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Face of a Fighter: Bizygomatic Width as a Cue of Formidability

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Humans can accurately extract information about men's formidability from their faces; however, the actual facial cues that inform these judgments have not been established. Here, through three studies, we test the hypothesis that bizygomatic width (i.e. facial width-to-height ratio, fWHR) covaries with actual physical formidability (*hypothesis #1*) and that humans use this cue when making assessments of formidability (*hypothesis #2*). Our data confirm that fWHR is predictive of actual fighting ability among professional combatants (study 1). We further show that subjects' assessments of formidability covary with the target's fWHR on natural faces (study 2), computer-generated images of strong and weak faces (study 2), and experimentally manipulated computer-generated faces (study 3). These results support the hypothesis that bizygomatic width is a cue of formidability that is assessed during agonistic encounters. Aggr. Behav. 41:322–330, 2015. © 2014 Wiley Periodicals, Inc.

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INTRODUCTION

Animals have conflicts of interest that can, at times, be resolved by aggression. Because the costs of fighting are often high, even for the winner (Krebs & Davies, 1993), many species have evolved mechanisms that assess contestants' asymmetries in fighting ability (or resource-holding power; Parker, 1974). These assessments inform the decision of whether to escalate or withdraw from the contest (Cluttonbrock-Brock, Albon, Gibson, & Guinness, 1979; Huntingford & Turner, 1987; Smith & Parker, 1976). Depending on the species, an individual's fighting ability may be evident in physiological and behavioral cues such as body weight (Archer, 1988; Wells, 1988), body weaponry (Hongo, 2003), physiological state indicators (e.g. recent injuries, Taylor & Jackson, 2003), age (Fischer, Perlick, & Galetz, 2008), and chemical cues (Bergman & Moore, 2001). Facial expressions (Ekman et al., 1987), vocal changes (Scherer, Banse, & Wallbott, 2001), body postures (Duclos et al., 1989), and submissive and dominant displays (Keltner & Buswell, 1997) co-occur to dynamically signal individuals' intentions, and therefore, negotiate cost-effective contest decisions. However, along with these indirect (and sometimes imprecise) signals of formidability, evidence suggests that the humans possess neurocognitive adaptations specifically evolved for assessing opponents' fighting ability.

In two articles, Sell et al. (2009, 2010) demonstrated that, across several cultures, humans could accurately estimate men's physical strength from the body, face, and voice. In particular, estimates of formidability were found to be cross-culturally accurate, independent of body size, more precise in male than female targets and specifically representative of upper body strength. These and similar findings (Windhager, Schaefer, & Fink, 2011) support the hypothesis that selection pressures have provided humans with neurocomputational mechanisms which function to assess fighting ability from specific cues in the human face. For example, Windhager et al. (2011) showed how a broad middle face, a widened region

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between the eyebrows and a rounded outline (well-curved jaw line and lower forehead) predicted actual strength and perceived masculinity among young men.

These findings and others suggest that the bone structure of the zygomatic arches is a potential cue of formidability. This testosterone-linked biometric index (Lefevre, Lewis, Perrett, & Penke, 2013; Verdonck, Gaethofs, Carels, & de Zegher, 1999) is measured as the ratio between the left and right zygion distance, and the nasion and prosthion distance (hereafter facial width-to-height ratio, or fWHR). It is believed to be independent of body size—not subject to allometric growth—and sexually dimorphic (Weston, Friday, & Lio, 2007). Support for these hypotheses is mixed (Coetzee, Chen, Perrett, & Stephen, 2010), particularly with regard to the claim that fWHR is highly sexually dimorphic (Lefevre et al., 2012; Ozener, 2012). In contrast, good agreement (though not without exceptions; Ozener, 2012) has been obtained on the association between the bizygomatic width and dominance-related behaviors, such as exploitation of others (Stirrat & Perrett, 2010), aggression (Carré & McCormick, 2008; Christiansen & Winkler, 1992), power-driven deception (Haselhuhn & Wong, 2012), and survival from violent encounters (Stirrat, Stulp, & Pollet, 2012).

For instance, Stirrat et al. (2012) measured width-to-height ratio in more than 500 male crania and found that men with broader faces were less likely to have died from physical homicides than men with narrower faces. The same biometric index was found to be associated with indirect measures of violent behavior (i.e. penalty minutes) among hockey players (Carré & McCormick, 2008). Lastly, among !Kung San men, hunter-gatherers from Namibia, Christiansen and Winkler (1992) reported that bizygomatic breadth, not corrected for face height, was a good predictor of the person's history of physically violent interactions, inferred from the number of head scars and wounds.

Complementary studies found that fWHR is a reliable cue of dominance-related traits such as aggression (Carré, McCormick, & Mondloch, 2009), lack of trustworthiness (Stirrat & Perrett, 2010), and self-interest (Haselhuhn, Wong, & Ormiston, 2013).

Here, through three studies, we test two primary hypotheses derived from the theory that formidability assessment mechanisms have evolved to use facial width as a cue of fighting ability:

A. *Hypothesis #1*—that facial width covaries with fighting ability as measured by career statistics and fighting success among professional combatants in mixed-martial arts (study 1).
B. *Hypothesis #2*—that wider faces are perceived to be more formidable than thinner faces, when viewing photographs of actual people (study 2b), or when viewing computer-generated facial images (study 2a and study 3).

If formidability assessment mechanisms have evolved to use fWHR as a cue of formidability, both of these predictions must be true.

STUDY 1

The purpose of study 1 was to test hypothesis #1—that better fighters have larger facial width-to-height ratios. The Ultimate Fighting Championship® (UFC) is the world's largest organization for mixed-martial arts, a style of full-contact combative sport that blends striking and grappling techniques in an effort to physically overpower and subdue an opponent. Fighters who experience a series of consecutive losses are usually expelled—the unspoken rule being "three strikes and you're out" (Horne, 2012). Despite occasional inconsistencies in verdicts (Chase, 2011), the "no-holds-barred" nature of the fights and the process of "cutting" serially defeated combatants from the championship makes for a somewhat Darwinian environment, well-suited to the investigation of fighting ability.

We employed several measures of fighting ability based on the records of the UFC fighters. The percentage of wins was employed as a standard measure, although some unavoidable error was introduced by the non-random matching of fighters (e.g. the best fighters are assigned to fight each other), and by the biased record of those fighters who had newly joined the UFC (because joining requires multiple victories, and very few losses, accrued in less challenging promotions). An alternative is to assess duration of UFC membership, because fighters who repeatedly lose matches are expelled from the UFC over time: a contestant's fighting ability is thus reflected in the length of his stay in the UFC. To capture this information, we recorded each fighter's total number of bouts as well as the number of those bouts that he had won. The same approach has been followed by recent studies on UFC fighters (Baker & Schorer, 2013).

Method

We gathered data on all 294 experienced UFC fighters —defined as having had a minimum of 10 official fights, at least one of which was in the UFC—up to September 29, 2012. This means that few fighters in the database had only one or two matches in the UFC. In order for an athlete to attain the status of UFC fighter he has to have a very good record in the previous organization he fought for, so, although the rules of these other leagues might be different from those of the UFC, athletes with even one of two defeats in these minor

leagues usually have little chance of getting to the UFC. Photos of each athlete were taken from the official UFC website (www.ufc.com); fighters' records were retrieved from Wikipedia. Close-up photographs were missing for five individuals and 15 people either retired or were cut from UFC before September 29, 2012. Twenty-one pictures were excluded because of long hair, thick sideburns, or thick beards covering the zygions, and eight were excluded because their head was tilted forward or because they did not have a neutral expression. In total, 29 subjects were excluded leaving a total of 245 fighters for our final database. Facial width-to-height ratio was measured as per Carré and McCormick (2008). Three fighters differed by more than three standard deviations from the mean number of total fights ($M = 21.27$, $SD = 9.01$), whereas one combatant had a face ratio almost four standard deviations away from our sample mean ($M = 1.95$, $SD = .14$). These four individuals were excluded from the final analyses (final $n = 241$). Inclusion of these outliers does not change the pattern of the results.

Results and Discussion

Hypothesis #1: Fighters who lasted longer in the UFC had wider faces (i.e. the correlation between width-to-height ratio and total number of fights in the UFC was $r = .163$, $P = .011$). Fighters who won more fights also had wider faces (number of wins correlated with fWHR at $r = .203$, $P = .001$); however, the percentage of wins did not significantly correlate with fWHR ($r = .097$, $P = .132$). This non-significance could have resulted from the fact that fighters' percentage of wins negatively correlated with their total number of fights ($r = -.223$, $P < .001$). Once total numbers of fights were controlled for, a fighter's percentage of wins correlated positively and significantly with their fWHR ($r = .139$, $P = .031$).

An ideal test of fighting ability would put fighters against one another at random. For ethical reasons, the UFC maintains weight classes and only fighters of a similar size are permitted to fight each other. This means that our measures of fighting ability artificially lower the estimates for fighting abilities of heavy fighters (who fight only large fighters) and inflate the estimates for fighting ability of lighter fighters (who fight only smaller opponents), relative to the total sample of fighters. To at least partially control for this error, we ran three partial correlations, one for each measure of fighting ability on fWHR controlling for BMI. The results did not change: fWHR was positively correlated with total number of fights ($r = .154$, $P = .017$) and total number of wins ($r = .190$, $P = .003$), but not with the win/loss records ($r = .088$, $P = .172$). However, when controlling for both BMI and number of fights, the correlation between fWHR and percentage of wins turned out to be significant ($r = .128$, $P = .048$).

Lastly, we considered the association between fWHR and fighting success in three categories: lightweight (from 57 to 70 kg, $n = 118$), middleweight (from 77 to 84 kg, $n = 73$), and heavyweight (from 90 to 120 kg, $n = 50$). A significant correlation between fWHR and number of wins was found among lightweight ($r = .183$, $P = .047$) and heavyweight ($r = .287$, $P = .043$) fighters. In middleweight fighters a non-significant correlation of comparable effect size was found ($r = .131$, $P = .270$) as well as a trend towards significance between fWHR and percentage of wins ($r = .217$, $P = .065$; $r = .242$, $P = .040$, when controlling for number of fights). Taken together, these results indicate that bizygomatic width is a cue of a man's formidability even among this highly truncated sample of professional fighters.

Recently, Trebicky and colleagues tested a very similar hypothesis to the one reported here and found that Caucasian mixed-martial arts fighters with wider bizygomatic range and deep-set eyes had a higher combat success (Trebicky, Havlicek, Roberts, Little, & Kleisner, 2013). There is a difference between the two studies in how the facial features were recorded. While Trebicky et al. first obtained measures of fighting ability and perceived aggressiveness and then, using geometric morphometric techniques, searched for those facial traits associated with these characteristics, we first measured fWHR and then correlated it to measures of fighting ability. Trebicky and colleagues' approach identified a more comprehensive set of facial features associated with variables of interests (i.e. actual fighting ability and perceived aggressiveness). Our approach, on the other hand, focused only on one facial ratio and provides a more direct test of the hypothesis we propose. In the Discussion of their article (Trebicky et al., 2013), the authors describe the overlap between their findings and pioneer work on the link between fWHR and perceived aggressiveness by Carré et al. (2009). Interestingly, in a separate unpublished contribution the same authors tested whether fWHR would predict proportion of fights won and perceived aggressiveness in Caucasian fighters (Trebicky, Fialova, Kleisner, & Havlicek, 2013). A correlation between fWHR and proportion of victories as well as fWHR and perceived aggression was found. The latter relationship was particularly evident for lightweight and heavyweight, but absent in middleweight combatants.

Similar analyses were performed in our database. Among Caucasian fighters, fWHR correlated with the percentage of wins ($r = .206$, $P = .019$) but not the total number of fights ($r = .058$, $P = .511$) or the total number of wins ($r = .134$, $P = .129$). Among non-Caucasian fighters, fWHR correlated with the total number of

fights ($r = .283$, $P = .003$) and the total number of wins ($r = .280$, $P = .003$), but not with the percentage of wins ($r = -.017$, $P = .858$). The partial correlation coefficient between fWHR and percentage of wins, controlling for number of fights, was significant for Caucasian fighters ($r = .234$, $P = .008$) but not for non-Caucasian fighters ($r = .023$, $P = .810$). Further, no association between fWHR and number of wins was found among lightweight ($r = .150$, $P = .252$), heavyweight ($r = .269$ $P = .203$), or middleweight ($r = .008$, $P = .956$) Caucasian fighters. These correlations were also not significant among non-Caucasian fighters (average $r = .27$, lowest $P = .090$). This non-significance is unsurprising given the small sample size of each group (higher n = 57, lower n = 21).

STUDY 2

The main purpose of study 2 was to test hypothesis #2 (i.e. wider faces should be perceived as more formidable than thinner faces) using composite faces generated from stimuli collected in study 1. Two pairs of composite faces were generated. The first pair juxtaposed a composite of the most experienced fighters (those with the highest number of fights, Fig. 1A) with a composite of the less experienced fighters (those with the least number of fights, Fig. 1B). The second pair juxtaposed a composite of the widest faced fighters (Fig. 1C) with a composite of the thinnest faced fighters (Fig. 1D). The first pair allowed us to both replicate previous findings on people's ability to estimate formidability from the face (Sell, Cosmides et al., 2009; Trebicky et al., 2013) as well as validate our measure of fighting ability; the second pair allowed us to test whether width-to-height ratio is being used as a cue to assess formidability in the face.

To further corroborate our second hypothesis, we conducted a follow-up study (study 2b) using the entire sample of fighters that were selected to create the four composites rather than the composites themselves (n = 48). This approach allows us to directly examine the association between width-to-height ratio and perceived formidability among UFC fighters.

Method

Experienced/inexperienced (Fig. 1A and B) and *wide/narrow-faced* (Fig. 1C and D) composites were created using PsychoMorph computer graphics software (Tiddeman, Burt, & Perrett, 2001). For the *wide/narrow-faced* composites we averaged the 15 widest faces (M = 2.25, SD = .06) and the 15 narrowest faces (M = 1.73, SD = .02). Twelve faces were used in the *inexperienced* composite (all fighters with 10 fights), and 13 faces were used in the *experienced* composite (fighters with a total number of fights between 36 and 48, M = 41.38, SD = 4.11). Previous research has shown that a minimum of 12 faces is necessary for composites to reduce differences not related with the variable of interest (Tiddeman et al., 2001). Participants were presented with each prototype in a randomized order and asked to rate "how tough each would be in a physical fight," on a 7-point Likert scale (Sell, Cosmides et al., 2009). Next, subjects chose the more formidable of the composite faces paired against their opposites (*wide* vs. *narrow* composites and *experienced* vs. *inexperienced* composites). Subjects were instructed to pick who would be more likely to win in a physical fight on scale of 1–8 from 1 = "Left image is much tougher" to 8 = "Right image is much tougher" (for similar procedure, see Watkins & Jones, 2012). The two pairs were presented in random order, with the *inexperienced faced* composite and the *wide-faced* composite always appearing on the left. One-sample t-tests were used to compare scores of perceived fighting ability with what would be expected by chance (i.e. 4.5). A total of 36 students (aged 18–29) from Simon

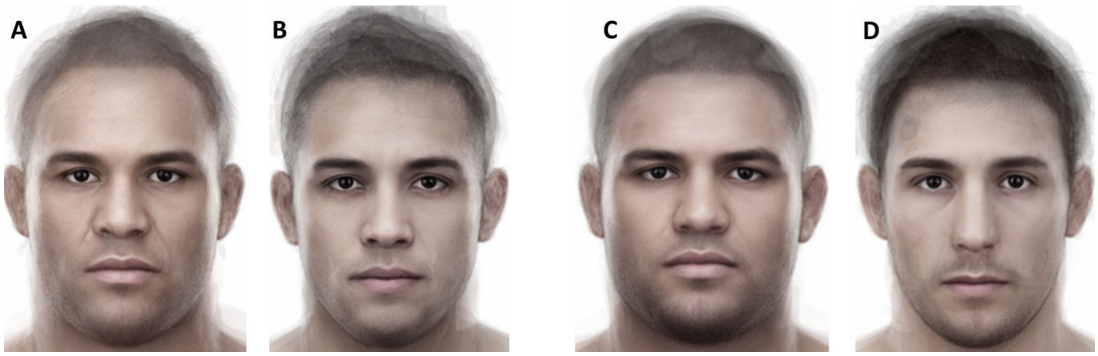

Fig. 1. The construction of composite faces used in study 2. The experienced (A) and the inexperienced composites (B) were generated by averaging fighters with the most and the least number of fights. The wide-faced (C) and narrow-faced composite (D) were generated by averaging fighters with the highest and the least fWHR values.

Fraser University, who reported no knowledge of UFC, participated (16 men, mean age = 21.7, SD = 2.12; 20 women, mean age = 21.8, SD = 2.38).

After testing, some concern was expressed that the *wide/narrow* composite faces might differ in perceived ethnicity (see Fig. 1C and D), which might confound the results. To control for this potential confounding effect in the *wide/narrow* faces we created new composites using the same criteria as Trebicky et al. (2013). We made composites of the 12 widest faced and the 12 narrowest faced images of men of only "apparent non-African or non-Asian origin" (see Fig. 2A and B). This new pair of images was presented to a new sample of 40 student participants (20 men, mean age = 20, SD = 1.82; 20 women, mean age = 20.3, SD = 2.15), who were asked to identify which would be more likely to win in a physical fight, using a scale of 1–8, where 1 = "Left image is much tougher" and 8 = "Right image is much tougher." The left-right order of presentation for the *narrow* versus *wide* composites was completely counterbalanced across participants.

In study 2b a new sample of 32 students (aged 18–27) from Simon Fraser University, who were unfamiliar with the UFC, participated (16 men, mean age = 21.5, SD = 1.77; 16 women, mean age = 21, SD = 1.06). This time subjects were asked to rate individual fighters' faces, presented randomly, on a 7-point Likert scale-, on "how tough each would be in a physical fight—how likely he would be to beat his opponent."

All procedures for the studies reported here were subject to review and prior approval by the Simon Fraser University Research Ethics Board.

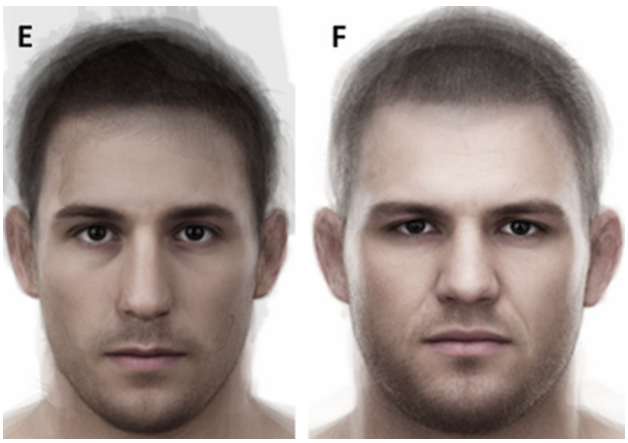

Fig. 2. The construction of composite faces used in study 2. The perceived non-African, non-Asian wide-faced, (E) and narrow-faced composites (F) were generated by averaging fighters with the highest and the lowest fWHR values.

Results and Discussion (Study 2a)

If humans can accurately assess fighting abilities in conspecifics, the composite of the experienced fighters ought to be rated as more formidable than the composite of the less experienced fighters. This was confirmed by an *independent samples t*-test showing that the composite composed of experienced fighters (M = 5.7, SD = 1.07) was rated as more formidable than the inexperienced composite (M = 4.5, SD = 1.21) (t (35) = −4.692, $P < .001$). This result replicates previous work establishing the ability to estimate formidability from the face (Sell, Cosmides et al., 2009; Trebicky et al., 2013), and also serves to validate our measure of fighting ability.

Hypothesis #2: If fWHR is perceived as a cue of formidability, subjects' ratings of the composites should show that the wider composite is rated as more formidable than the thinner composite. An independent-samples t-test confirmed this: The composite of the widest faces (M = 5.28, SD = 1.11) was rated as more formidable than the narrow composite (M = 4.61, SD = 1.25) (t (35) = −2.366, $P = .024$).

Data from a forced choice task provided a second test of hypothesis two: When subjects were forced to pick which composite face appeared tougher, they reliably chose the experienced face over the inexperienced face (t (35) = 5.540, $P < .001$) and the wide over the narrow face (t (35) = −3.416, $P = .002$). Likewise, the same results were seen when we used alternate composite faces including only images that appeared non-African and non-Asian in origin (t (39) = 2.516, $P = .016$). These last two findings support the prediction that width-to-height ratio is being used as a cue to assess formidability in the face.

The subsamples of fighters used to create the composites were used to further test hypothesis #1—that better fighters had wider faces. An independent-samples t-test indicated that combatants with the most fights had wider faces (M = 2.07, SD = .18) than people with only 10 fights (M = 1.92, SD = .13) (t (23) = 2.447, $P = .022$). Furthermore, those fighters with the widest faces had more wins (M = 18.93, SD = 10.46) than fighters with the narrowest faces (M = 13.07, SD = 4.45) (t (18.90) = 1.998, $P = .060$). Similarly, those Caucasian fighters with the widest faces had more wins (M = 16.07, SD = 6.39) than those Caucasian fighters with the narrowest faces (M = 12.33, SD = 4.34) (t (28) = 1.873, $P = .072$). These results strengthen our findings in study 1, showing that fWHR is a correlate of fighting ability.

Results and Discussion (Study 2b)

Results of study 2b further confirmed our second hypothesis. First, we confirmed that ratings of formidability did indeed track fighting ability: raters' judgments

of formidability were positively correlated with both total number of fights ($r = .456$, $P = .001$) and total number of wins ($r = .445$, $P = .002$), predicting respectively 21% and 20% of their unique variance. When looked at dichotomously the same results were found: fighters in the *experienced* group (M = 5.1, SD = .54) were rated as significantly more formidable than fighters in the *inexperienced* group (M = 4.3, SD = .56) (t (23) = 3.445, $P = .002$). On the other hand, the win/loss record did not correlate with perceived formidability ($r = -.061$, $P = .680$), suggesting that—as expected—it is an inferior measure of fighting ability than our other measures of survival in the UFC (see study 1 and Baker & Schorer, 2013).

Hypothesis #2: As predicted, facial width-to-height ratio positively correlated with perceived formidability ($r = .460$, $P = .001$) in our sample of fighters. Controlling for BMI did not change this pattern of results ($r = .338$, $P = .02$). When these data were dichotomized into those fighters with wide faces and those with narrow faces, the same results were found: fighters in the *wide-faced* group (M = 4.9, SD = .6) were rated as significantly more formidable than fighters in the *narrow-faced* group (M = 4.1, SD = .6; t (28) = 3.791, $P = .001$). These data further validate the hypothesis that width-to-height ratio is used as a substantial cue when assessing a person's formidability.

STUDY 3

The results described so far support both the hypotheses that fWHR covaries with fighting ability and that individuals use this feature when assessing others' formidability. However, the use of natural faces prevented rigorous experimental control of other facial characteristics, which might convey cues of formidability (e.g. hairstyle, forehead size, ethnicity). To control for these naturally varying features, the fWHR of individual facial images was artificially varied to create multiple test stimuli, and then employed to probe subjects' perceptions of fighting ability.

Methods

A sample of 124 students (aged 17–45) from Simon Fraser University participated (66 men, mean age = 21.3, SD = 2.5; 58 women, mean age = 21.3, SD = 3.7). Stimuli were taken from experiment 3 of Stirrat and Perrett's study (2010) which consisted of 12 image pairs: each pair of images was made from a base composite face transformed to make a *wider* fWHR image and a *narrower* fWHR image (for more details, see Stirrat & Perrett, 2010). During the task, face pairs (*wider* vs. *narrower*) were presented in random order, counterbalanced for left/right presentation and rated in forced choice interface for strength on scale of 1–8 from 1 = "Left image is much stronger" to 8 = "Right image is much stronger" (for similar procedure, see Watkins & Jones, 2012). All procedures for the studies reported here were subject to review and prior approval by the Simon Fraser University Research Ethics Board.

Results

One-sample t-tests, comparing perceived formidability score to what would be expected by chance (i.e. 4.5), revealed that the *wider* faces were rated as significantly stronger than their *narrower* counterparts (t (123) = 3.566, $P = .001$). We conclude that facial width-to-height ratio is used to estimate individuals' formidability.

GENERAL DISCUSSION

Hypothesis #1: Width-to-height ratio predicts fighting ability. If facial width-to-height ratio is one of the cues that enable humans to accurately estimate physical formidability from the face, this measure must covary with fighting ability. Our data show that bizygomatic width covaries with fighting success in a sample of fighters who "survived" in a fighting competition—the UFC—that is highly competitive, quasi-Darwinian, and arguably the most realistic fighting competition in the world (study 1 and Table I).

The phenotypic origin of this relationship requires both a proximate developmental mechanism and an ultimate

TABLE I. Summary of Results on the Link Between fWHR and Formidability

Formidability Assessment	Effect Size, *P*-Value
Study 1: survival in the UFC correlated with fWHR	$r = .163$, $P = .011$
Study 1: wins in the UFC correlated with fWHR	$r = .203$, $P = .001$
Study 1: percentage of wins (controlled for total fights) correlated with fWHR	$r = .139$, $P = .031$
Study 2a: wide-faced composite perceived tougher than narrow-faced composite	$d = .57$, $P = .024$
Study 2a: wide-faced composite perceived tougher than narrow-faced composite in a forced choice task	$d = 1.15$, $P = .002$
Study 2a:Caucasian wide-faced composite perceived tougher than Caucasian narrow-faced composite in a forced choice task	$d = .81$, $P = .016$
Study 2b: fighters in the wide composite perceived tougher than fighters in the narrow composite	$d = 1.38$, $P = .001$
Study 2b: tough ratings correlated with fWHR	$r = .460$, $P = .001$
Study 3: wide composite perceived stronger than narrow composite in identical pairs	$d = .33$, $P = .001$

explanation. Developmentally, androgens are a promising candidate given (1) their effect on the body (Jansson, Ekberg, Isaksson, Mode, & Gustafsson, 1985; Schoutens et al., 1984), face (Lefevre et al., 2013; Verdonck et al., 1999), and bone growth; and (2) the link between genotypic (Simmons & Roney, 2011) and phenotypic (Auyeung et al., 2011; Bhasin et al., 1996) characterizations of high-testosterone individuals and strength. For instance, in two studies, Lefevre et al. (2013) reported a positive association between male fWHR and both basal level of testosterone and testosterone responses to potential mates. However, the contribution of additional hormonal mechanisms, such as insulin/insulin-like growth factor—which has been recently identified as responsible for growth of sexually selected ornaments/weapons in some species (Emlen, Warren, Johns, Dworkin, & Lavine, 2012) and growth hormone (Pirinen, 1995), could play a role as well.

The larger question of why these developmental mechanisms exist in the form that they do—such that better fighting morphology is linked to wider faces remains unanswered. One possibility is that this relationship is a by-product of allometric growth (though see, Weston et al., 2007). Alternatively, some bone structures may offer an advantage over others in terms of blunt force trauma resistance (Stirrat et al., 2012), bite strength, or oxygenation of the body; in such a case the developmental systems that regulate the tradeoffs in the body and develop more combat-designed bodies in some men would also develop more combat-designed faces (Archer, 2006; Proffit, Fields, & Nixon, 1983; Rosas & Bastir, 2002).

Regardless of its origin, the existence of this relationship between facial structure and fighting ability would have given natural selection an opportunity to design a more accurate formidability assessment mechanism.

Hypothesis #2: Width-to-height ratio predicts perceived fighting ability. If natural selection did indeed tailor our formidability assessment mechanisms to track fWHR, than fWHR must correlate with perceived fighting ability as well. Our data show that bizygomatic width is—along with other cues—used to estimate formidability (Table I). Using the faces of professional fighters (studies 1 and 2), we found that wider faced men were perceived to be more formidable. These relationships were significant and consistent even after controlling for BMI, another trait linked to fighting ability (Deaner, Goetz, Shattuck, & Schnotala, 2012; Felson, 1996) and accurately estimated from the face (Coetzee, Perrett, & Stephen, 2009). Lastly, we used an experimental design to show that controlled modifications of a man's facial width-to-height ratio caused the face to appear more formidable (study 3). In conclusion, our data indicate that facial width-to-height ratio is a covariate of fighting ability in men, and is spontaneously perceived as such when assessing a man's formidability.

Explaining the link between fWHR and aggression. There are theoretically profound implications for the link between facial width-to-height ratio and strength. The most important of which, is an evolutionarily derived explanation for the data showing an association between fWHR and a variety of male dominant behaviors (Carré & McCormick, 2008; Stirrat & Perrett, 2010; Stirrat et al., 2012). Basic animal conflict theory holds that more formidable animals should be more aggressive (Archer & Thanzami, 2007; Huntingford & Turner, 1987; Krebs & Davies, 1993; Sell, Tooby, & Cosmides, 2009), and therefore to the extent that fWHR predicts formidability more generally, it will also predict aggressive and dominant behavior. The studies reported herein were not designed to test the hypothesis that the effect of fWHR on aggressiveness is mediated by fighting ability; however, it is plausible that the relationship between fWHR and aggression that has been found in previous studies (though not always consistently, see Ozener, 2012) is most likely due to the fact that fWHR predicts fighting ability, and that males with greater fighting ability exhibit more anger and aggression. This interpretation, which awaits empirical testing, is supported by the robust multicultural evidence that fighting ability is associated with physical aggression and success in interpersonal conflicts (Archer & Thanzami, 2007; Gallup, White, & Gallup, 2007; Hess, Helfrecht, Hagen, Sell, & Hewlett, 2010; Sell, Tooby et al., 2009; Von Rueden, Gurven, & Kaplan, 2008) as well as studies on a non-human primate (i.e. capuchin monkeys) showing that fWHR is associated with dominance status (Lefevre et al., 2014).

LIMITATIONS

These studies support the hypothesis that selection has provided humans with neurocomputational mechanisms which function to assess fighting ability from specific cues in the human face. Other studies converge on this conclusion as well; for example, Windhager et al. (2011) showed that a broad middle face, a widened region between the eyebrows and a rounded outline (well curved jaw line and lower forehead) predicted actual strength and perceived masculinity among young men. In our studies, the strong covariation between fWHR and perceived and actual formidability does not allow us to rule out the contribution of other facial metrics (e.g. jaw line, but see Carré, Morrissey, Mondloch, & McCormick, 2010) known to correlate with fWHR (Stirrat & Perrett, 2010, but see Lefevre et al., 2013) and predict human strength (Windhager et al., 2011). The link between other facial measures and fWHR, as well as their

role in predicting human formidability, awaits further empirical research.

CONCLUSION

This research tested the claim that fWHR is one of the cues that indicate formidability in the human face. Here, through three studies, we provided compelling experimental and correlational evidence in support of this claim by showing that fWHR predicts physical formidability (*hypothesis #1*) and that humans use this cue when making assessments of formidability (*hypothesis #2*). First, our data show that fWHR covaries with formidability in a sample of UFC fighters. Second, using the faces of professional fighters, we found that those men with wider faces were perceived to be more formidable. Lastly, we used an experimental design to show that controlled modifications of a man's fWHR caused the face to appear more formidable.

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