Journal of Environmental Psychology 64 (2019) 107–112

Contents lists available at ScienceDirect

Journal of Environmental Psychology

journal homepage: www.elsevier.com/locate/jep

Testosterone, facial and vocal masculinization and low environmentalism in men

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ARTICLE INFO

Keywords:
Testosterone
Cortisol
Pro-environmental attitudes
Environmentalism
Facial masculinization
Vocal masculinization
Testosterone
Physical masculinization
Low environmentalism in men

ABSTRACT

Robust sex differences in environmentalism have been observed, such that males express fewer pro-environmental attitudes than their female counterparts. To date, most explanations of this sex difference have relied upon socio-cultural and psychological explanations. The present study sought to extend this inquiry by examining the role of testosterone (T), its interaction with cortisol (C), as well as androgen-linked phenotypes (facial and vocal masculinization) in relation to environmental attitudes. In a sample of 162 males, results found a TxC interaction such that high T predicted lower environmental attitudes when C was high, but T also predicted higher environmental attitudes at the lowest levels of C. Moreover, facial and vocal masculinization, as putative phenotypic markers of developmental T exposure, correlated negatively with pro-environmental attitudes. Together these findings suggest that both state T and phenotypic masculinization negatively predict environmentalism among men, thus highlighting the potential role of androgens in understanding environmental engagement.

1. Introduction

Previous research suggests that exhibiting pro-environmental attitudes and behavior is, at least in part, a feminine quality. Zelezny, Chua, and Aldrich (2000) found that individuals' self-reported masculinity predicted lower scores on the New Ecological Paradigm. More recently, Brough, Wilkie, Ma, Isaac, and Gal (2016) observed that participants cognitively associated eco-friendly products with femininity, and that male participants were less inclined than female participants to purchase them. Similarly, an individual performing acts of pro-environmental behavior was also rated as less masculine, regardless of the actor's actual gender (Brough et al., 2016); these studies coalesce with those demonstrating that men consistently report lower scores on pro-environmental attitude measures relative to women (e.g., Arnocky & Stroink, 2011; Desrochers, Albert, Milfont, Kelly, & Arnocky, 2019). These findings are often characterized within the context of cultural influence and the socialization of gender roles which ostensibly promote women to care more for the environment than men. Conversely, scarce attention has been paid to the hypothesis that underlying biological factors, such as the male sex hormone testosterone (T), might predict reduced pro-environmental attitudes. The present study sought to address this gap by exploring (1) whether state T (directly or via interaction with the stress hormone cortisol (C), (Sollberger, Bernauer, & Ehlert, 2016a) or (2) androgen-dependent physiological characteristics (vocal and facial masculinization) predict reduced pro-environmental attitudes among young adult men.

1.1. Testosterone's direct relation to environmentalism

Only one study to date has examined whether T relates specifically to pro-environmental behavior. Sollberger et al. (2016a) found that state T and C interacted to predict lower pro-environmental behavior in a male sample. TxC interactions are commonly explored in psychology research under the dual-hormone hypothesis, which posits that testosterone's role in men's social and status-relevant behavior, including prosocial behavior, cooperation, empathy, and collaborative decision-making, should depend on concentrations of the stress hormone cortisol (reviewed in Mehta & Prasad, 2015; Sollberger et al., 2016a, 2016b). For those with lower C, T negatively related to participant's self-reported pro-environmental behavior (a measure of energy conservation), controlling for age and chronic stress exposure. This study highlighted the potential role of biological markers of masculinity toward a more comprehensive understanding of environmentalism among men. However, the saliva samples used in the aforementioned research were taken on different days from when the participants responded to the energy conservation measure (exact time elapse from reporting to

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https://doi.org/10.1016/j.jenvp.2019.05.007
Received 4 April 2019; Received in revised form 16 May 2019; Accepted 17 May 2019

saliva sampling was not reported, but average return of sample time via mail was approximately four days). This is potentially problematic given that both T and C fluctuate not only diurnally but also in relation to a host of contextual factors including social (Gleason, Fuxjager, Oyegbile, & Marler, 2009) and environmental (Choi et al., 2014) variables, suggesting that T and environmentalism should ideally be measured during the same testing session, and that more research is needed regarding the state versus trait (i.e., putative physical indices of long term exposure) based relationhip between T and environmentalism, particularly with respect to broader measures of environmentalism than that used in the Sollberger et al. (2016a)) study. Moreover, many of the conservation behaviors measured in their study, such as "turn down/off heating before leaving for holidays, turning off lights when leaving a room, avoid buying foods flown in", are somewhat ambiguous with respect to their underlying motives. These actions may be performed due to positive attitudes toward protecting the environment, but may also be performed for other reasons such as for financial savings. Interestingly, another recent study found that a stress induction task (confirmed via cortisol assessments) related negatively to the amount of money men donated to an environmental organization, irrespective of their initial pro-environmental orientation (Sollberger et al., 2016b), further highlighting the potential role of C in men's environmentalism. Accordingly, the first goal of the present study was to examine whether salivary T and C from samples taken at the time of participation interact (controlling for state/trait anxiety and age) to predict a broader measure of pro-environmental orientation (H1).

1.2. Testosterone's indirect relation to environmentalism

One factor that has yet to be considered in the environmental psychology literature is whether androgen-dependent phenotypic traits might also predict environmental attitudes. For instance, the maturation of facial features, which occurs during puberty, reflects the masculinization or feminization, due to hormones, of this secondary sex characteristic. During the course of this maturation, a male face increases in jaw size, decreases in cheek size, and develops a larger prominence in the cheekbones (Little, Jones, & DeBruine, 2011). Faces of men with higher circulating T were rated as more masculine than those of men with lower circulating T (Penton-Voak & Chen, 2004; Roney, Hanson, Durante, & Maestripieri, 2006). In terms of objective facial structure measurements of masculinization, studies have observed links between the facial width-to-height ratio (FWHR; where higher ratios indicate a wider and shorter face) and both peri-pubertal T (Welker, Bird, & Arnocky, 2016), and prenatal T (Whitehouse et al., 2015). However, it is important to note that other studies have failed to find links between T and FWHR (Bird et al., 2016). Beyond facial structure, male vocal pitch has also been linked to T, and therefore also serves as a candidate marker of physiological masculinization which might ostensibly be linked negatively to environmentalism. Voice pitch is among the most sexually dimorphic of human traits (Puts, Apicella, & Cárdena, 2012). Previous research has shown that, for males, T and voice pitch are highly related (Dabbs Jr. & Mallinger, 1999). Moreover, the relationship between T and masculinity was mediated by voice pitch, such that men with higher salivary T and lower voice pitch were perceived by raters as more masculine (Cartei, Mond & Reby, 2014). Yet similar to the facial masculinization literature, some studies have failed to observe links between adult circulating T and vocal masculinization (see Arnocky, Hodges-Simeon, Ouellette, & Albert, 2018).

1.3. Testosterone and environmentally-relevant individual differences

Interestingly, masculinization of the face and voice have also been linked to traits such as lower prosociality (Haselhuhn & Wong, 2012; Stirrat & Perrett, 2010), higher dominance (Carré & McCormick, 2008; Carré, McCormick, & Mondloch, 2009; Lefevre, Etchells, Howell, Clark, & Penton-Voak, 2014; Puts, Apicella, & Cárdena, 2012; Puts, Gaulin, & Verdolini, 2006; Puts, Hodges-Simeon, Cárdenas & Gaulin, 2007), low empathy (Harris, Rushton, Hampson, & Jackson, 1996), and higher psychopathy (Noser, Schoch, & Ehlert, 2018). Importantly, these factors have also been identified as predictors of pro-environmental attitudes. For example, Arnocky and Stroink (2011) found that empathy mediated gender differences in environmentalism, where women reported more trait empathy which in turn predicted higher levels ecological cooperation and pro-environmental behavior. Milfont and Sibley (2016) found that both empathy and social dominance mediated the gender difference in environmental attitudes, where women were lower in social dominance and higher in empathy, each of which in turn predicted pro-environmental attitudes. Recent work by Huang, Zuo, Wang, Cai, and Wang (2018) reported links between psychopathy and lower pro-environmental attitude scores. Masculinized facial traits have also been linked to acts of unethical behavior, such as deceiving their opponent in a negotiation, and cheating to receive greater personal gains (Haselhuhn & Wong, 2012; see also:; Stirrat & Perrett, 2010). Given the aforementioned links between developmental T and both facial and vocal masculinization, we hypothesized that men with more masculinized facial structure (H2) and vocal traits (H3) would express lower pro-environmental attitudes.

1.4. The current study

To date, little research has examined whether physiological markers of masculinization predict men's attitudes towards the environment. Given that one recent study has linked men's high T and low C to reduced environmentalism, the goal for the current research was to replicate the hormonal findings of Sollberger et al. (2016a), and to examine facial and vocal secondary sex characteristics previously linked to T as predictors of lower pro-environmental attitudes in a sample of young adult men.

2. Method

2.1. Participants

This research was approved by the Nipissing University Research Ethics Board and, as such, adhered to all principles of Canada's Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS-2). Power analysis was used to determine an expected sample size of 162 ($\eta^2 = 0.08$, $\alpha = 0.05$, $1 - ß = 0.90$). One-hundred and sixty-two males from a university in Ontario, Canada ($M_{age} = 22.71$, $SD = 4.71$; 91.4% were students) provided a saliva sample in the laboratory, along with voice recordings, facial photographs, and completed a survey package. As part of a larger study on physiological development, immunology, and social behavior, participants received either $50 CAD remuneration or partial course credit and $10.

2.2. Measures

Hormonal assays. Participants provided a saliva sample via passive drool into a transparent 5 ml polystyrene culture tube. Participants were instructed to not eat, drink (excluding water), brush their teeth or engage in strenuous activity for 2 h prior to participation. Saliva sample provision time was recorded, and ranged between 8:30 a.m. and 5:00 p.m., Sample provision time was related to C ($r = -0.38$, $p < .001$), and accordingly was included as a covariate in all hormonal analyses. Likewise, participant age was related to both C ($r = -0.21$, $p = .007$) and T ($r = -0.24$, $p = .002$), and so was also included as a covariate in all hormonal analyses. Saliva samples were stored at −80 °C until assayed using commercially available enzyme immunoassay kits (DRG International, NJ, USA). Samples were assayed in duplicate where the average of the duplicates (log-transformed) was used for all statistical analyses. Each kit was used to assay 40 samples, with 5 kits being used for each hormone; the additional wells in the final kit for each hormone were used to re-run previous samples with the highest levels of error. Intra- and inter-assay CVs were as follows: T (3.47%, 7.86%), C (1.72%, 10.57%). All assays were conducted in the Contact Author (PI's) Human Evolution Laboratory at Nipissing University, in Ontario, Canada.

State and trait anxiety. State and trait anxiety were measured using the state-trait

Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). All items are scored using a 4-point scale (e.g. "Almost Never" to "Almost Always"). Items were summed to create total state-trait anxiety scores; higher scores indicate greater anxiety. Anxiety scores were used in lieu of chronic stress as a control variable in the hormonal analyses. Two subscales were calculated: state ($\alpha = 0.92$), and trait ($\alpha = 0.92$) anxiety.

Environmental Attitudes. Although external factors also play a role in shaping environmentalism (Dupuis & Arnocky, 2012), environmental attitudes have been identified as an important individual difference predictor of environmental engagement (Milfont & Duckitt, 2010). Pro-environmental attitudes were measured using the brief version of the Environmental Attitude Inventory (EAI-24; Milfont & Duckitt, 2010). The EAI-24 consists of 24 items scored using a 7-point Likert-type scale anchored at 1 = *strongly disagree* and 7 = *strongly agree*. Items were combined and averaged to form two subscales assessing general attitudes toward environmental preservation ($\alpha = 0.77$) and utilization ($\alpha = 0.68$), whereby preservation reflects the belief that priority should be given to preserving and protecting nature, and where utilization reflects the belief that it is appropriate for nature to be used and altered for human objectives; a general score encompassing both subscales was also calculated.

Face index. Facial photographs were taken using a 16 megapixel Nikon CoolPix L830 digital camera using standardized distance and lighting and against a neutral backdrop. ImageJ (NIH open-source software) was then used by two independent raters. Raters were one male and one female research assistant trained independently to measure facial structure using the aforementioned software. Both raters were blind to the goals of the research. The raters measured FWHR, or the bi-zygomatic width of the face (left and right zygion or the most lateral point of the zygomatic arch) divided by the height of the upper face (i.e., the distance between the upper lip and brow) (see Weston, Friday, & Liò, 2007); cheekbone prominence (bi-zygomatic width divided by the width of the face at the corners of the mouth); and face width/lower face height (FWHR-lower) (bi-zygomatic width divided by the height of the lower face)(see Hodges-Simeon et al., 2016). Intraclass correlation showed that raters' FWHR ($r = 0.93$), cheekbone prominence ($r = 0.72$), and FWHR-lower ($r = 0.88$) measurements were highly consistent so the average of the measurements for each face was computed. A principal component analysis of the three facial measurements revealed a single factor solution which accounted for 60% of the variance on a facial masculinization factor. The three measurements were then standardized, and a composite facial masculinity score was created.

Voice index. Participants were recorded in a quiet room reciting five monophthong vowel sounds (i.e., eh as in 'bet', ee as in 'see', ah as in 'father', oh as in 'note', oo as in 'boot') into an Audio-Technica ATR-1200 microphone, positioned approximately 20 cm from the participants' mouths. Voices were recorded using Goldwave version 6.10 software in mono with a sampling rate of 44.1 kHz and 16-bit quantization. The voice recordings were saved as high quality uncompressed wav files. All voice recordings were analyzed using Praat voice analysis software version 5.4.22 (Boersma & Weenink, 2014) to measure average pitch (fundamental frequency), pitch variation (standard deviation of pitch), formant position (average standardized measures of formants 1 through 4), and vocal tract length estimate (see Arnocky et al. (2018) for detailed description of how each variable is calculated). A principal component analysis of the four vocal measurements revealed a two factor solution, in which the primary factor accounted for 51% of the variance (pitch), and the secondary factor (loaded upon by the remaining three variables) accounted for 29% of the variance. The four measurements were then standardized, and composite vocal masculinity score was created. Given that F0 (pitch) loaded on a separate factor, we also report its relation to environmental attitudes independently in the results section.

3. Results

Descriptive statistics for all variables are provided in Table 1. We examined the relations between T, C, and environmental attitudes (EAI-24) using multiple moderated regressions (Hayes, 2013). The Johnson-Neyman technique (Aiken & West, 1991) assessed the ranges within which the moderation was significant. Concentration values for both T and C were log-transformed to achieve normal distributions. Time of sample provision, participant age, along with state and trait anxiety were included as covariates; none of the covariates were themselves directly related to EAI-24 scores (Table 2).

T did not directly predict environmental attitudes ($B = 0.65$, $SE = 0.30$, $p = .51$, $LLCI = -0.39$, $ULCI = 0.78$); however, T interacted with C ($B = -3.09$, $SE = 0.39$, $p = .003$, $LLCI = -1.96$, $ULCI = -0.43$) to predict EAI-24 scores.[1] Deconstruction of the interaction showed that the moderation effect was significant for C concentrations (log transformed) below -0.53 ($B = 1.98$, $SE = 0.42$, $p = .05$, $LLCI = 0.00$, $ULCI = 1.66$), and above 0.69 ($B = 1.98$, $SE = 0.32$, $p = .05$, $LLCI = -1.25$, $ULCI = 0.00$); such that T had a *positive* relation to EAI-24 scores at the lowest levels of C, and a *negative* relation to EAI-24 scores at the highest levels of C (Fig. 1). The model accounted for 13% of explained variance ($R^2 = 0.13$, $F_{(6, 107)} = 2.26 = .035$) in EAI-24 scores, with the TxC interaction accounting for 8% (R^2-change = 0.08, $F_{(1, 107)} = 9.52$, $p = .003$). See Table 2 for model summaries.

Relationships between the physical markers of masculinity and environmental attitudes were analyzed using one-tailed bivariate correlations according to the directional hypotheses. All correlations included the full sample of 162.[2]

EAI-24 scores were negatively related to facial masculinity ($r = -0.21$, $p = .004$), such that more masculine markers were associated with less favorable environmental attitudes. When considering the EAI subscales, higher facial masculinity was related to an increased willingness to utilize the environment for human needs ($r = 0.23$, $p = .002$), and with decreased attitudes in favor of environmental preservation ($r = -0.14$, $p = .038$). Further investigation of the component facial measures revealed that cheekbone prominence did not relate to the EAI or its subscales; however, both the FWHR and FWHR-l measures were either significantly, or marginally associated with the overall EAI-24 ($r = -0.21$, $p = .003$, $r = -0.21$, $p = .004$), the utilization subscale ($r = 0.25$, $p = .001$, $r = 0.20$, $p = .004$), and the preservation subscale ($r = -0.13$, $p = .055$, $r = -0.16$, $p = .023$).

Vocal masculinity was likewise shown to be related to overall EAI-24 scores ($r = -0.14$, $p = .037$), such that more masculine voices were associated with less favorable environmental attitudes. When considering the EAI subscales, higher vocal masculinity was associated with decreased willingness to preserve the environment ($r = -0.17$, $p = .018$); though it only showed a marginal relation to environmental utilization for human needs ($r = 0.11$, $p = .079$). Further investigation of the component vocal measures revealed that voice pitch was driving

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[1] Missing data in the state/trait anxiety variables due to their requisite summation scoring resulted in sample size for the moderation analysis dropping to 114. Recalculating these variables as means raised the sample size to 160; two remained missing due to ages not being provided. Interpretation of the model upon reanalysis did not meaningfully change.

[2] Analysis of partial correlations including age and state/trait anxiety variables as controls did not meaningfully change the relationships.

Table 1
Descriptive statistics for each study variable. Note: For testosterone and cortisol we report concentration values for descriptive purposes, although log-transformations of these variables were used for all analyses.

	Testosterone (pg/mL)	Cortisol (ng/mL)	State Anxiety	Trait Anxiety	Vocal Masculinity	Facial Masculinity	EAI	EAI Preservation	EAI Utilization
N	162	162	137	138	162	162	162	162	162
Mean	132.62	6.09	34.50	39.63	19.26	0.62	4.69	4.95	3.67
Std. Deviation	101.30	4.86	9.82	9.90	5.09	0.07	0.65	0.78	0.80
Range	1144.22	20.29	47	46	29.69	0.39	3.20	3.67	3.90
Minimum	11.285	0.066	20	20	0.00	0.45	3.09	3.00	1.60
Maximum	1155.500	20.360	67	66	29.69	0.85	6.29	6.67	5.50

Table 2
Model summaries. Outcome variable: EAI-24 scores.

	Covariates Included					Covariates Not Included				
	B	*SE*	*p*	LLCI	ULCI	*B*	*SE*	*p*	LLCI	ULCI
Constant	5.75	.81	< .001	3.06	6.28	7.61	.54	< .001	3.04	5.18
T	.65	.30	.515	-.39	.78	1.04	.28	.302	-.26	.84
C	3.29	.74	.001	.97	3.93	2.15	.72	.033	.12	2.96
Interaction	−3.09	.39	.003	−1.96	-.43	−2.05	.36	.043	−1.46	-.03
Age	.92	.01	.362	-.01	.04					
State Anxiety	-.96	< .01	.341	-.03	.01					
Trait Anxiety	.91	< .01	.365	-.01	.03					
Sample Time	−1.66	< .01	.100	.00	.00					

Note. Log-transformed values of testosterone (T) and cortisol (C) were used in all analyses.

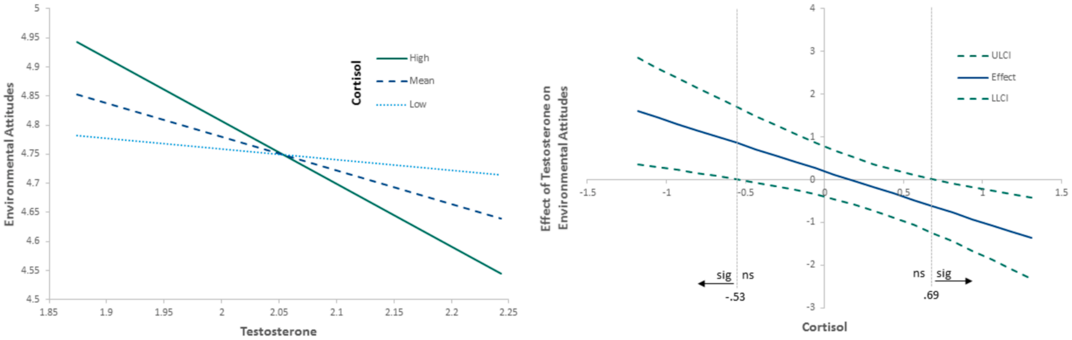

Fig. 1. Standardized (a) conditional moderation effect of cortisol (C; log-transformed; 84th (high), 50th (mean), 16th (low) percentiles) on the relationship between testosterone (T; log-transformed) and environmental attitudes (EAI scores), and Johnson- Neyman confidence limits (b).

the relation, such that lower pitch (more masculine) was associated with lower overall EAI-24 scores ($r = -0.17$, $p = .014$), lower preservation attitudes ($r = -0.17$, $p = .016$), and higher utilization attitudes ($r = 0.16$, $p = .02$); no other vocal measures were significantly related to environmental attitudes.

Neither facial nor vocal masculinity were related to T ($r = 0.06$, $p = .24$, and $r = -0.05$, $p = .27$, respectively).

4. Discussion

Congruent with Sollberger et al. (2016a), we found no direct relationship between T and environmental attitudes; however, we did similarly find an interaction between T and C, though the interaction was distinct. Sollberger et al. (2016a) found a negative effect of T on self-reported environmental behavior, specifically when coinciding with *lower* C levels. In contrast, our study found T had a negative relation with environmental attitudes at the *highest* levels of C, whereas T had a positive relation to environmentalism at the *lowest* levels of C. In other words, the detrimental effects of high T upon environmentalism in our study relied upon an interaction with heightened C levels, whereas in the Sollberger et al. (2016a2016b) study, the detrimental effects of T hinged on an interaction with low C levels. This finding highlights the role of T in low environmental engagement, although the role of C appears to be less clear. Furthermore, this mixed result in interaction directionality between T and C is not atypical. For example, previous research has identified the mixed findings in the interaction of C and T in predicting facial attractiveness (Kordsmeyer, Lohöfener, & Penke, 2019). Future correlational research should employ more comprehensive measures of T across time of day for multiple days. Experimental research might benefit this directional understanding by pharmacologically suppressing C and administering T to examine the causal roles of the interaction.

Although our state measure of salivary T differs slightly with the Sollberger et al. (2016a) finding, our measures of physiological indices of masculinization coalesce with the hypothesis that physical masculinization is linked with reduced environmentalism. The majority of environmental research has focused on social and psychological factors that influence environmentalism, however the current study demonstrates the impact of biologically driven differences. The physical sex characteristics of facial and vocal masculinization related to overall pro-environmental attitudes. Individuals with more masculine faces were more likely to want to use the environment for their own personal gain and were less likely to want to protect the environment. Individuals with more masculine voices were less likely to want to protect the environment, but were only marginally likely to want to use the environment for human gain. These preliminary findings demonstrate a novel and potentially important facet of research concerning the relationship between sex differences and pro-environmentalism. Though T did not relate to either of the masculinity markers in our study, this could be due to the preceding effect that developmental T has on physical markers of masculinity, such as facial masculinity; Whitehouse et al. (2015) found prenatal T, but not circulating T, to be related to facial masculinity in adulthood (see also Bird et al., 2016). Future research may benefit from exploring the distinct effects of both physical markers and circulating trait levels of T in relation to adulthood attitudes and behavior.

4.1. Limitations

The correlational design precludes drawing a causal relation between the measured markers of physical masculinity and environmental attitudes. It is possible that this relation is mediated via an unspecified variable; e.g., more sexually dimorphic males may be more sensitive to socialization cues regarding pro-environmental attitudes than their more effeminate counterparts. Moreover, this study measured participants' attitudes towards the environment, a measure which may not always translate to environmental behaviors (Landry, Gifford, Milfont, Weeks, & Arnocky, 2018). Finally, although the focus of this research was on T and T-mediated phenotypic traits, it is noteworthy that our TxC interaction conflicts with those expected via the dual-hormone hypothesis. More research is required before any directional links can be confirmed regarding TxC interactions and men's environmentalism.

5. Conclusion

The extant literature on gender differences in environmentalism, which focuses principally on social and contextual factors such as feminine versus masculine socialization, is lacking in its depth and ability to explain sex differences in environmentalism across diverse contexts. This study aimed to expand understanding of why males appear to care less for the environment relative to females by examining (1) TxC interactions, and (2) physical markers of androgen-driven masculinity, in relation to pro-environmental attitudes. Results largely support the finding that state T (interacting with high C) and markers of phenotypic masculinization are linked to reduced environmentalism amongst males. These findings may have implications for future research, which might benefit from exploring the effects of experimental T suppression and administration upon environmental attitudes and action. This may ultimately afford a better understanding of the role of sex hormones in environmental behavior.

Acknowledgements

Funding provided by the Natural Sciences and Engineering Research Council of Canada (NSERC), Discovery Development Grant (DDG) program (file # DDG-2017-00013) awarded to Steven Arnocky.

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