Inhibited power motivation is associated with the facial width-to-height ratio in females

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Abstract

The inhibited power motive is a disposition for obtaining a functional influence on others (Schultheiss, 2008) and characterized by a high implicit need for Power (n Power) and high activity inhibition (AI; McClelland, 1979). Organizational effects of gonadal steroid hormones on the brain during prenatal development affect the emerging n Power (Schultheiss & Zimni, 2015) but it is unknown whether there are similar associations during puberty, a second phase of endocrine organization (Schulz, Molenda-Figueira, & Sisk, 2009). In two studies (combined for analyses; total $N = 213$, after exclusions), we investigated this relationship using the facial width-to-height ratio (fWHR; Weston, Friday, & Liò, 2007), assessed via anthropometry, as a marker of organizational hormone effects during puberty in a cross-sectional, correlational design. N Power and AI were measured via Picture Story Exercise (PSE; McClelland, Koestner, & Weinberger, 1989). Controlling for BMI and age in a multiple regression analysis predicting fWHR, we found a significant n Power x AI-effect, $B = 0.15$, $SE = 0.07$, $t(207) = 2.03$, $p = .04$, $\Delta R^2 = .02$. N Power and fWHR approached a marginally significant positive association, when AI was high (+1*SD*; $B = 0.16$, $SE = 0.10$, $t(207) = 1.64$, $p = .10$) and showed a negative but insignificant association, when AI was low (-1*SD*; $B = -0.14$, $SE = 0.10$, $t(207) = -1.40$, $p = .16$). After adding gender to the model on an exploratory basis, we found a significant n Power x AI x Gender-effect ($B = 0.34$, $SE = 0.17$, $t(203) = 2.00$, $p = .05$, $\Delta R^2 = .02$), predominantly driven by a positive effect of the inhibited power motive in females, $B = 0.28$, $SE = 0.13$, $t(55) = 2.24$, $p = .03$, $\Delta R^2 = .08$. Compared with past research, this finding was unexpected since fWHR is commonly linked to various criteria in males. Implications for the understanding of the development of n Power are discussed, respecting the limitations of our design.

Keywords: implicit motives, power motivation, facial width-to-height ratio, puberty, organizational hormone effects, Picture Story Exercise

Inhibited Power Motivation is Associated with the Facial Width-to-Height Ratio in Females

Implicit motives are motivational dispositions that operate out of conscious awareness and facilitate deriving pleasure from the attainment of specific classes of incentives (Schultheiss 2008; Schultheiss and Köllner 2014). Therefore they select, energize and direct behavior (McClelland 1987), partly by interacting with endocrine systems (McClelland 1989; Schultheiss 2013). Despite implicit motives, such as the implicit need for power (n Power; Winter 1973), being well established motivational constructs with predictive validity (e.g., regarding behavior: McClelland and Watson 1973; Schultheiss et al. 2003; Lansing and Heyns 1959; deCharms et al. 1955; physiological parameters: McClelland 1979, 1989; learning processes: Schultheiss and Köllner 2014; Schultheiss et al. 2005; attentional processes: Schultheiss and Hale 2007) and practical relevance (e.g., connections with: managerial success, McClelland and Boyatzis 1982; work accomplishment, McClelland and Franz 1992; life satisfaction, Hofer et al. 2006; less depression, Pueschel et al. 2011; emotional well-being, Schultheiss et al. 2008), little is known about their development. McClelland and Pilon (1983) identified behavioral differences of parents during early childhood as antecedents of n Power, though it remains vastly unclear what leads to these differences in the first place. Recent work from Schultheiss and Zimni (2015) suggested that lasting effects of gonadal steroid hormones on the brain during prenatal development are precursors of the emerging n Power. It is known that such organizational hormone effects (Phoenix et al. 1959) are not limited to prenatal development but also occur during puberty as a second phase of organization (Schulz et al. 2009). Whether n Power is also associated with organizational effects of gonadal steroid hormones during puberty has not been tested before. In the present paper, we address this issue for the first time by using the facial width-to-height ratio (fWHR; bizygomatic width divided by upper face-height; Weston et al. 2007) as a marker of the latter.

Individuals high in n Power derive pleasure from having impact on others while experiencing the other's impact on themselves as aversive (Schultheiss 2008; Winter 1973). N Power influences affective responses to these motive-specific stimuli and thus alters stimulus-driven learning processes (Schultheiss and Köllner 2014). Furthermore, n Power is tied to endocrine systems and especially to the gonadal steroid hormones testosterone (T) and estradiol (E) that can exert an influence on behavior (Schultheiss 2013; Stanton and Schultheiss 2009; Schultheiss et al. 1999; Schultheiss and Rohde 2002; Stanton and Schultheiss 2007; Stanton and Schultheiss 2011; Schultheiss et al. 2004; Schultheiss et al. 2005). For example, n Power predicts the increase of T in males (r-values ranging from .21 to .88, weighted average $r = .57$; see Schultheiss 2013) and the increase of E in females after winning a dominance contest ($r = .35$; see Schultheiss 2013). A similar pattern can be observed for decreases in case of a defeat (Schultheiss 2013). As a result n Power is associated with a wide range of observable behaviors that allow the motivated individual to gain influence over others (Schultheiss 2008), such as persuasive communication (Schultheiss and Brunstein 2002), aggressive behaviors (Dutton and Strachan 1987; Winter 1988) or seeking attention by taking risks (McClelland and Watson 1973). Also, individuals high in n Power have been shown to adjust their behavior in a way that increases their contact to signals of submission and decreases their contact to signals of dominance (Stoeckart et al. 2016). Furthermore, they are quicker in the recognition of emotions in others compared to individuals low in n Power (Donhauser et al. 2015).

Regarding the predictive validity of the n Power-construct, it is important to note that it is fundamentally different from motivational constructs measured via self-report (see Schultheiss 2008). Other than these explicit motives, the non-verbalizable implicit motives respond primarily to non-verbal cues (e.g., facial expressions of emotion, Hall et al. 2010; Stanton et al. 2010; experimenter behavior, Klinger 1967) rather than to verbal cues and predict spontaneous behaviors (e.g., performance on an attention task, Schultheiss and Brunstein 1999; task performance allowing a high-score entry, Brunstein and Hoyer 2002) rather than planned behaviors or judgements (Biernat 1989; deCharms et al. 1955; Schultheiss 2008). A meta-analysis by Köllner and Schultheiss (2014) showed that there is no significant association of implicit and explicit measures of the need for power. These characteristics also have implications for the measurement of n Power as described in the methods section.

Furthermore, it is necessary to take activity inhibition (AI) into account. The measurement of AI is based on the frequency of negations in running text and, according to Schultheiss et al. (2009a), may constitute a marker for stronger right-hemispheric brain activation during stress. Past research also hinted at AI playing a role in emotion regulation, especially during confrontation with stressors (see Langens 2010; Langens and Stucke 2005). Initially seen as a tendency to restrain motivational impulses, AI was shown to be a recurrent moderator of n Power’s behavioral expression (Langens 2010; Schultheiss et al. 2009a; Schultheiss 2008). Thus, the simultaneous measurement of both n Power and AI allows distinguishing two meaningful configurations in power-motivated individuals: The inhibited power motive (high n Power, high AI) and the disinhibited power motive (high n Power, low AI). On the one hand, the inhibited power motive has been shown to be associated with more sophisticated and socially acceptable forms of gaining influence over others (Langens 2010; Schultheiss 2008), such as the previously mentioned persuasive communication indicated by higher verbal fluency, gesturing and usage of facial expressions (Schultheiss and Brunstein 2002), and also predicted managerial success (McClelland and Boyatzis 1982) as well as work accomplishment (McClelland and Franz 1992). On the other hand, the disinhibited power motive is linked to more blunt and impulsive behavioral manifestations (Langens 2010; Schultheiss 2008), like exerting physical violence, promiscuous sexual activity and boasting about it or getting into arguments (McClelland 1975).

Although, as outlined above, there is plenty of evidence demonstrating n Power’s predictive capabilities, especially with AI as a moderator, showcasing its practical relevance as a functional disposition (Schultheiss et al. 2010), not much effort has been spent on understanding its development. A longitudinal study by McClelland and Pilon (1983) identified differences in parental reactions to childhood behaviors as possible antecedents of n Power. They observed that parents’ self-reported permissiveness for sexual and aggressive behaviors (e.g., masturbation, aggression towards siblings) predicted the adult n Power of their children at the age of 31 or 32 (accounting for 10-30% of variance of adult motive scores). However, this study has not examined whether even earlier influences on motive development exist and whether behavioral differences in childhood could reflect differences in an already emerging n Power.

There is evidence that early organizational effects of gonadal steroid hormones on the brain during prenatal development (i.e. long lasting changes of brain structure and functioning through characteristics of the intrauterine endocrine milieu) have the potential to affect even adult motivational and dominance behaviors in rats (Baum 2002; Schulz et al. 2009; Sisk and Zehr 2005), and notably those that are comparable to the behaviors that McClelland and Pilon (1983) identified as roots of n Power.

Grounding on these two lines of research, Schultheiss and Zimni (2015) hypothesized that an early exposure to specific concentrations of T and E could be predictive of n Power’s adult expression. To test their assumption, Schultheiss and Zimni (2015) measured n Power and the second-to-fourth-digit ratio (2D:4D), a sexually-dimorphic body feature (Manning 2002), in a cross-sectional design. 2D:4D is assumed to be a marker of organizational hormone effects since it partly reflects the prenatal exposure to steroid hormones (Manning 2011). Experimental evidence from an animal model suggests that higher concentrations of T lead to an elongation of the fourth digit (lower 2D:4D, “male-typical”) while higher concentrations of E cause a shortening of the fourth digit (higher 2D:4D, “female-typical”) by altering chondrocyte proliferation in the fourth digit exclusively during prenatal development (Zheng and Cohn 2011). These findings align with insights from correlational and quasi-experimental studies in humans that show small to medium-sized associations of 2D:4D with prenatal sex-steroid exposure (e.g., Brown et al. 2002; Lutchmaya et al. 2004). Schultheiss and Zimni (2015) found that the inhibited power motive is associated with a lower 2D:4D and the disinhibited power motive is associated with a higher 2D:4D (medium effect sizes). They concluded that this points to an early organization of the brain by gonadal steroid hormones as a precursor of n Power.

Their findings were replicated in a much larger two-study sample (total *N* = 303) that revealed that the described associations are gender-dimorphic (associations were reversed in women: Inhibited power motive was assiciated with higher 2D:4D and disinhibited power motive with lower 2D:4D; Schultheiss et al. in preparation). Schultheiss et al. (in preparation) have assumed that this is due to the different roles of T and E in the brain vs. the body: While T and E both have similar masculinizing effects on the brain (see Baum 2002), they can have opposing influences on the developing body (see Zheng and Cohn 2011).

Recently, the negative association of the inhibited power motive and 2D:4D was again replicated by Schultheiss (in press) in a third sample. The consistency of these results is remarkable since elsewise findings regarding associations of 2D:4D and criteria are mixed and very small (e.g., 2D:4D and aggression; see Hönekopp and Watson 2011; Pratt et al. 2016; Turanovic et al. 2017).

The review by Schulz et al. (2009) includes convincing evidence that the occurrence of organizational hormone effects is not limited to prenatal development but instead can also happen during puberty. Puberty represents a second phase of organization that is characterized by high levels of gonadal steroid hormones and concurrent brain sensitivity to them (Schulz et al. 2009). It is not known whether the development of n Power is also affected by this second phase of organization. Paralleling the approach of Schultheiss and Zimni (2015), linking a marker of organizational hormone effects during puberty to motive assessment could provide us with a first glimpse on this relationship.

A possible marker is fWHR, a body feature that may become sexually dimorphic during puberty (Weston et al. 2007; Geniole et al. 2015; but see Kramer 2017). Although the marker function of fWHR is not well researched in comparison with 2D:4D, there are findings besides its presumed sex dimorphic development that support an according assumption. Past research demonstrated medium-sized associations of fWHR with adolescent T-levels after controlling for age in a small sample of Tsimane-males (Hodges-Simeon et al. 2016; Welker et al. 2016). Also, higher values for fWHR (“male typical”) were linked to dominance behaviors and aggression, behavioral parameters which can be influenced by organizational hormone effects of steroid hormones (see Schulz et al. 2009), in correlational designs with objective measures, such as the amount of penalty minutes of professional hockey players (e.g., Carré and McCormick 2008; Goetz et al. 2013). These findings are backed up by two meta-analyses, observing these small to medium-sized associations not exclusively but primarily in males (Geniole et al. 2015; Haselhuhn et al. 2015). Lefevre et al. (2013) tried to explain these relationships, reporting small-sized relationships of fWHR with baseline T-concentrations and T-secretion (in reaction to a speed dating event). However, their findings could not be replicated in a seven-sample study with large overall *N* (Bird et al. 2016). Considering the lack of significant results and referring to work on organizational hormone effects, Bird et al. (2016) concluded that the associations of fWHR and behavior might be due to earlier influences of T rather than to circulating T. Furthermore, there is quasi-experimental evidence that the development of certain facial features in humans can be influenced by T-administration during puberty (Verdonck et al. 1999). This finding had previously been supported by an experimental animal model (Verdonck et al. 1998; Barrett and Harris 1993).

In the present paper, we investigated for the first time whether organizational hormone effects during puberty are associated with the adult n Power. As a first approach, we linked n Power to fWHR as a presumed marker of those effects in a cross-sectional, correlational design. N Power was assessed with the Picture Story Exercise (PSE; McClelland et al. 1989), a well-established method for measuring implicit motives (Smith 1992), and fWHR via anthropometry (Kramer et al. 2012). In order to maximize statistical power, we grounded our analyses on samples from two independent studies with identical procedures concerning the relevant measures. We expected results that would parallel the findings of Schultheiss and Zimni (2015): AI should moderate the association between n Power and fWHR. The inhibited power motive should be associated with higher values in fWHR, which are considered more “male-typical”. The disinhibited power motive should be associated with lower values in fWHR, which are considered more “female-typical”. Furthermore, we analyzed whether these relationships are gender-dimorphic on an exploratory basis since Schultheiss et al. (in preparation) observed exactly this in their larger scale follow-up study concerning 2D:4D. We considered these analyses exploratory because to our best knowledge there is no robust evidence that T and E have opposing effects on the developing fWHR.

Method

Participants

As we were expecting small to medium effect sizes, we tried to maximize our overall sample size in order to meet requirements of statistical power that emerged from preliminary analysis (Cohen 1992). Power analyses revealed that 176 participants were needed to achieve a test power of .80 (based on $r = .21$ as the meta-analytically derived average correlation of fWHR with criteria in laboratory settings; Haselhuhn et al., 2015). Therefore, we combined two samples from studies, run by former students as parts of their respective theses with identical design and procedure concerning our measured variables (in the following referred to as studies 1 and 2). Overall, we had access to data from $N = 246$ adult, mainly German (90.14%) participants that were sampled via opportunity sampling (responders to flyers, responders to online advertisement, undergraduate students). They were rewarded with individual feedback, which included their results on our motive measure. Thirty-three participants had to be excluded from analyses due to various reasons[1]. A quantitative description of the overall sample and the subsamples including sex, age, and education can be found in Table 1.

Table 1

Sample description

	Overall	Study 1	Study 2
N	213	92	121
Sex	125 ♀ 88 ♂	54 ♀ 38 ♂	71 ♀ 50 ♂
Age (*M*, *SD*)	24.23, 8.41	27.1, 11.42	21.6, 3.15
Education	87.79%	77.17%	95.87%

Note. Education-scores describe the proportions of the (sub-)samples with the German *Abitur* (≈ A levels), a graduate degree, or a PhD as their highest educational attainment.

Design

Both studies had a cross-sectional, correlational design. Continuous variables, relevant to our hypothesis, were n Power and AI, assessed via PSE, and fWHR, which was assessed via anthropometry and represented a marker of organizational hormone effects during puberty. BMI was assessed via anthropometry and age was assessed via self-report, since both variables are known to influence fWHR and therefore had to be controlled (Hehman et al. 2014; Lefevre et al. 2012; Geniole et al. 2015).

Materials

Motive Assessment. N Power and AI were assessed via PSE, since the characteristics of the n Power-construct impede a valid assessment via questionnaire (see Schultheiss 2008). We used a six-picture version following the recommendations given by Schultheiss and Pang (2007) that included pictures showing persons in

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[1] Combined exclusion criteria were adopted from studies 1 and 2. Three participants had to be excluded because their work on the motive measure was insufficient (average story length below 30 words or missing stories on the PSE; for further information concerning these criteria see Smith 1992). Five participants were excluded because they reported being familiar with our motive measure or guessed our hypothesis. Four participants were excluded because their Body Mass Index (BMI) was below 17.50. These values are associated with an increased risk of anorexia nervosa which could lead to impaired bone growth (Russell 1985), and in turn have an abnormal influence on fWHR. Seventeen participants were excluded because their BMI was above 30, since all experimenters reported that clinically relevant adiposity had led to intolerable measurement error due to uncertainty with determining anthropometric measuring points on strongly expanded skin tissue. One participant was excluded due to her pregnancy, which rendered a valid interpretation of her BMI-score impossible. Three participants were excluded because measured values on one or more dependent variables were identified as statistical outliers (more than 3 *SD*s away from the mean). This indicates that these participants were not part of the target population (Osborne 2013).

ambiguous social interactions (*Two Women in Laboratory*, *Boxer*, *Trapeze Artists*, *Couple by River*, *Ship Captain* and *Nightclub Scene*; Schultheiss & Pang, 2007). The pictures were presented for 10 seconds each on a computer screen in random order. After the presentation of every single picture, participants had four minutes to write an imaginative story in a textbox. They were asked to write complete stories with an introduction, a main part and a conclusion, describing what the depicted persons feel, think and want, how it came to the situation and how the situation will end. The stories were later scored by two independent coders who previously had exceeded 85% interscorer-agreement on training materials that were previously scored by experts. Coding was facilitated by the free software utility *PSECoder* (Frisch and Schultheiss 2012) that allows economic data management and secures the traceability of the coding process. Coders analyzed all stories for imagery that belonged to the domain of power (e.g. impressing others, intentionally eliciting emotions in others, executing strong forceful actions; for additional information and coding examples from participants' stories, see p. 74 in Schultheiss et al. 2009b), using the *Manual for Scoring Motive Imagery in Running Text* by Winter (1994). The manual had been empirically derived and therefore holds internal validity (Borsboom et al. 2004; Schultheiss and Pang 2007; Winter 1991). All scorers used extended coding rules (coding *every* sentence; scoring of different subcategories of the same motive in *one* sentence, but not of the same subcategory in the same sentence, unless the coding instances are divided by motive imagery of another domain specified in Winter's manual). Scores obtained with this method are highly correlated with scores resulting from classical Winter-coding ($r = .99$ in study 1; $r = .97$ in study 2) as well as considered more reliable due to their lowered proneness to coding-errors (Schönbrodt et al. 2013). Interscorer-agreement was $r = .96$ in study 1 and $r = .83$ in study 2. For our analyses sum scores of the coded imagery were averaged across the two respective coders. AI (measured by counting the German negation "nicht"; see McClelland 1979) and story word count were automatically determined by *PSECoder.* Because the distributions of n Power and AI scores were skewed, we added a constant of one and subjected them to a square-root transformation following the recommendations by Smith (1992). Since n Power and AI were significantly correlated with story word count (Study 1: $r = .64$ and $r = .61$; Study 2: $r = .56$ and $r = .55$), we used linear regression analysis to residualize motive-scores for word count in order to account for influences of verbal fluency (see Schultheiss and Pang 2007). The resulting scores were transformed into z-scores.

Anthropometric Measurements. FWHR was assessed by using anthropometry rather than by using 2D photographs. We favored anthropometry because, while being highly correlated with scores obtained from 2D photographs (Kramer et al. 2012), resulting scores are absolute and might offer advantages concerning validity and reliability (see Kramer 2016). FWHR was computed by dividing bizygomatic width (horizontal distance between right and left zygion) by upper face-height (vertical distance between prosthion and nasion; Weston et al. 2007). Since we measured these distances on living participants, we had to approximate measuring points. Zygions were approximated by measuring on the skin surface, where the zygions were expected to be after visual or, if necessary, haptic inspection. The prosthion was approximated by the highest point in the middle of the upper lips (see Carré and McCormick 2008; Lefevre et al. 2013). Several measurement strategies for approximating the nasion are considered common practice, like using a) the highest point in the middle of the eyelids (see Lefevre et al. 2013) or b) the lowest point on the inner edge of the eyebrows (see Carré and McCormick 2008). Because we used anthropometry, we also had the opportunity to c) test a more direct approximation of the nasion on the skin surface (Kramer et al. 2012). We determined upper face-height three times using the described measuring points with the aim to choose the one that allowed the most reliable assessment for our analysis. In most cases in study 1 (> 75%) and in all cases in study 2, an additional experimenter assessed bizygomatic width and upper-face height for a second time. Both were using common calipers (Study 1: DRAPER PVC200F; Study 2: PROMAT RV08304281). Reliability-scores are shown in Table 2.

Table 2

Reliability and intercorrelations of anthropometric measurements

	Reliability		Intercorrelations		
	Study 1	Study 2	a)	b)	c)
Bizygomatic width	.95	.88	.27	.20	.20
a) Upper face-height$_{\text{eyelids}}$	.86	.52		.79	.75
b) Upper face-height$_{\text{eyebrows}}$	.93	.72			.76
c) Upper face-height$_{\text{nasion}}$	.91	.74			

Note. a), b), and c) describe three different ways of measuring upper face-height using either eyelids, eyebrows, or the skin surface above the nasion as approximated measuring points. Reported values are Pearson's *r*s. Z-scores were used for computation of intercorrelations. All intercorrelations were significant (*p*s < .01).

Assessment of upper face-height by using measuring points b) or c) appeared to be superior over assessment by using a) in terms of reliability. Because choosing c) would have been associated with losing 12 participants due to missing values in study 1 (experimenters erroneously skipped the assessment in the first participants), we chose measurement point b) for our subsequent analyses. Since the caliper in study 2 was modified by the attachment of foam pads to increase safety for participants, their width was subtracted from affected scores. When scores from two raters were available, they were averaged before the computation of fWHR. Computed fWHR-scores underwent a z-transformation.

Body height and weight for computation of the BMI were assessed by an experimenter with the help of common scales (SOEHNLE) and a measuring tape attached to a wall. Clothed participants' weight and height were measured after they had removed their shoes and jackets.

Procedure

Study 1 and 2 shared identical procedures concerning our variables. Data collection took place in the Human Motivation & Affective Neuroscience Lab at the Friedrich-Alexander University Erlangen from February to March 2015 (Study 1) and from October to November 2015 (Study 2). Assessment began after participants had signed an informed consent form. At first, participants completed a standardized computer task, which included our motive measure. The PSE was presented at the very beginning in order to avoid unwanted interactions with other tasks (Bosson et al. 2000; Schultheiss and Pang 2007). Then, participants completed several other tasks that were unrelated to our hypothesis presented here and provided demographic information. After their completion, they were prompted via an on-screen message to inform the experimenters that subsequently conducted the anthropometric measurements in the adjoining room. Afterwards, participants were debriefed.

Statistical analysis. We used SYSTAT 13.00.05 for data management, statistical analyses and creation of figures. Simple slopes analyses were computed with the help of SPSS 24.0.0.1. All described measures of data preparation were carried out within studies 1 and 2 before the samples were combined to account for possible coder/rater differences in absolute levels between studies. Because this is the first paper that includes measures of both n Power and fWHR, we provide full descriptive statistics. Testing of our hypothesis was achieved by using multiple regression analysis.

Results

Descriptive Statistics

Table 3 shows descriptive statistics for the overall sample as well as the intra-sex subsamples. All measures were checked for sex differences using Welch's unequal variances *t*-tests. As expected, fWHR was found to be sexually dimorphic ($M_{♂} > M_{♀}$). This finding was mirrored by sex differences in n Power ($M_{♂} > M_{♀}$).

Table 3

M, SD and sex differences of n Power, AI, fWHR and BMI

	Overall		♀		♂		Sex differences			
	M	*SD*	*M*	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
N Power	5.21	3.27	5.16	3.32	5.29	3.21	2.62	191.75	.01	.36
AI	4.83	3.73	5.22	4.01	4.27	3.10	0.03	204.46	.98	.00
FWHR	1.94	0.28	1.91	0.27	1.98	0.30	3.42	167.60	.001	.49
BMI	22.88	2.79	22.47	2.83	23.45	2.65	2.58	194.71	.01	.36

Note. N = 213. N Power = implicit need for power, AI = activity inhibition, fWHR = facial width-to-height ratio, BMI = Body Mass Index. Raw scores were used for computation of *M* and *SD*. Prepared scores were used for testing of sex differences via Welch's unequal variances *t*-test (z-scores; AI and n Power: square-root transformed after adding constant of 1 and residualized for story word-count prior to standardization). Hedges' *g* was used for the computation of effect sizes.

Table 4 shows intercorrelations (Pearson's *r*) of all continuous variables. No significant bivariate intercorrelations between n Power, AI, and fWHR were detected, neither overall, nor within sexes. As expected, fWHR was associated with BMI and age. Therefore, we included those latter variables as covariates in all models for hypothesis testing.

Table 4

Overall and intra-sex intercorrelations of all continuous variables

	Overall					Intra-sex ♀ \ ♂				
	1.	2.	3.	4.	5.	1.	2.	3.	4.	5.
1. N Power		.01	.01	.01	.02		.02	-.09	.01	.00
2. AI			.07	-.01	.01	.00		-.08	.01	$.18^{\#}$
3. FWHR				$.18^{**}$	$-.14^{*}$	.01	.07		.15	$-.24^{*}$
4. BMI					$.23^{**}$	-.05	-.01	$.14^{\#}$		$.18^{\#}$
5. Age						.02	.01	-.11	$.26^{**}$	

Note. $N = 213$. N Power = implicit need for power, AI = activity inhibition, fWHR = facial width-to-height ratio, BMI = Body Mass Index. Prepared scores were used for computation of bivariate correlations (z-scores; AI and Power: square-root transformed after adding constant of 1 and residualized for story word-count prior to standardization). Intra-sex intercorrelations for females are presented below the diagonal and intercorrelations for males are presented above.

** $p < .01$. * $p < .05$. $^{\#}$ $p \leq .10$.

Hypothesis Testing

To test our hypotheses, we computed a multiple regression analysis with n Power and AI as predictors of fWHR that also included BMI and age as covariates. As expected, we found a significant n Power x AI-effect, $B = 0.15$, $SE = 0.07$, $t(207) = 2.03$, $p = .04$, $\Delta R^2 = .02$ (see Figure 1). Follow-up analyses after creating subsamples by a median split on the AI variable revealed that n Power was positively associated with fWHR in high-AI-individuals ($B = 0.14$, $SE = 0.10$, $\beta = .13$, $t(102) = 1.34$, $p = .18$, $\Delta R^2 = .02$), and negatively in low-AI-individuals ($B = -0.07$, $SE = 0.09$, $\beta = -.07$, $t(103) = -0.75$, $p = .46$, $\Delta R^2 < .01$), while controlling for BMI and age. Both associations failed to reach significance. In order to avoid the disadvantages using a median split, we additionally probed the interaction with the help of simple slopes analysis (Aiken and West 1991). It revealed that n Power and fWHR approached a marginally significant positive association when AI was high (+1*SD*), $B = 0.16$, $SE = 0.10$, $t(207) = 1.64$, $p = .10$. When AI was low (-1*SD*), n Power and fWHR were associated negatively but insignificantly, $B = -0.14$, $SE = 0.10$, $t(207) = -1.40$, $p = .16$ (see Figure 2).

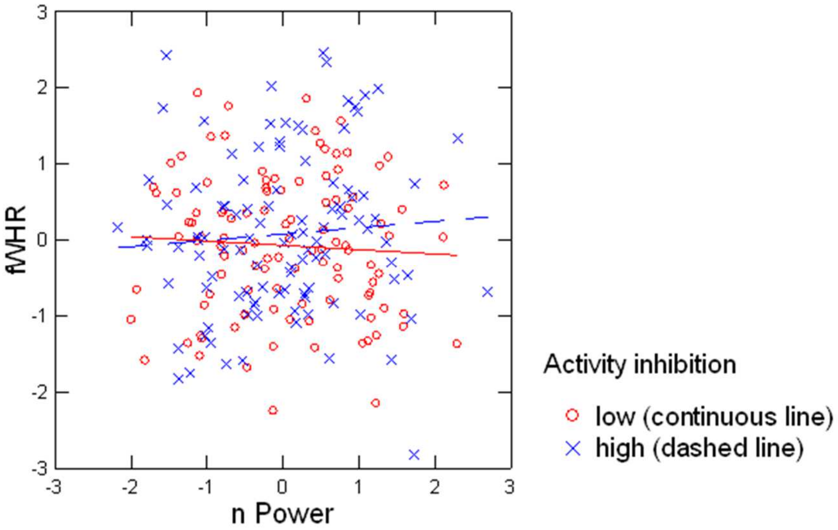

Fig. 1 Scatter plot showing associations of fWHR and n Power in low-/high-AI subsamples after median split on AI variable. Z-scores were used for computation. AI and n Power were subjected to a square-root transformation after adding a constant of 1 and residualized for story word-count

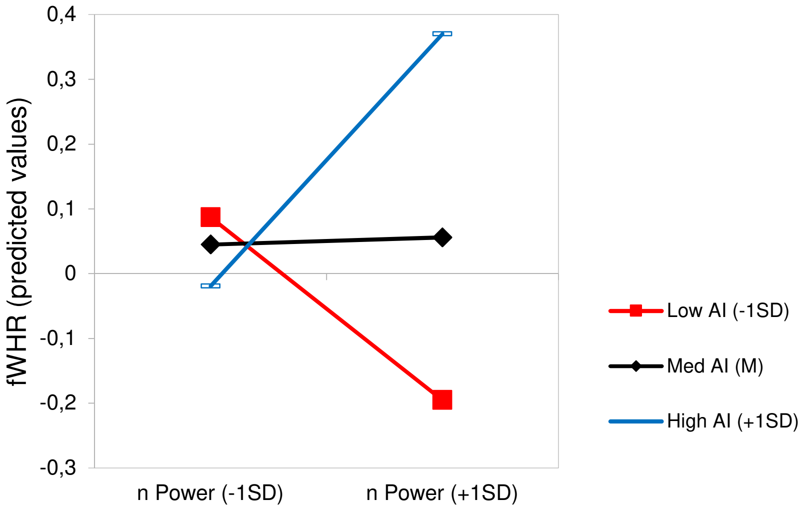

Fig. 2 Simple slopes analysis showing associations of fWHR and n Power, when AI was low (-1*SD*), medium (*M*) or high (+1*SD*). Z-scores were used for computation. AI and n Power were subjected to a square-root transformation after adding a constant of 1 and residualized for story word-count

We additionally tested whether these associations were sexually dimorphic by adding gender and the respective interaction terms to our regression analyses. We found a significant n Power x AI x Gender-effect, $B = 0.34$, $SE = 0.17$, $t(203) = 2.00$, $p = .05$, $\Delta R^2 = .02$ (see Figure 3). Follow-up analyses revealed that the previously observed n Power x AI-effect could be found among women ($B = 0.21$, $SE = 0.08$, $t(119) = 2.65$, $p = .01$, $\Delta R^2 = .05$), but not among men, $B = -0.10$, $SE = 0.16$, $t(82) = -0.62$, $p = .54$, $\Delta R^2 < .01$. After creating subsamples by a median split on the AI variable and while controlling for BMI and age, n Power was positively associated with fWHR in high-AI-females (*B* = 0.28, *SE* = 0.13, β = .29, *t*(55) = 2.24, *p* = .03, $\Delta R^2 = .08$) and negatively but insignificantly in low-AI-females (*B* = -0.17, *SE* = 0.11, β = -.20, *t*(62) = -1.62, *p* = .11, $\Delta R^2 = .04$). Among men, both associations failed to reach significance (high-AI-males: *B* = -0.12, *SE* = 0.17, β = -.10, *t*(43) = -0.69, *p* = .50, $\Delta R^2 = .01$; low-AI-males: *B* = -0.02, *SE* = 0.16, β = -.02, *t*(37) = -0.15, *p* = .88, $\Delta R^2 < .01$). Additional simple slopes analyses revealed a nearly significant positive association of n Power and fWHR in females, when AI was high (+1*SD*; *B* = 0.22, *SE* = 0.11, *t*(119) = 1.97, *p* = .05) and a marginally significant negative association, when AI was low (-1*SD*; *B* = -0.21, *SE* = 0.11, *t*(119) = -1.81, *p* = .07). In males n Power and fWHR were associated negatively but insignificantly, both when AI was high (+1*SD*; *B* = -0.21, *SE* = 0.21, *t*(82) = -0.99, *p* = .33) and low (-1*SD*; *B* = -0.01, *SE* = 0.19, *t*(82) = -0.03, *p* = .98; see Figure 4).

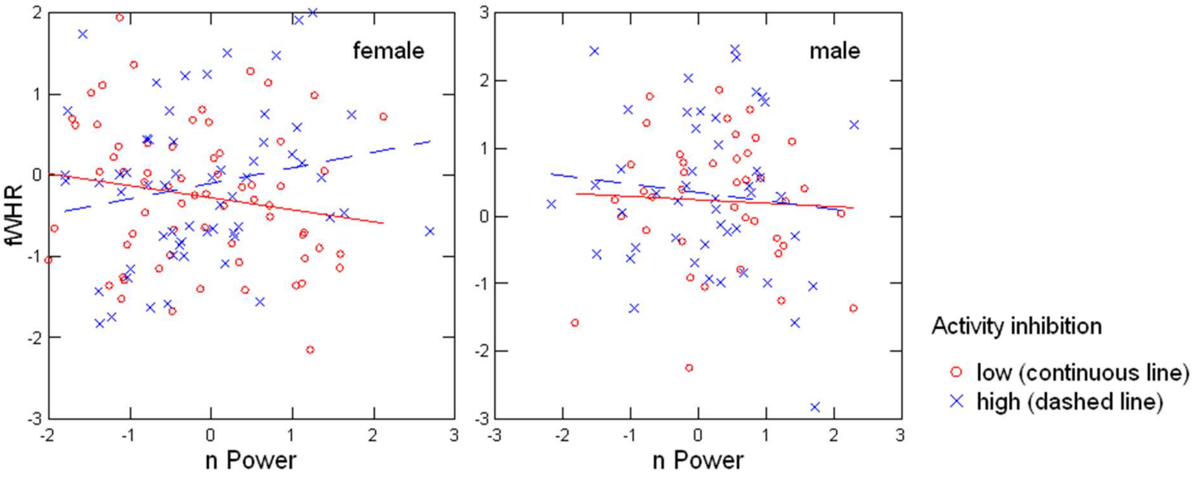

Fig. 3 Scatter plots showing within-sex associations of fWHR and n Power in low-/high-AI subsamples after median split on AI variable in the overall sample. Z-scores were used for computation. AI and n Power were subjected to a square-root transformation after adding a constant of 1 and residualized for story word-count

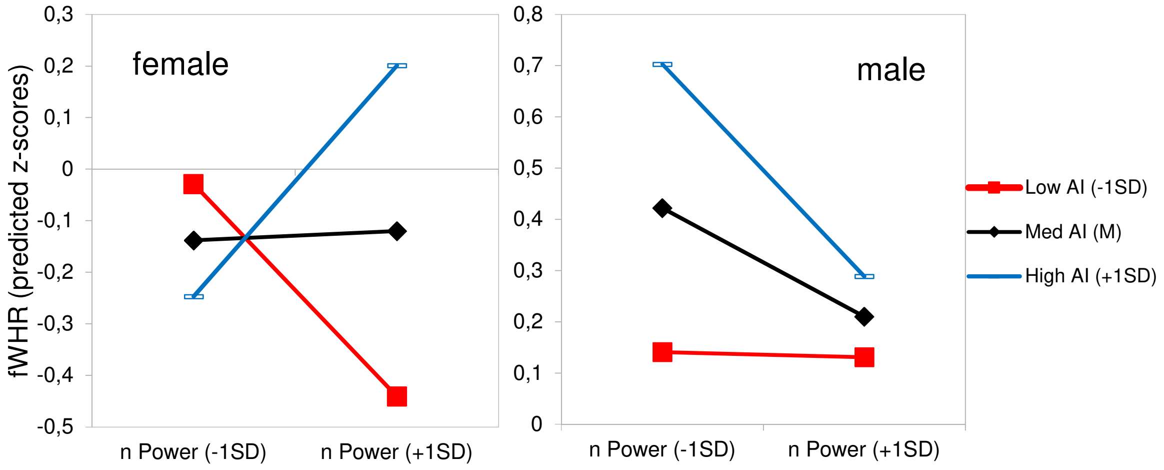

Fig. 4 Simple slopes analyses showing within-sex associations of fWHR and n Power, when AI was low (-1*SD*), medium (*M*) or high (+1*SD*). Interaction-effect in males was insignificant. Z-scores were used for computation. AI and n Power were subjected to a square-root transformation after adding a constant of 1 and residualized for story word-count

Finally, we checked whether our results would persist while controlling for a study variable since we had aggregated two individual studies for adequate statistical power. Therefore, we computed the above described multiple regressions with study entered as an additional covariate. We again found the previously illustrated n Power x AI-effect ($B = 0.15$, $SE = 0.07$, $t(206) = 2.02$, $p = .04$, $\Delta R^2 = .02$), as well as the n Power x AI x Gender-effect ($B = 0.34$, $SE = 0.17$, $t(202) = 2.01$, $p = .05$, $\Delta R^2 = .02$).

Discussion

We examined whether n Power is associated with fWHR in a cross-sectional, correlational design. fWHR was used as a presumed marker of organizational effects of gonadal steroid hormones on the developing brain during puberty. As expected, we found that AI moderated the association between n Power and fWHR. In-depth analysis revealed that this interaction occurred only among women and was mainly driven by a substantial positive association of n Power and fWHR in females with high AI.

Under the premise of a valid marker function of fWHR, our results point to an organizing effect of gonadal steroid hormones on the female brain during puberty, which influences the development of n Power. This aligns with meta-analytic evidence for an association of fWHR and dominance behaviors (which are also believed to be influenced by organizational hormone effects of steroid hormones during puberty) that is not limited to men (Geniole et al. 2015). In an animal model observing monkeys, Lefevre et al. (2014) also found relationships of fWHR and dominance behaviors in female individuals.

Based on work that has identified the (anterior) hypothalamus as a target of organizational effects of gonadal steroid hormones (de Vries et al. 2014) and its crucial role in animal dominance behaviors (Nelson and Trainor 2007), Schultheiss et al. (in preparation) proposed that said structure and its interplay with a network of subcortical nuclei could be the neuronal basis of long lasting organizational influences on the developing n Power. There is evidence that hypothalamic functioning is influenced by organizational hormone effects during puberty for a second time (Evuarherhe et al. 2009; Romeo et al. 2004). For instance, Evuarherhe et al. (2009) showed that the capability of T to lower the sensitivity of the hypothalamic-pituitary-adrenal (HPA-)axis (which might be important for the engagement in dominance contests and aggressive behaviors; see Terburg et al. 2009) is strongly dependent on pubertal organization by steroid hormones in rats. Thus, the assumption of a second phase of organizational hormone effects on the developing n Power also fits up-to-date theories regarding their neuronal site of action.

Similar to the findings of Schultheiss et al. (in preparation) regarding the association between n Power and 2D:4D, we found that AI is also an important moderator of the association between n Power and fWHR in females. N Power was only positively correlated with the marker when AI was high. Schultheiss et al. (in preparation) hypothesized that this could be due to an interaction of a lateralized brain development (reflected by AI) on the one hand and the endocrine organization on the other hand. Previously, higher levels of T had been assumed to disadvantage the development of the right hemisphere to a lesser extent than the left hemisphere (Geschwind and Galaburda 1985). Schultheiss et al. (in preparation) inferred that this could explain why individuals high in AI appear to have better access to functions associated with the right-hemisphere, such as certain emotional competencies (see Schultheiss et al. 2009a). Thus, a higher AI could be an indicator for the potential to develop a functional n Power (namely the inhibited power motive, see Schultheiss and Brunstein 2002), partly by going through multiple phases of endocrine organization (Schultheiss et al. in preparation).

It is not a trivial task to find an elaborate explanation for the fact that the presented relationships were found in females but not in males, though we tried to form assumptions backed up by empirical findings. After the reading of above mentioned meta-analyses on fWHR and experts' bodies of work on the topic (e.g., Lefevre and Lewis 2014; Lefevre et al. 2013; Carré and McCormick 2008; Carré et al. 2009; Haselhuhn et al. 2015) one would expect to find significant correlations predominantly among men similar to previously reported findings. Past research has shown ties of fWHR to dominant and aggressive behaviors in men (Carré et al. 2009; Stirrat et al. 2012; Welker et al. 2015), as well as to non-aggressive but deceptive unethical behavior (Haselhuhn and Wong 2011) or negotiation performance (Haselhuhn et al. 2014). Although one has to note that females have occasionally been excluded from study designs (e.g. Haselhuhn et al. 2015; see supplementary material to

Geniole et al. 2015), repeatedly no significant associations with behavior could be found in females, when both genders were tested (Carré and McCormick 2008; Goetz et al. 2013; Geniole et al. 2014). This is also true for some papers which tested only women or only men but were comparable with each other regarding design and observed criteria (Zilioli et al. 2015; Palmer-Hague et al. 2016). Despite evidence for associations between fWHR and female behaviors exists (as outlined above), respective studies are outnumbered by findings regarding male behaviors.

Nevertheless, it is possible that relationships between fWHR and n Power observed in male and female participants might diverge from classical results, since n Power is a non-declarative, motivational construct that spans a wider range of behaviors than the sole display of aggression or single facets of dominance behavior (e.g. persuading others, impressing others, eliciting emotions in others, see Schultheiss 2008) and is tied to both T- and E-effects (Stanton and Schultheiss 2009; Schultheiss et al. in preparation).

This line of argumentation brings to attention that to our best knowledge nothing is known about the role of E in the emergence of a sexually dimorphic fWHR during puberty. Lefevre et al. (2013) argued that sex differences in underlying mechanisms that influence facial bone growth are probable, since differences in facial structure would be far more striking if T-effects were the only influencing factor (about five times higher baseline concentrations of T in men than in women; Mazur et al. 1997). Past research on long bone growth revealed that E plays a crucial role in growth by direct effects on the bone or by interacting with other hormone axes in *both* males and females (Grumbach 2000; Juul 2001; Ohlsson et al. 1998). E-effects on bone growth appear to be biphasic: E is involved in both the initiation of the pubertal growth spurt and the epiphyseal fusion (Grumbach 2000; Juul 2001). These empirical findings suggest that the presence of E is a critical factor for regular pubertal bone growth (see Grumbach 2000). Referring to a study that provided longitudinal data on female facial bone growth by Baughan et al. (1979), Thornhill and Grammer (1999) inferred that E appears to have a similar growth-capping effect on certain facial bones. Baughan et al. (1979) reported average relative bone growth velocities of different facial bones across participants' ages (annual measurements from ages of six to 15). When taking a closer look, growth velocity changed in a differential way during pubertal growth spurt. For example, growth velocity of the maxilla (distance from nasion to anterior nasal spine, thus part of the height-component and divisor of fWHR) seemed to be lowered compared to body height and other facial bones around puberty.

Without drawing too heavy conclusions without statistical testing but with respect to the plethora of findings that indicate an involvement of E in bone growth, one could assume that fWHR also holds information on E-exposure during puberty. Using n Power as a criterion that shows gender-specific links to T and E, this information could be pivotal for the marker function of fWHR in females. A possible explanation for our gender-specific results might be obscuring effects of the same information in males that could be overcome in larger samples.

Limitations and Future Directions

The previous section already touches upon the most obvious limitation of our study: The lacking knowledge regarding the marker function of fWHR. There is no controlled experimental evidence that showcases fWHR's marker function like there is for 2D:4D and as stated above, to our best knowledge no research on the role of E in the emergence of fWHR has been conducted so far. However, it must not be overlooked that, as mentioned before, there are several lines of indirect evidence that indicate the possibility of a marker function that could be used to get a glimpse on associations between n Power and pubertal organizational hormone effects. These are a) the emergence of a sexually dimorphic fWHR during puberty, a phase of endocrine organization by gonadal steroids (Weston et al. 2007), b) correlational connections of T and fWHR in healthy adolescents (Hodges-Simeon et al. 2016; Welker et al. 2016), c) quasi-experimental evidence from T-administration in adolescents regarding facial features (Verdonck et al. 1999), and d) experimental evidence for T-effects on facial features from animal models (Verdonck et al. 1998; Barrett and Harris 1993).

Using fWHR as a marker variable might also complicate a clear cut distinction of organizational effects from associations that are mediated by activational hormone effects (i.e. reversible hormonal changes that facilitate certain behaviors, Phoenix et al. 1959) in our design. This problem would arise from small, yet observable correlations of fWHR and baseline T-levels as reported by Lefevre et al. (2013; see Hönekopp et al. 2007, for a review on this methodological issue). However, a newer large-scale replication by Bird et al. (2016) did not find these correlations supporting our line of argumentation resting on fWHR's association with *pubertal* T (Welker et al. 2016).

The usage of the marker fWHR also makes it inevitable to factor in a set of possible covariates and moderators (BMI, age, gender, diseases etc.), as well as forces a very careful interpretation of results. This was especially true for our correlational and cross-sectional study-design that did not allow us to infer causal relationships between our variables.

Despite suffering from the arising limitations, our study was suitable to identify research on organizational hormone effects of gonadal steroid hormones during puberty on the developing n Power as promising. It provides us with a first glimpse on a relationship that has to be further explored in follow-up studies. In a long-term perspective, future designs should ideally move away from using proxy measures like morphological markers and use longitudinal data on n Power, AI and concentrations of gonadal steroid hormones instead. Until such data is available, replications using easily measurable morphological markers like fWHR are needed to back up our first results. Replications are crucial for a better understanding of the reported relationships and their gender-specificity, especially when designs are optimized in a way that allows the further exploration of marker functions. A first step could be incorporating measures of both baseline and reactive concentrations of T and E.

This could also facilitate distinguishing activational effects from organizational effects by acting as covariates or even reveal respective interactions and thus shed light on how pubertal organization unfolds its influence on adult behaviors. As stated above, past findings demonstrated that T-related activational functions of the HPA-axis are dependent on pubertal organization by steroid hormones in rats (Evuarherhe et al. 2009; Romeo et al. 2004). Future research might show that comparable mechanisms (partly) mediate the influence of organizational hormone effects on the adult functioning of n Power. A first approach could be a design that compares changes in steroid hormone concentrations after suitable arousal in high-power-individuals (e.g., dominance stress; Schultheiss et al. 2005). If markers for pubertal organization predicted the extent to which concentrations change, this would point to the described interplay of activational and organizational effects regarding n Power. First evidence for this interplay - that did not factor in n Power and was not interpreted this way - came from Lefevre et al. (2013) who reported relationships of fWHR and T-levels after a speed-dating event controlling for pre-T-levels (but see Bird et al. 2016). However, these results have to be interpreted in a careful manner since it is unclear if the speed-dating event was suitable arousal (no significant pre-post-differences in the overall sample). Future designs would have to secure the presence of fitting motivational dispositions like n Power that allow the manipulation to work reliably.

Though our results allow arguing within the framework of existing theory, they of course do not enable strong inferences about the neuronal site of action regarding organizational hormone effects. Thus, future designs could also profit from using a set of brain imaging methods, such as functional magnetic resonance imaging (fMRI; Huettel et al. 2004) or electroencephalography (EEG; Niedermeyer and da Silva 2005) that could reveal whether markers for organizational hormone effects are associated with actual differences in brain structure and activity.

Conclusion

Respecting the limitations of our study, our results point to an organizational refinement of the female brain during puberty that is driven by high levels of gonadal steroid hormones and influences n Power’s transition into its adult appearance. Further effort in the form of replications and extensions of our design has to be spent on understanding the associations of n Power, AI and organizational hormone effects using refined designs that make use of multiple methods.

Author contributions

Author KTJ wrote the manuscript, MGK designed Study 1 and 2 and refined the manuscript. Measurement protocols for fWHR were designed by KB, KTJ, and MGK for Study 1, and by KB, JF, FJ, and MGK for Study 2. KTJ and LTR recruited participants and conducted the experiment in Study 1 with assistance of KB. KB, JF, and FJ recruited participants and conducted the experiment in Study 2. PSEs were coded by KTJ and LTR in Study 1, and by KB and JF in Study 2. KTJ undertook the statistical analysis, assisted by MGK. All authors contributed to and have approved the final manuscript.

Ethical standards

All conducted experiments comply with the current laws of Germany. All participants gave their informed consent prior to their inclusion in the studies. The manuscript does not contain clinical studies or patient data.

Conflict of interest

The authors had no financial relationship with the organization that sponsored the research and no conflict of interest.

Open Science

Reproducible analysis scripts for all reported results, the data files, as well as the output files are available at the Open Science Framework (https://osf.io/3gtm6/).

Published version

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