky behaviors while in losers, a decrease in T should work to reduce competitive motivation, thus preventing further loss and harm to the organism. Outside the laboratory setting, acting like a winner or assuming a dominant position after a defeat, could result in further aggression or attack from an opponent. Thus it is possible – assuming this finding is real – that the decrease in T observed in losers who assume powerful postures, is an adaptive response designed to depress further "winner-like" behavior that could result in further loss and harm. Again, this finding was not anticipated and the explanation is speculative.

The field of ethology has long been interested in the question of why low-ranking individuals do not display signals of high-status (e.g. armaments), given that high status confers many benefits in terms of access to resources and mates. In other words, why are there so few individuals faking high-status? In a classic study, Rohwer (1977) dyed the plumage of subordinate sparrows to match the plumage of high-ranking sparrows and found that the legitimate high-ranking birds persecuted the "fakers". Other studies on low-ranking males with experimentally exaggerated armaments find similar detrimental effects – these males are more likely to be attacked, barred from feeding and excluded from social groups (for review, Berglund et al., 1996). Thus perhaps, Carney et al. (2015) was right to argue that the social context of power posing is important. Ironically however, the social context itself may undermine the supposed benefits of power posing.

5.2. What variables predict economic risk taking?

Neither competition outcome, posture held, changes in T, C or their interaction, predicted economic risk-taking in the current study. Ranehill et al. (2015) and now more recently, Garrison et al. (2016) also failed to find an effect of power poses on economic risk-taking. A prior study examining T change following wins and losses also failed to find an effect of competition outcome on risk aversion, though T change, following wins and losses, was predictive of risk such that higher levels of T were associated with less risk aversion (Apicella et al., 2014). The current study was primarily designed to test the effects of postural displays on economic risk –rather than winner-loser effects or the relationship between T change and risk. Thus, unlike Apicella et al. (2014) participants in the current study were not randomly assigned to win or lose the competition. That said, the nature of the relationship between T and economic risk in men is far from certain (for review, Apicella et al. 2015) as both linear (e.g. Apicella et al. 2008; Sapienza et al., 2009) and non-linear relationships have been observed (e.g. Stanton et al. 2011), as well as null results (e.g. Sapienza et al., 2009). Moreover, exogenous administration of T does not lead to increased economic risk in women (Zethraeus et al., 2009, Boksem et al., 2014).

There was some evidence that winners with low C and higher levels of T were more risk-seeking, whereas losers with low C and higher levels of T were less risk-seeking. Again though, the analysis between risk-taking and hormones was exploratory and we conducted multiple tests, some requested by reviewers, with no corrections, and the tests were only marginally significant. We offer an interpretation of these results with the caveat that this is highly speculative. In the face of a victory, individuals who may feel more dominant than others, such as those with high T, receive positive feedback about their status in the local dominance hierarchy and may upregulate status-seeking behaviors, such as risk taking, accordingly. However, in the face of a defeat, these same individuals receive negative feedback about their status in the hierarchy and may downregulate status-seeking and risk taking. Similarly, decreases in T may be acting as an indicator to losers holding high power poses to down-regulate their status behavior. Future research should seek to replicate this finding in studies explicitly testing this model before strong conclusions are drawn.

5.3. Future directions

There is now a strong consensus in the academic community that the original power posing effects reported by Carney et al. (2010) were not real. It is important however to remember that the hypothesized effects of power posing were not made in a vacuum, but rather, the research was motivated by a large and growing body of work on embodied cognition. Much of this work has been widely accepted[11] and based on foundational work examining how emotions are affect by arousal (e.g. Schachter, 1959). Today, many social psychologists continue to regard embodiment as powerful framework for explaining human cognition and emotion (Winkielman et al., 2015). For these reasons, we expect that psychologists will continue to conduct research on power poses, and embodiment more generally, despite growing evidence that this may not be a prosperous research tract. Accordingly, we do provide some ideas for future directions, grounded in evolutionary theory, that we believe would be most fruitful to pursue with a forewarning that we would not be surprised if power posing yielded no discernable effects on behavior and physiology.

Carney et al. (2015) hypothesized that the 'social context' in which the poses are held, are likely important. Indeed, much evidence suggests that vocal and physical displays in animals evolved for their social communicatory function, rapidly signaling asymmetries in status to conspecifics. For these reasons, we decided to study power posing within the context of a competition. Humans too, are not exempt from status competitions. Even in egalitarian hunter-gatherers subtle differences in status exist (see Henrich and Gil-White, 2001). Furthermore, both bodily displays and hormonal changes are associated with competitive outcomes in humans. We chose to use a physical competition, based primarily on strength, given that these expansive displays have been described as "dominant" and "powerful" (Carney et al. 2010). That said, it is possible that a different type of competition may have generated a different result. It has been argued that status attainment in humans can be achieved via dominance (e.g. use of fear and intimidation) or prestige (e.g. use of knowledge, skills and success) (Henrich and Gil-White, 2001). Future work might consider studying power posing within the context of competitions where the outcome is based on skills and/or expertise rather than strength. This type of competition might be more meaningful to university students who invest much of their resources and time to increasing their skill set and knowledge base. Future work could also explore which emotions are most closely associated with the displays. For instance, these displays may have less to with feelings of dominance and submissiveness, and more to do with feelings of pride and shame (see Tracy and Matsumoto, 2008).

Given the possible communicatory function of bodily displays, future work could also examine the effect of holding power displays in the presence of competitors. In the current study, we wanted to keep our method similar to Carney et al. (2010) and chose to have participants isolated from one another following the competition. We think that future work could have the participants face each other following the competition. Another avenue for research would be to examine the effects of power poses on hormones and behavior *prior* to a

[11] One of the most acclaimed findings in embodied cognition documented by Strack et al. (1988) found that people holding a pen with their teeth (aiding a smile) rated cartoons funnier than people holding a pen with their lips (impeding a smile), has not survived replication (Wagenmakers et al., 2016).

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competition. We focused on the post-competition environment since competitive outcomes are associated with dimorphic postural displays and hormone changes. However, many competitions in humans and other animals occur following subtle and/or ritualized vocal and auditory displays. For example, the New Zealand rugby team performs a ritualized war dance, a haka, of the Maori people before their matches. It is thought that this dance is meant to intimidate the opposing team, but perhaps it also has the added benefit of increasing confidence and decreasing anxiety in its performers via changes in hormones. While it is not known whether performing a haka increases T or decreases C, a recent study suggests that individuals who watch a haka, experience slight elevations in T (Kilduff et al., 2013).

To the extent that future research finds that the social context in which bodily displays occur matters for generating effects, this might suggest that the route via which it occurs is unlikely to be embodiment. Different signals sent out into the world generate different responses from conspecifics – responses that, in turn, the signaler needs to react to. That is, holding a power pose may lead to psychological and physiological changes via muscle memory or autonomic nervous system activity (for review see, Price et al., 2012), but it is also possible that it is the *knowledge* itself, of what the display is signaling to others, that is generating the effects. Holding your fists up in full sight of your enemy will likely generate very different feelings and reactions than holding your fists up behind your enemy's back. One avenue for future research would be to determine whether status signals (e.g. via clothing, written messages), independent of body or vocal movements, lead to changes in physiology, risk taking or feelings of power.

6. Conclusion

Bi-directional relationships exist between hormones and behavior and thus, it is not entirely farfetched to think that postural changes could affect hormones. That said, simple one direction hormone – behavior relationships are rare in humans, if they exist at all. Thus far, the two largest studies (e.g. the current study and Ranehill et al. 2015) examining the effect of power poses on hormones and economic risk suggest that the effects are either minimal or strongly influenced by context. It is possible that previous studies that have reported positive results were false positives. An analysis of *p*-values in the power posing literature suggests that power posing has no effect or so small of an effect that sample sizes need to be substantially larger than what has been used in previous studies (Simmons and Simonsohn, 2015). In the current study, we do perform multiple comparisons and our significant results do not survive corrections for multiple hypothesis testing. Despite the increased number of cells in the study, our sample was large enough to achieve a power of 0.99 to detect the original effect size reported in Carney et al. (2010), and could detect a medium effect-size ($\eta^2 = 0.04$) with a power of 0.82. In sum, our significant and null results should be interpreted with caution. A recent paper found that among 100 psychology papers, only about a third of the results were successfully replicated, and the replication rate was lower in social psychology than in cognitive psychology (Open Science Collaboration, 2015). Researchers who choose to continue to work in this area should proceed cautiously.

Author contributions

CLA and KMS designed the study. KMS conducted the statistical analyses and CLA checked analyses. CLA and KMS wrote and revised the paper.

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