

# Arching the Back (Lumbar Curvature) as a Female Sexual Proceptivity Signal: an Eye-Tracking Study

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**Abstract** It is common in studies of human mate preference to have participants judge the attractiveness of photographs in which models adopt a neutral facial expression or a neutral body posture. However, it is unlikely that humans adopt neutral expressions and postures in normal social circumstances. One way in which posture can vary is in the curvature of the lower spine. In some non-human animals, a “lordotic” posture (in which the lower spine is curved towards the belly) is associated in females with readiness to mate. In humans, this posture may serve a similar function, attracting heterosexual men. In this study, participants were presented with computer-generated images of female bodies in which the back curvature was systematically manipulated. The result showed that small changes in lumbar curvature are associated with changes in the perception of attractiveness. Specifically, the result showed that there is a relationship between the range of the back curvatures used in this study and attractiveness, such that increasing the curvature increased the perception of attractiveness. Additionally, as the curvature increased, participants looked longer and fixated more on the hip region of the female bodies. This paper argues that the attractiveness of women in lordotic posture is due to a conserved mechanism across the taxa which signals proceptivity to men.

**Keywords** Lumbar curvature · Lordosis · Proceptive behavior · Receptivity · Sexual behavior · Eye-tracking

“Human sexuality is not unique, nor is human sexual behavior totally different from that of other animals.”—Alan F. Dixson 2015

There exist sex differences in courtship and mating behavior. These differences in mating behavior are due to an interplay between endocrine and genetic factors throughout development and life span. Behavioral sex differences are affected by organizational hormones during all stages of organisms’ lives, with critical prenatal and pubertal periods (Berenbaum and Beltz 2011). Prenatally, hormones influence brain development resulting in permanent and pronounced differences in sex-typed behavior beginning at puberty and expressed in adolescence (Berenbaum and Beltz 2011). The hypothalamic ventromedial nucleus (VMH) is a site of ovarian hormone action critical to the lordosis response. Sex differences in neural circuitry and neurochemistry of the VMH have been reviewed elsewhere (Flanagan-Cato 2011). Lordosis, or the arching of the back, is a female-specific copulatory behavior which indicates that the female is sexually receptive (Beach 1976). In many female mammals, VMH is involved in the display of proceptive and receptive behaviors (Flanagan-Cato 2011; Henley et al. 2011), and lesions in this center reduce sexual receptivity and lordosis behavior in female rats (Clark et al. 1981), hamsters (Malsbury et al. 1977), guinea pigs (Goy and Phoenix 1963), ferret (Robarts and Baum 2007), sheep (Clegg et al. 1958), cats (Leedy and Hart 1985), and primates (Aou et al. 1988). As lesions to the VMH of female whiptail lizards inhibit receptive sexual

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behavior, it is indicated that this neural mechanism is conserved in all vertebrates (Kendrick et al. 1995).

Concerning the putative attractiveness of human female lumbar curvature, Lewis et al. (2015) recently suggested that the transition to bipedalism introduced novel selective pressures that favored female lumbar vertebral wedging. They suggested that male mate preferences for women exhibiting cues to such wedging are exhibiting an evolution-related psychological response adapted to detect fitness-relevant traits. Lewis et al. proposed that “men who preferred and selected these women as mates would have gained several key fitness benefits, including having a mate who was less vulnerable to spinal injuries, better at foraging during pregnancy, and better able to sustain multiple pregnancies without debilitating injury”.

In addition to the adaptive vertebral wedging being closer to the optimum in women as is suggested by Lewis et al. (2015), lumbar curvature can be viewed as facilitating dynamic and fluctuating posture in human females associated with signaling proceptivity/receptivity. Through intended change in the degree of lordotic curvature, a given woman with the fixed body morph can change the degree of back curving and the perceived attractiveness. The dynamicity of female body postures on the perceived attractiveness to men was investigated in the previous research. For example, in an ecological study, Guéguen (2015) recruited a female confederate who wore three types of high-heeled shoes (flat heels, 5-cm heels, and 9-cm heels). The results showed that the same woman wearing high-heeled shoes received more interest from surrounding males who approached more often, suggesting increased perception of the attractiveness. Moreover, when body motion such as female dance is considered, research has shown that the perceived attractiveness of a woman changes across different movements and postures. For example, McCarty et al. (2017) showed that greater hip swing and thigh movement in women’s dance are associated with higher perceived attractiveness. Additionally, it has been shown that by changing only a given woman’s body posture from standing to contrapposto, the perceived attractiveness increases (Pazhoohi et al. 2017). Also, in a theoretical paper, Doyle (2009) proposed that actual waist-to-hip ratios (actual WHRs) create a wider range of view-dependent WHRs (vdWHRs) while women are in motion (e.g., while walking and dancing), creating both higher and particularly lower than 0.7 vdWHRs; that these alternating vdWHRs create a peak shift effect on the perception of physical attractiveness; and that these super low vdWHRs are supernormal stimuli perceived from behavior patterns. Given that men are attracted by both female forms and movements, vdWHRs in the supernormal range, when contrasted within behavior patterns and generating peak shift effects in the perception of attractiveness, may

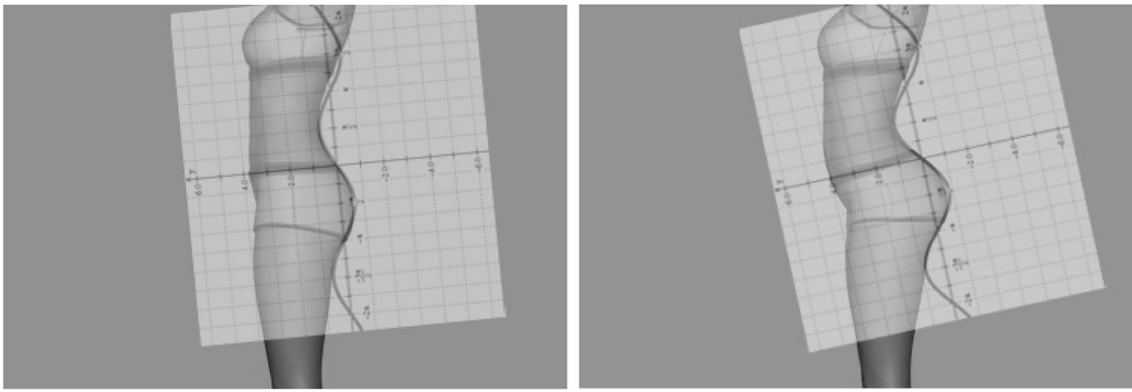
partially explain the attractiveness of other than 0.7 actual WHRs.

Overall, the dynamicity of female body postures and the subtle and nuanced changes in posture on perceived attractiveness, both from static and moving stimuli (Doyle 2009, Fink et al. 2015; Röder et al. 2016), imply that the perception of attractiveness from a static stimulus is not necessarily reflecting adaptiveness; rather, individual images might simply represent a captured section of a broader movement such as an attractive dancing and/or proceptive behavior.

## Current Study

While Lewis et al. (2015) were considering an adaptive explanation of preference for an intermediate optimum between hypolordosis and hyperlordosis and used stimuli to investigate this hypothesis, in this study, we are interested to see whether slight incremental changes in the lumbar curvature in the physically normal human female figure with a fixed WHR would also increment the perceived attractiveness. In the current study, we used 3D models of realistic stimuli and developed a new method for creating systematically manipulated curvatures. The 3D models were created to conform to a series of graphed sinusoidal waves. We created sinusoid graphs, i.e.,  $y = \alpha \sin(x)$ , where  $\alpha$  ranged from 0.5 to 1, increasing by 0.05. Then, we aligned these graphs with the 3D models varying in curvatures See Fig. 1 for an example. Creating stimuli below  $\alpha = 0.6$  was not possible without decreasing the buttock mass. We aimed to mimic natural body motion using static stimuli; therefore, we did not include  $\alpha = 0.5$  and 0.55. In other words, we were interested in the different possible curvatures of a woman with a fixed WHR and body mass. We only manipulated the lumbar curvature. Moreover, as is previously shown by the Lewis et al. (2015) study, lumbar curvature over a specific point is perceived as less attractive. Likewise, stimuli over 0.85 (i.e.,  $\alpha = 0.9, 0.95,$  and 1) were categorized as abnormal and physically impossible by five raters (including one of the authors); hence, six final lumbar curvatures each in three different viewing angles were used in this study as the stimuli.

In addition to the ratings of attractiveness for 3D images of a woman with different lumbar curves from three viewing angles, we also used eye tracking to monitor participants’ gaze while looking at the images. Eye tracking is considered a robust method to study human physical attractiveness and provides a behavioral link between evolutionary studies of sexual selection and morphology (Dixson et al. 2010; Silva et al. 2016; Wenzlaff et al. 2016). We hypothesized that slight increments in the lumbar curvature in the physically normal ranges of a woman with fixed WHR and body morph should direct more visual attention to the hip region, compared to other body parts and should be rated as more sexually



**Fig. 1** Example of Female body figure with the lumbar curvature adjusted to  $\alpha = 0.6$  and  $\alpha = 0.85$  (left and right)

attractive. Arching the back and thrusting out the buttocks as are presented by female erotic lap dancers are a manifestation of sexual receptivity/proceptivity and are appealing to men (Miller et al. 2007), which are similar to proceptive sexual presentation postures in female primates (Dixson 1998, 98–99). Here, we use stimuli with gradually increased arching of the back and predict that as the curvature increases, the perception of attractiveness also increases. If associated with higher attractiveness, a graded increase in the exhibition of lordosis in human female might serve as a signal of proceptivity. Additionally, we hypothesized that arching the back is more salient to male participants than female ones. Specifically, we predicted that the arched back is more attractive to men and that they will pay more attention to the hip region than female participants. Finally, we hypothesized that the side and behind-side views where the hip is most visible are perceived to be more attractive than the front-side view.

## Method

**Participants** Eighty-two heterosexual individuals (50 female and 32 male participants) were recruited from undergraduate students at the University of Minho. The mean age was 20.9 years ( $SD = 3.3$ ). Students received course credit in return for their participation. All participants were Portuguese and possessed normal or corrected-to-normal vision. Each one gave written informed consent. The experiment was approved and conducted in accordance with ethical committee guidelines.

**Stimuli** The stimuli were generated using DAZ 3D software. Eighteen stimuli were generated using a female model posed in six systematically manipulated curvatures. Their back curvatures were aligned with six sinusoid graphs; i.e.,  $y = \alpha \sin(x)$ ; where  $\alpha = 0.6, 0.65, 0.7, 0.75, 0.8, \text{ and } 0.85$  (Fig. 1). Each profile stimulus was also rotated in  $\pm 45^\circ$  to create two additional angles for each stimulus, i.e., showing the stimulus from

the front-side and behind-side (Fig. 2) views. Therefore, the total number of stimuli was 18.

**Eye-Tracking Equipment and Procedure** Eye movements were monitored using a binocular infrared, remote eye-tracker running at 250 Hz (RED250, SMI Gmb Germany) controlled with iView X software (v2.8). Stimuli were presented on a 22-in LCD monitor (Dell P2210, 60 Hz,  $1680 \times 1050$  pixels). Initially, participants completed a five-point calibration procedure. Calibration was accepted if the mean spatial shift for four validation points was  $0.5^\circ$  of visual angle or less for vertical and horizontal deviations. The experiment was carried out in a room with dim light ( $\sim 10$  lx). Participants were seated, head free, at 70 cm from the monitor. The experimental procedure was adopted from similar previous studies (Dixson et al. 2010, 2011; Garza et al. 2016). Participants then viewed all 18 stimuli in one block, individually, and in a random order for 5 s each. To ensure that participants' attention was focused on the center of the screen before the onset of each stimulus presentation, a gaze-contingent fixation cross appeared in the center of the computer screen (dwell time required 500 ms). Data analysis was performed using the BGaze software (v3.6). Saccades were separated from fixations using a peak velocity



**Fig. 2** From left to right: front-side view, side view, and behind-side view

threshold of 40°/s computed from a peak velocity window based on the methods defined by Smeets and Hooge (2003). Fixations with a duration of less than 50 ms were discarded. Dwell time was considered the sum of durations from all fixations and saccades that hit the region of interest. After viewing the stimuli, participants viewed and rated all the images for the perceived attractiveness on a 10-point Likert scale from 1 (*extremely unattractive*) to 10 (*extremely attractive*).

**Regions of Interest** The stimulus images were divided into four regions of interest (ROI): (a) the chest, from the top of the clavicle to the end of the rib cage; (b) the waist, beginning from the end of the rib cage, including the waist, to the beginning of the hip; (c) the hip, from the highest point of the iliac crest to the bottom of the pubic area and the upper portion of the leg; and (d) the thighs, from the upper portion of the leg to the knee.

## Results

### Results for Rating of Attractiveness

A repeated-measure analysis of variance (ANOVA) with the six lumbar curves and the three viewing angles as within-subject and sex as between-subject was performed. Results showed a significant effect for the curve [ $F(5, 400) = 54.57, p < .001, \eta^2 = 0.40$ ]. Pairwise comparison showed that the ratings were significantly higher as the curvature got higher ( $\alpha = 0.60: M = 4.64, SE = 0.21; \alpha = 0.65: M = 5.37, SE = 0.22; \alpha = 0.70: M = 5.54, SE = 0.21; \alpha = 0.75: M = 5.70, SE = 0.23; \alpha = 0.80: M = 5.94, SE = 0.23; \alpha = 0.85: M = 6.41, SE = 0.23$  all  $p < 0.01$ , except for the comparison between  $\alpha = 0.70$  and  $0.75$ , where  $p = .053$ ; see Table 1). The results showed a significant effect for sex [ $F(1, 80) = 8.36, p = .005, \eta^2 = 0.09$ ]; men ( $M = 6.22, SE = 0.36$ ) rated the stimuli higher than women ( $M = 4.98, SE = 0.21$ ). Also, results showed a significant main effect for angle [ $F(2, 160) = 9.32, p = .001, \eta^2 = 0.10$ ]. Results showed that participants rated the front-side view ( $M = 5.30, SE = 0.22$ ) lower than the side view ( $M = 5.68, SE = 0.21$ ) and the behind-side view ( $M = 5.82, SE = 0.23$ ).

### Result for Eye-Tracking

**Dwell Time** A repeated-measure ANOVA with the three viewing angles, six lumbar curves, and four ROI as within-subject and sex as between-subject was performed to analyze mean dwell time. Results showed a significant main effect for angle ( $F(1160) = 9.71, p < .001, \eta^2 = 0.11$ ), with behind-side view significantly higher than both side and front-side views ( $p < .001$ ).

**Table 1.** Mean and SD for ratings of attractiveness of different curvatures

Curve	Side View		Front-Side View		Behind-Side View	
	Mean	SD	Mean	SD	Mean	SD
0.60	4.72	2.03	4.54	2.21	4.67	2.31
0.65	5.38	2.18	5.23	2.26	5.50	2.14
0.70	5.65	2.22	5.29	2.05	5.68	2.15
0.75	5.84	2.31	5.20	2.17	6.06	2.38
0.80	5.88	2.29	5.69	2.12	6.27	2.38
0.85	6.60	2.24	5.88	2.14	6.76	2.70

Three ANOVAs with the six lumbar curves and four ROI as within-subject and sex as between subject were performed to analyze mean dwell time for each viewing angle. Results for the side view showed a significant ROI effect ( $F(3240) = 87.54, p < .001, \eta^2 = 0.52$ ); however, the ROI  $\times$  sex interaction was not significant ( $F(3240) = 0.59, p = .621, \eta^2 = 0.01$ ), meaning that dwell time on different ROIs was not different between men and women. Pairwise comparison for ROI showed significant differences between all the ROIs (chest:  $M = 566.39$  ms,  $SE = 57.86$ ; waist:  $M = 1154.02$ ;  $SE = 93.16$ ; hip:  $M = 2113.08$ ;  $SE = 110.47$ ; thighs:  $M = 208.08$ ;  $SE = 34.17$ , all  $p < .001$ ). Moreover, the curve  $\times$  ROI interaction was significant,  $F(15, 1200) = 4.01, p < .001, \eta^2 = 0.04$ ; see Table 2. For the heat map of the side view, see Fig. 3.

Likewise, results for the front-side view showed a significant ROI effect ( $F(3240) = 32.78, p < .001, \eta^2 = 0.29$ ); however, the ROI  $\times$  sex interaction was not significant ( $F(3240) = 1.73, p = .161, \eta^2 = 0.02$ ), meaning that dwell time on different ROIs was not different between men and women. Pairwise comparison for ROI showed significant differences between all the ROIs (chest:  $M = 722.73$ ;  $SE = 60.32$ ; waist:  $M = 969.12$ ;  $SE = 89.85$ ; hip:  $M = 1678.70$ ;  $SE = 88.77$ ; thighs:  $M = 645.17$ ;  $SE = 52.76$ , all  $p < .05$ ). Additionally, the curve  $\times$  ROI interaction was significant,  $F(15, 1200) = 21.56, p < .001, \eta^2 = 0.21$ .

Results for the behind-side view also showed a significant ROI effect ( $F(3240) = 239.95, p < .001, \eta^2 = 0.75$ ), and the ROI  $\times$  sex interaction was significant ( $F(3240) = 6.84, p < .001, \eta^2 = 0.08$ ), meaning that dwell time on the hip was longer for men ( $M = 3262.87$ ;  $SE = 204.15$ ) than women ( $M = 2612.19$ ;  $SE = 115.94, p = .007$ ) and that on the waist was longer for women ( $M = 821.94$ ;  $SE = 68.46$ ) than men ( $M = 451.61$ ;  $SE = 120.55, p = .009$ ). Pairwise comparison for ROI showed significant differences between all the ROIs except the chest and the thighs (chest:  $M = 366.53$ ;  $SE = 44.57$ ; waist:  $M = 636.77$ ;  $SE = 69.31$ ; hip:  $M = 2937.53$ ;  $SE = 117.39$ ; thighs:  $M = 253.60$ ;  $SE = 40.39$ , all  $p < .001$ , except between chest and thighs, where  $p = .068$ ).

**Table 2.** Mean and SD of dwell time (ms) for regions of interest of different curvatures

Curve	AOI	Side View		Front-Side View		Behind-Side View	
		Mean	SD	Mean	SD	Mean	SD
0.60	Chest	834.23	823.12	927.04	962.48	407.00	593.61
	Waist	1162.86	1213.73	965.25	1045.01	718.71	924.86
	Hip	1787.42	1247.29	551.22	730.36	2747.12	1373.22
	Thighs	282.74	560.03	1656.38	1008.59	337.41	684.74
0.65	Chest	725.61	805.15	696.27	802.99	467.96	662.64
	Waist	1156.51	1259.63	1111.32	1115.00	716.17	790.08
	Hip	1958.86	1473.79	1773.71	1223.72	2778.31	1439.32
	Thighs	220.40	582.50	475.45	723.48	244.87	465.70
0.70	Chest	590.39	846.24	767.79	844.07	309.59	537.61
	Waist	1207.47	1168.46	881.10	1204.61	436.08	765.15
	Hip	2087.06	1361.71	1815.03	1355.28	3023.87	1481.70
	Thighs	252.33	487.44	429.73	623.19	355.24	661.39
0.75	Chest	563.20	757.61	814.72	873.60	369.20	569.22
	Waist	1070.01	1200.35	930.69	1064.56	829.19	1117.51
	Hip	2031.50	1294.36	1732.56	1142.61	2856.46	1359.89
	Thighs	190.78	455.41	497.30	707.15	223.49	493.20
0.80	Chest	370.55	610.10	651.08	737.00	385.60	607.55
	Waist	1161.31	1098.24	938.90	1150.31	573.70	739.19
	Hip	2379.70	1285.68	1940.34	1320.45	3049.80	1377.78
	Thighs	198.33	523.43	438.75	696.67	144.16	323.52
0.85	Chest	314.37	582.10	479.48	781.48	259.85	545.80
	Waist	1165.97	994.82	987.47	955.00	546.82	834.37
	Hip	2433.98	1309.09	2259.38	1222.50	3169.66	1319.01
	Thighs	103.91	253.86	373.43	597.32	216.45	489.93

Additionally, the curve × ROI interaction was significant,  $F(15, 1200) = 2.79, p < .001, \eta^2 = 0.03$ .

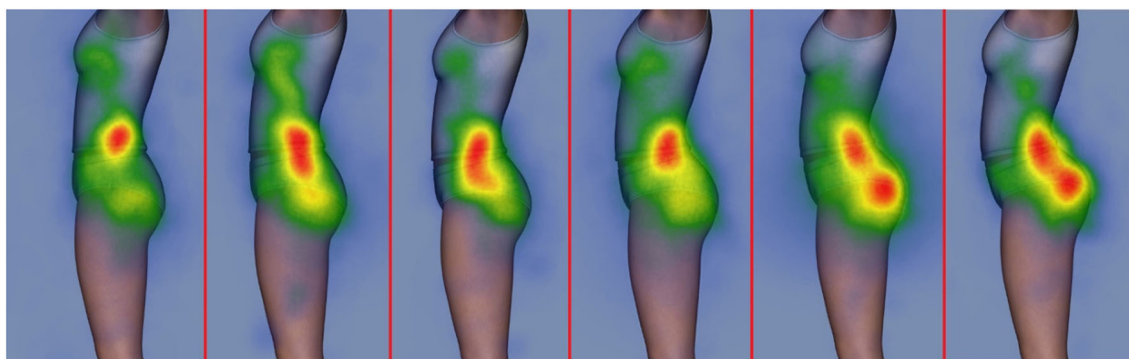
**Fixation Number** A repeated-measure ANOVA with the three viewing angles, six lumbar curves, and four ROI as within-subject and sex as between-subject was performed to analyze mean fixation numbers. The main effect for angle was not significant ( $F(1160) = 9.71, p = .119, \eta^2 = 0.02$ ).

Three ANOVAs with the six lumbar curves and four ROIs as within-subject and sex as between-subject was performed to analyze mean fixation numbers for the three viewing angles. Results for the side view showed a significant ROI effect ( $F(3240) = 89.09, p < .001, \eta^2 = 0.52$ ); however, the ROI × sex interaction was not significant ( $F(3240) = 0.56, p = .641, \eta^2 = 0.01$ ), meaning that fixations on different ROIs were not different between men and women. Pairwise comparison for ROI showed significant differences between all the ROIs (chest:  $M = 1.68, SE = 0.17$ ; waist:  $M = 3.26, SE = 0.22$ ; hip:  $M = 5.35, SE = 0.27$ ; thighs:  $M = 0.70, SE = 0.10$ , all  $p < .001$ ). Moreover, the curve × ROI interaction was significant,  $F(15, 1200) = 3.22, p < .001, \eta^2 = 0.04$ ; see Table 3.

Likewise, results for the front-side view showed a significant ROI effect ( $F(3240) = 35.52, p < .001, \eta^2 = 0.30$ ). Pairwise comparison for ROI showed significant differences between all ROIs except the chest and the thighs (chest:  $M = 1.96, SE = 0.16$ ; waist:  $M = 2.82, SE = 0.22$ ; hip:  $M = 4.48, SE = 0.22$ ; thighs:  $M = 1.97, SE = 0.16$ , all  $p < .01$ , except between the chest and the thighs, where  $p = .982$ ). Additionally, the curve × ROI interaction was significant,  $F(15, 1200) = 20.91, p < .001, \eta^2 = 0.21$ . Results for the behind-side view also showed a significant ROI effect ( $F(3240) = 182.35, p < .001, \eta^2 = 0.69$ ), and the ROI × sex interaction was not significant ( $F(3240) = 2.07, p = .104, \eta^2 = 0.02$ ). Pairwise comparison for ROI showed significant differences between all the ROIs except the chest and the thighs (chest:  $M = 1.14, SE = 0.13$ ; waist:  $M = 1.99, SE = 0.19$ ; hip:  $M = 6.83, SE = 0.30$ ; thighs:  $M = 0.84, SE = 0.11$ , all  $p < .001$ , except between the chest and the thighs, where  $p = .100$ ). Additionally, the curve × ROI interaction was significant,  $F(15, 1200) = 1.94, p = .016, \eta^2 = 0.02$ .

**Discussion**

Results of the current study showed that as the lordosis in the stimuli that we used in this experiment increases, both men and women perceived and rated them as more attractive and increased their visual attention in the hip region. Additionally,



**Fig. 3** Heat map for side views, showing female body curves with  $\alpha = 0.6, 0.65, 0.7, 0.75, 0.8,$  and  $0.85$  from left to right

**Table 3.** Mean and SD of fixation numbers for regions of interest of different curvatures

Curve	AOI	Side View		Front-Side View		Behind-Side View	
		Mean	SD	Mean	SD	Mean	SD
0.60	Chest	2.55	2.48	2.61	2.40	1.20	1.75
	Waist	3.51	3.19	2.86	2.33	2.07	2.27
	Hip	4.83	3.41	2.03	2.61	6.32	3.36
	Thighs	1.05	1.88	4.83	2.88	1.04	1.83
0.65	Chest	1.94	2.16	1.67	1.70	1.44	1.93
	Waist	3.21	3.14	3.20	2.51	2.24	2.73
	Hip	5.27	3.43	4.70	3.04	6.57	3.84
	Thighs	0.69	1.34	1.60	2.26	0.80	1.51
0.70	Chest	1.67	2.50	2.09	2.22	0.96	1.68
	Waist	3.00	2.28	2.59	2.71	1.58	2.63
	Hip	5.00	2.97	4.91	2.99	6.86	3.78
	Thighs	0.88	1.56	1.40	1.94	1.13	1.84
0.75	Chest	1.62	2.00	2.19	2.33	1.12	1.78
	Waist	3.05	2.53	2.80	3.02	2.29	2.75
	Hip	5.37	3.19	4.76	3.34	6.81	3.41
	Thighs	0.64	1.44	1.49	2.02	0.78	1.75
0.80	Chest	1.21	1.81	1.84	2.16	1.24	1.92
	Waist	3.10	3.14	2.65	3.31	1.99	2.54
	Hip	5.82	3.51	4.97	3.34	7.06	3.58
	Thighs	0.58	1.38	1.24	1.83	0.60	1.11
0.85	Chest	1.08	1.85	1.39	1.97	0.88	1.79
	Waist	3.70	3.13	2.84	2.51	1.78	1.93
	Hip	5.84	3.81	5.51	3.00	7.36	3.55
	Thighs	0.42	0.93	1.26	1.99	0.74	1.47

our results showed that men rated the stimuli more attractive than women. Moreover, the side and behind-side views were rated more attractive than the front-side view. Results of the eye tracking showed that participants viewed the behind-side view longer than the side and front-side views and men had longer dwell time on the hip from the behind-side view than women while women looked for a longer time on the waist from the behind-side view than men. No other sex difference was observed regarding the dwell time and fixation number.

Our results differ from those reported by the Lewis et al. (2015) study which could be due to the differences in the methodology. Here, we aimed to systematically investigate whether small changes in arching the body or an increase in lordosis posture of a given human female body influences the perception of attractiveness and the gazing behavior. Therefore, the current study's stimuli did not capture the upper portion of the lumbar curvature where the relationship between lumbar curvature and attractiveness was inverted in Lewis et al. (2015). However, the results of the current study indicate that increments in the lumbar curvature in the physically possible range used here are associated with an increase in the perception of attractiveness.

The association of the graded increase in lumbar curvature (or the exhibition of lordosis) with the perception of attractiveness and visual attention to the hip region suggests that lordosis might serve as the signal of proceptivity in human females. Interestingly, both the results of attractiveness ratings and eye tracking indicate that the effect is more robust from the side and back-side views compared to the front-side view where the hip is most visible. The latter highlights the unique influence of arching the back in the perception of attractiveness.

As noted by Doyle and Pazhoohi (2012) who tested Marlowe's (1998) nubility hypothesis cross-culturally, breast size, shape, and firmness, indicated by topline fullness, may be proxies for youthfulness and residual reproductive value. Similarly, increased lumbar curvature increases the apparent convexity of the topline curvature of the buttocks. Firmer, non-ptotic buttocks may likewise signal youthfulness and act as honest signals of reproductive capacity. It may be that this characteristic has been sexually selected resulting in the "super-normal" form, steatopygia.

Human females express a number of behavior patterns signaling their interest towards men. In the early stages, human females use nonverbal behaviors such as smile, hair flip, head tilt, lean, and neck presentation (Moore 1985). These flirting behaviors attract men's attention and solicit approach to women (Moore and Butler 1989). Similar to results from the field, the same result is confirmed in the laboratory setting (Grammer 1990). Women's patterns of signaling interest and sexual proceptivity can be observed while they are in motion such as walking and dancing. Guéguen (2012) has shown that women walk more slowly and their gait is sexier around ovulation. Women's dance and movements are shown to be more attractive around ovulation (Fink, Hugill, & Lange, 2012; Miller et al. 2007), and also, attractive dancers move differently than unattractive dancers (Röder et al. 2016). The perceived attractiveness of women's gaits and dance appears to be related to greater hip swing and thigh movement (McCarty et al. 2017) or in the frequency of appearance of contrapposto posture (Pazhoohi et al. 2017). Moreover, arching the back while wearing high-heel shoes and thrusting the hips during lap dances have been found to be attractive to some men (Guéguen 2015; Miller et al. 2007). Twerking, which appears to be a simulated copulatory act, performed while dancing, also exaggerates lumbar curvature and juxtaposes an array of view-dependent stimulus dimensions. As is mentioned above, arching the back or the lordotic posture and the neural mechanism associated with that appear to be phylogenetically conserved in nonhuman animals. While researchers argue that compared to other mammals, human sexual cues, such as estrous and lordotic reflexes, are considered to be hidden and absent in humans (Burt 1992; Dixson 1998); recent evidence shows that women near ovulation are more attractive to men (Cobey et al. 2013; Haselton and Gildersleeve 2011). Likewise, while reflexive lordosis posture is not exhibited by human females and receptivity is not passive or obligatory for them

(Dixson 1998, p. 102), a manifestation of lumbar curvature might serve as a vestigial remnant of proceptivity/receptivity-communicative signal between men and women. Arching the back and thrusting out the buttocks can signal sexual readiness. During mating in dorso-ventral posture (in which the male mounts the female from the rear), to maintain the copulation, in addition to immobilization, receptive females of many species push backward towards the male while the male is copulating (Beach 1976). As for the copulatory postures of the nonhuman primates closest to humans, it is also noteworthy to mention that bonobos mate in both dorso-ventral and ventro-ventral (face to face) positions and chimpanzees only mate in the dorso-ventral position (Dixson 2009; p. 88). The dorso-ventral position is a less frequent practice compared to the ventro-ventral position in most human populations; nevertheless, full dorso-ventral position occurs from modern to indigenous societies (Dixson 2009; p. 83; Prokop et al., 2017). Therefore, the current study extends this posture in human female as a signal of proceptivity/receptivity to males.

Our results should be interpreted with respect to the limitations of the current research. While we used stimuli without the head and the arms to decrease the distractions such as the body being covered by the arms and the hands, this might have affected the participants' behavior and the ratings. However, the current paper showed that small changes in lumbar curvature are associated with the perception of attractiveness. The current study did not directly measure female mating behavior and/or the receptivity associated with lumbar curvature. Further studies should consider whether human females arch their backs when they are sexually proceptive and also whether human males perceive arching as a signal of proceptivity. In addition to the previously suggested function of lumbar curvature in pregnancy by Lewis et al. (2015), the results of the current study suggest that arching the lumbar curves of women's backs is perceived to be physically attractive and can be a nonverbal cue used by women signaling proceptivity/receptivity.

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## References

- Aou, S., Oomura, Y., & Yoshimatsu, H. (1988). Neuron activity of the ventromedial hypothalamus and the medial preoptic area of the female monkey during sexual behavior. *Brain Research*, 455(1), 65–71.
- Beach, F. A. (1976). Sexual attractivity, proceptivity, and receptivity in female mammals. *Hormones and Behavior*, 7(1), 105–138.
- Berenbaum, S. A., & Beltz, A. M. (2011). Sexual differentiation of human behavior: effects of prenatal and pubertal organizational hormones. *Frontiers in Neuroendocrinology*, 32(2), 183–200.
- Burt, A. (1992). 'Concealed ovulation' and sexual signals in primates. *Folia Primatologica*, 58(1), 1–6.
- Clark, A. S., Pfeifle, J. K., & Edwards, D. A. (1981). Ventromedial hypothalamic damage and sexual proceptivity in female rats. *Physiology and Behavior*, 27(4), 597–602.
- Clegg, M. T., Santolucito, J. A., Smith, J. D., & Ganong, W. F. (1958). The effect of hypothalamic lesions on sexual behavior and estrous cycles in the ewe. *Endocrinology*, 62(6), 790–797.
- Cobey, K. D., Buunk, A. P., Pollet, T. V., Klipping, C., & Roberts, S. C. (2013). Men perceive their female partners, and themselves, as more attractive around ovulation. *Biological Psychology*, 94(3), 513–516.
- Dixson, A. (1998). *Primate sexuality: comparative studies of the prosimians, monkeys, apes, and human beings*. Oxford: Oxford University Press.
- Dixson, A. (2009). *Sexual selection and the origins of human mating systems*. Oxford: Oxford University Press.
- Dixson, A. (2015). Primate sexuality. *The International Encyclopedia of Human Sexuality*, 1–9.
- Dixson, B. J., Grimshaw, G. M., Linklater, W. L., & Dixson, A. F. (2010). Watching the hourglass. *Human Nature*, 21(4), 355–370. <https://doi.org/10.1007/s12110-010-9100-6>.
- Dixson, B. J., Grimshaw, G. M., Linklater, W. L., & Dixson, A. F. (2011). Eye-tracking of men's preferences for waist-to-hip ratio and breast size of women. *Archives of Sexual Behavior*, 40(1), 43–50.
- Doyle, J. F. (2009). A woman's walk: attractiveness in motion. *Journal of Social, Evolutionary, and Cultural Psychology*, 3(2), 81–92.
- Doyle, J. F., & Pazhoohi, F. (2012). Natural and augmented breasts: Is what is not natural most attractive?. *Human Ethology Bulletin*, 27(4), 4–14.
- Fink, B., Hugill, N., & Lange, B. P. (2012). Women's body movements are a potential cue to ovulation. *Personality and Individual Differences*, 53(6), 759–763.
- Fink, B., Weege, B., Neave, N., Pham, M. N., & Shackelford, T. K. (2015). Integrating body movement into attractiveness research. *Frontiers in Psychology*, 6.
- Flanagan-Cato, L. M. (2011). Sex differences in the neural circuit that mediates female sexual receptivity. *Frontiers in Neuroendocrinology*, 32(2), 124–136.
- Garza, R., Heredia, R. R., & Cieslicka, A. B. (2016). Male and female perception of physical attractiveness: an eye movement study. *Evolutionary Psychology*, 14(1), 1474704916631614.
- Goy, R. W., & Phoenix, C. H. (1963). Hypothalamic regulation of female behavior: establishment of behavioral oestrus in spayed guinea-pigs following hypothalamic lesions. *Journal of Reproduction and Fertility*, 5(1), 23-NP.
- Grammer, K. (1990). Strangers meet: laughter and nonverbal signs of interest in opposite-sex encounters. *Journal of Nonverbal Behavior*, 14(4), 209–236.
- Guéguen, N. (2012). Gait and menstrual cycle: ovulating women use sexier gaits and walk slowly ahead of men. *Gait & Posture*, 35(4), 621–624.
- Guéguen, N. (2015). High heels increase women's attractiveness. *Archives of Sexual Behavior*, 44(8), 2227–2235.

- Haselton, M. G., & Gildersleeve, K. (2011). Can men detect ovulation? *Current Directions in Psychological Science*, 20(2), 87–92.
- Henley, C. L., Nunez, A. A., & Clemens, L. G. (2011). Hormones of choice: the neuroendocrinology of partner preference in animals. *Frontiers in Neuroendocrinology*, 32(2), 146–154.
- Kendrick, A. M., Rand, M. S., & Crews, D. (1995). Electrolytic lesions to the ventromedial hypothalamus abolish receptivity in female whip-tail lizards, *Cnemidophorus uniparens*. *Brain Research*, 680(12), 226–228.
- Leedy, M. G., & Hart, B. L. (1985). Female and male sexual responses in female cats with ventromedial hypothalamic lesions. *Behavioral Neuroscience*, 99(5), 936–941.
- Lewis, D. M., Russell, E. M., Al-Shawaf, L., & Buss, D. M. (2015). Lumbar curvature: a previously undiscovered standard of attractiveness. *Evolution and Human Behavior*, 36(5), 345–350.
- Malsbury, C. W., Kow, L.-M., & Pfaff, D. W. (1977). Effects of medial hypothalamic lesions on the lordosis response and other behaviors in female golden hamsters. *Physiology and Behavior*, 19(2), 223–237.
- Marlowe, F. (1998). The nubility hypothesis. *Human Nature*, 9(3), 263–271.
- McCarty, K., Darwin, H., Cornelissen, P. L., Saxton, T. K., Tovée, M. J., Caplan, N., & Neave, N. (2017). Optimal asymmetry and other motion parameters that characterise high-quality female dance. *Scientific Reports*, 7, 42435. <https://doi.org/10.1038/srep42435>.
- Miller, G., Tybur, J. M., & Jordan, B. D. (2007). Ovulatory cycle effects on tip earnings by lap dancers: economic evidence for human estrus? *Evolution and Human Behavior*, 28(6), 375–381.
- Moore, M. (1985). Nonverbal courtship patterns in women: context and consequences. *Ethology and Sociobiology*, 6, 237–247.
- Moore, M., & Butler, D. (1989). Predictive aspects of nonverbal courtship behavior in women. *Semiotica*, 3, 205–215.
- Pazhoohi, F., Macedo, A. F., Doyle, J. F., Arantes, J. (2017). Waist to hip ratio as supernormal stimuli: effect of contrapposto pose and viewing angle.
- Prokop, P., Onyishi, I. E., Okafor, C. O. & Pham, M. N. (2017). Preliminary evidence for existence of oral sex in a rural igbo community in Southeast Nigeria. *Human Ethology Bulletin*, 32(3), 129–140.
- Robarts, D. W., & Baum, M. J. (2007). Ventromedial hypothalamic nucleus lesions disrupt olfactory mate recognition and receptivity in female ferrets. *Hormones and Behavior*, 51(1), 104–113.
- Röder, S., Carbon, C. C., Shackelford, T. K., Pisanski, K., Weege, B., & Fink, B. (2016). Men's visual attention to and perceptions of women's dance movements. *Personality and Individual Differences*, 101, 1–3.
- Silva, J., Macedo, A. F., Albuquerque, P. B., & Arantes, J. (2016). Always on my mind? Recognition of attractive faces may not depend on attention. *Frontiers in Psychology*, 7, 53.
- Smeets, J. B., & Hooge, I. T. (2003). Nature of variability in saccades. *Journal of Neurophysiology*, 90(1), 12–20.
- Wenzlaff, F., Briken, P., & Dekker, A. (2016). Video-based eye tracking in sex research: a systematic literature review. *The Journal of Sex Research*, 53(8), 1008–1019.