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Original Article

High heels as supernormal stimuli: How wearing high heels affects judgements of female attractiveness

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ABSTRACT

There is a strong contemporary association between high heels and female sexuality. We investigated the hypothesis that one motivation for women wearing high heels is that it artificially increases the femininity of gait. We isolated the effects of heels on gait using point-light methodology. Females were recorded walking in flat shoes and high heels. Participants viewed point-light videos of the women wearing the two types of shoe. Participants judged the females in the heels condition as significantly more attractive (with a large effect size) than the females in the flat shoe condition. Biomechanical analyses revealed that wearing high heels led to increased femininity of gait including reduced stride length and increased rotation and tilt of the hips. We conclude that high heels exaggerate sex specific aspects of female gait and women walking in high heels could be regarded as a supernormal stimulus.

1. Introduction

From a historical perspective there have been a variety of influences on the height of shoes. For example, in the medieval period platform shoes served to raise the wearer out of muck on the street (Severn, 1964) and were worn by both men and women. However, in contemporary Western culture wearing high heels is associated exclusively with females. Furthermore, there is a popular association between high heels and women as erotic objects. Dietz and Evans (1982) in an analysis of the cover photographs of pornographic magazines noted that over 50% involved women wearing high heels. We investigated the hypothesis that the association between high heels and female sexuality is partly a function of the effect of high heels on how women walk; high heels may have the effect of exaggerating the sex-specific aspects of female gait.

Wearing high heels can cause chronic damage and increase the likelihood of accidental trauma (Saltzman, 1998). Despite the damaging physical effects of wearing high heels, an evolutionary explanation has been suggested (Smith, 1999; Smith & Helms, 1999) to explain why women wear high heels. Secondary sexual characteristics are thought to be important for attractiveness in both sexes. Therefore if wearing high heels emphasises some sex specific aspects of the female form they may make women more attractive, and one motivation (which may be conscious or unconscious) for wearing heels is that it is part of mate selection. In addition to any effects on gait, Smith and Helms (1999) suggest that wearing heels could make women more attractive by enhancing the contours of the leg and ankle, decreasing the perceived size of the foot, accentuating the bosom and the buttocks, adding height which would increase confidence and therefore attractiveness. However, there is little systematic empirical evidence to support such claims. Furthermore, we do not suggest that sexual attraction is necessarily the only motivation for wearing high heels. High heels have become a part of the uniform of female attire in a number of different contexts and as such are part of a much more complex set of display rules (Craik, 2009).

It is well established that there are characteristic differences in the way males and females walk and that such differences are perceivable from movement cues alone (Kozlowski & Cutting, 1977). In order to isolate movement cues from other cues to sex, researchers have employed point-light display methodology. Point-light displays represent the body as a series of markers placed on key landmarks on the body; the perceiver is presented with a pattern of dots on a screen. It has been found that perceivers are remarkably good at making sense of the patterns of movement of these dots and are able to distinguish between male and female gait (Mather & Murdoch, 1994), identify friends (Cutting & Kozlowski, 1977) and even recognise emotional expressions (Clarke, Bradshaw, Field, Hampson, & Rose, 2005). An increasing number of point-light studies have also examined the relationship between movement and attractiveness within the context of an evolutionary approach (Fink, Seydel, Manning, & Kappeler, 2007).

Using point-light methodology, people can identify the sex of walkers quite accurately (71% for views other than side-on [Pollick,

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Kay, Heim, & Stringer, 2005]). Specifically, male gait involves greater velocity, longer stride length and slower cadence (Murray, Kory, & Sepic, 1970). There are also differences in lateral sway. Men have more translation of the head and greater upper body lateral sway (Mather & Murdoch, 1994), whereas women have increased translation in the hips (Murray et al., 1970). Kerrigan, Todd, and Croce, (1988) in a study focused specifically on the biomechanics of gait, found that the most characteristic difference between males and female gait was greater hip flexion and less knee extension before contact in females.

In the current study in order to establish whether or not walking in high heels does enhance the femininity, attractiveness and youthfulness of gait, we compared judgements of females walking in flat shoes with the same women walking in high heels. We predicted than women wearing high heels would be rated as more attractive, feminine and younger. In a second judgement study participants were asked to categorise the same point-light walkers as male or female even though they were in fact all female. We predicted that more females wearing flat shoes would be incorrectly categorised as male than females wearing high heels. To ensure that perceivers focus exclusively on movement we employed a point-light methodology. One previous study (Walter, Brownlow, Ervin, & Williamson, 1998) examined the effects of wearing high heels on judgements of female gait using point light methodology. They found that women in high heels were judged to walk more rigidly and less sexily. The second result was particularly surprising, however, the point light methodology used was primitive and the biomechanical effects were based entirely on subjective judgements. The recording equipment we used allowed precise objective biomechanical measurement of female gait. Therefore, in addition to comparing the judgements of gait in high heels and flat shoes, we also compared biomechanical differences in gait and examined the relationship between the judgements and biomechanics. We also examined the extent to which one relatively stable individual difference (Body Mass Index [BMI]) would affect judgements of gait.

2. Method

2.1. Collection of stimuli

An opportunity sample of twelve women (age M = 21.58; SD = 3.39; BMI M = 23.52, SD = 3.99) were paid to act as the walkers in the study. All possessed high heeled shoes (M [pairs] = 10.58, SD = 8.82) and wore them at least once a week. Biomechanical gait testing consisted of participants walking on a treadmill (1% gradient, Jones & Doust, 1996) at 4 $km \cdot h^{-1}$ for a total of four minutes in two conditions (in a random order); flat shoes and high-heeled shoes (height = 6 cm). All walkers were provided with identical styles of high heeled (heel height 6 cm, flat sole) and flat shoes of different sizes. Kinematic data on complete gait cycles (right heel strike to right heel strike) were collected via an 8-camera optoelectronic motion analysis system (200 Hz, Qualysis, Sweden) during the last two minutes of walking in each condition. Retroreflective markers (7 mm) were placed on participants (lateral border of heel, lateral malleolus of the ankle, lateral epicondyle of the knee, greater trochanter, anterior superior iliac spine, ACROMION process, on both sides of the body) using hypoallergenic tape to obtain three-dimensional data. Selection of marker positions was based on a previous paper on the clinical effects of wearing high heels (Opila-Correia, 1990).

All kinematic data were filtered using a fourth-order zero-lag low-pass digital filter with cut-off frequencies between 6 Hz and 10 Hz; frequencies were chosen by visual inspection of the frequency spectrum for each variable (Winter, 2009). Temporal and angle data were obtained by averaging data from five consecutive gait cycles at the end of the two minute data collection period, this ensured participants were familiarised with the shoes. Means and standard deviations will be presented; intrasubject and intersubject variabilities were determined by calculating the coefficients of variance (CV%).

Judgement Study One.

2.2. Method

2.2.1. Participants

Fifteen females (M [age] = 24.13; SD = 8.30) and fifteen males (M [age] = 28.60; SD = 7.97) participated in the judgement study. There were no specific inclusion or exclusion criteria.

2.2.2. Design

Participants viewed point-light displays of walkers in a $2 \times 2 \times 12$ mixed factorial design. The independent groups factor was sex (of judge), the repeated measures factors were shoe type (heels vs. flat shoes) and walker (twelve walkers). The order of presentation of the stimuli was counterbalanced. The dependent variables measured were the perceived femininity, attractiveness and age of the walkers.

2.2.3. Procedure

Thirty second video clips of the point-light displays of the walkers in high heels and flat shoes were presented on a standard computer monitor. The participants viewed the walkers as if they were walking towards them (see Fig. 1 for an example screen capture). The participants made judgements about the femininity and attractiveness of the displays on five point Likert scales (the walk is very feminine, 1 strongly disagree to 5 strongly agree), they were given no further information about the displays. Participants were also asked to place the walk in one of five age categories (16–18, 19–29, 30–39, 40–49, 50+). The participant recorded their judgements after the presentation of each individual walk.

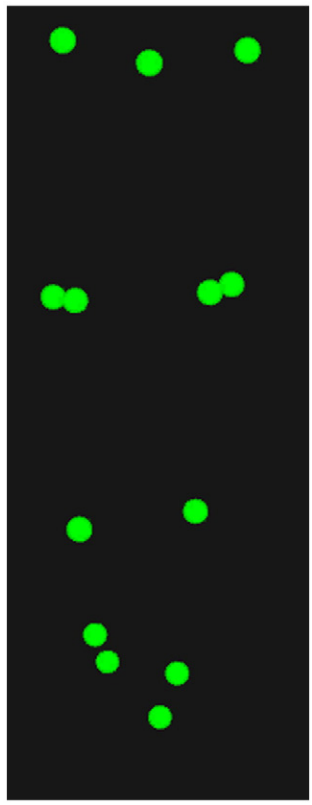

Fig. 1. Example screen capture of one of the walkers (flat shoe condition).

3. Results

3.1. Judgement data

Participants made judgements of the femininity, attractiveness and age of the walkers. However the correlations between the results of the three judgements were all large (range of correlations .79 to .92), positive and statistically significant, therefore we decided to combine the scores to produce a single composite score (the link between age, femininity and female attractiveness is well established [Buss, 1989; Perret et al., 1998]). We named this composite score the attractiveness index (shortened to attractiveness for the remainder of the paper). The higher the score on the attractiveness index the more attractive, feminine and youthful were the judgements.

A 2×2×12 mixed factorial ANOVA (female vs, male judges; heels vs. flats; 12 walkers) was conducted on the attractiveness scores. Degrees of freedom were adjusted using the Greenhouse–Geisser adjustment where violations of sphericity were observed.

A large and statistically significant main effect of shoe type was observed where wearing high heels led to higher attractiveness ratings ($M = 3.23$, $SD = .78$) than wearing flat shoes ($M = 2.88$, $SD = .77$), $F(1,28) = 158.02$, $p < 001$, $\eta_p^2 = .85$. There was also a moderate and statistically significant main effect of walker, $F(11,308) = 12.07$, $p < .001$, $\eta_p^2 = .30$. There was a significant but modest interaction between shoe and walker, $F(7.12, 190.19) = 3.06$, $p < .01$, $\eta_p^2 = .10$ (see Fig. 2). There were no other significant interactions.

As can be seen in Fig. 2, for all walkers the attractiveness score was higher in the heels condition than in the flat condition. Simple comparisons between heel and flat attractiveness ratings of each walker revealed that for ten of the twelve walkers (the exceptions were walkers one and two) the higher rating was statistically significant (all $p < .001$). We also observed a significant main effect of sex; female raters judged the walkers to be more attractive ($M = 3.23$, $SD = .52$) than males ($M = 2.89$; $SD = .59$), $F(1,28) = 7.87$, $p < .001$, $\eta_p^2 = .22$. However, it is important to note that there was no shoe type gender interaction showing that both males and females judged high heels to be more attractive than flat shoes. Furthermore, there were large and statistically significant correlations between the male and female judgements of the walkers in the heels condition, $r(12) = .63$, $p = .028$ and the walkers in the flat shoe condition, $r(12) = .76$, $p = .004$. To summarise the effect of sex of judge, both males and females rate females wearing heels as more attractive, but females are more positive in their judgements in both conditions than males; furthermore, there were high correlations between male and female attractiveness ratings of the walkers in both the flat and heels condition demonstrating that males and females agreed which were the attractive and unattractive walkers.

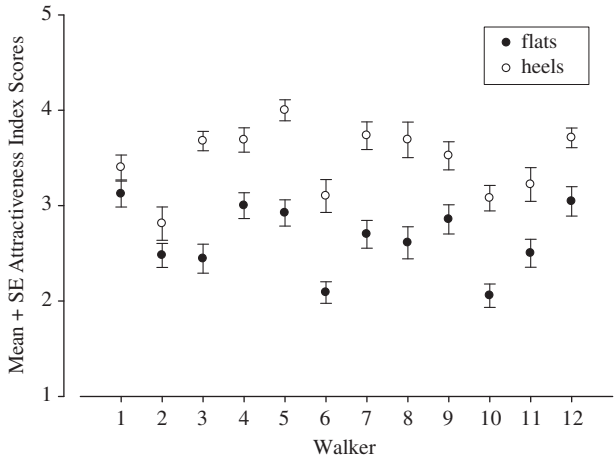

Fig. 2. Mean attractiveness index rating for each walker in heels and flat shoe conditions.

3.2. The relationship between perceived attractiveness and BMI

The mean attractiveness of rating of each of the 12 walkers was calculated for the high heels and flat shoes conditions separately. The attractiveness rating of each walker in each condition was then correlated with their BMI. There were strong, negative and significant correlations between BMI scores and mean attractiveness ratings of individual walkers in the flat shoe condition ($r = -.64$) and the heels condition ($r = -.66$). The higher the BMI the less attractive was the judgement of the walker in both the flat and heels condition.

Judgement Study Two.

4. Method

4.1. Participants

An opportunity sample of 120 participants (82 female; 38 male) was used in the study. There were no inclusion or exclusion criteria.

4.2. Design

Participants were randomly allocated to see one of 24 point-light displays of a female walking either in flat shoes or high heels. Five participants viewed each of the 24 displays, thus 60 participants (5 participants×12 examples) viewed a female walking in high heels and 60 participants viewed a female walking in flat shoes (to ensure representative sampling of the stimuli). Therefore each participant contributed one categorical judgement allowing the data to be analysed using chi square. It is also particularly strict test of the hypothesis as participants were using absolute rather than relative judgements.

4.3. Procedure

Participants were informed that they were going to view a point-light display of either a male or female walking and were asked to judge whether they had seen a male or a female even though in reality there were no male stimuli.

5. Results

The data from all walkers were collapsed into a single analysis. Participants classified more walkers as female than male in both the high heels and flat shoes condition. However, more females were incorrectly classified as males in the flat shoes condition (inaccuracy rate 28%) than in the heels condition (17%), χ^2 (1, $N = 120$) = 7.06, $p = .008$. Cramer's $V = .24$.[1]

5.1. Biomechanics results

Temporal and angle data for flat and high-heeled gait can be seen in Table 1. Results are for the right side of the participants only. Maximum hip flexion at heel strike was also the maximum hip flexion seen during the stance phase of gait; therefore only data for hip flexion at heel strike are presented. Knee flexion and extension angles were calculated relative to the static knee angle. In high-heeled gait, participants walked with a significantly higher cadence and shorter stride length compared with walking in flat shoes (110.2 vs. 106.4 steps/min and 1.20 vs. 1.24 m). At heel strike hip flexion was greater

[1] After completing the study, we asked participants if they could make any additional comments about the walkers they had seen and three participants suggested that they had seen someone wearing high heels.

Table 1
Differences in gait pattern between high heels and flat shoes.

	Flat shoes M	(SD)	High heels M	(SD)	Difference	t	df	Significance Level	Cohen's *d*
Stride duration (s)	1.13	0.05	1.09	0.05	0.04	1.69	11	0.12	0.80
Cadence (steps/min)	106.4	5.41	110.22	5.38	−3.82	4.23	11	0.001[a]	−0.71
Stride length (m)	1.24	0.05	1.2	0.06	0.04	4.39	11	0.001[a]	0.73
Knee flexion/extension									
Heel strike (°)	−0.39	*5.11*	−2.98	*6.31*	2.59	1.62	*8*[a]	0.143	0.45
Stance max flexion (°)	10.03	*5.82*	15.96	*5.00*	−5.93	4.44	*8*[a]	0.002[a]	−1.10
Toe-off (°)	−4.56	*3.86*	−2.74	*5.43*	−1.82	0.89	*8*[a]	0.401	−0.39
Swing max flexion (°)	62.25	*3.50*	51.48	*4.44*	10.77	8.46	*8*[a]	<0.001[a]	2.71
Hip flexion/extension									
Heel strike (°)	23.75	*3.80*	29.43	*3.12*	−5.68	2.75	*11*	0.019[a]	−1.64
Toe-off (°)	−9.40	*2.12*	−9.34	*3.76*	−0.06	0.07	*11*	0.945	−0.02
Swing max flexion (°)	29.39	*3.23*	25.87	*3.92*	3.52	0.04	*11*	0.971	0.98
Pelvic rotation (°)	3.06	*1.00*	4.16	*1.07*	−1.1	3.28	*11*	0.007[a]	−1.06
Lateral pelvic tilt (°)	12.34	*2.70*	14.57	*2.69*	−2.23	4.90	*11*	<0.001[a]	−0.83
Shoulder rotation	4.42	*2.49*	4.38	*1.93*	0.04	.47	11	0.638	0.02

[a] Two walkers omitted due to recording error.

(29.43° vs. 23.75°), during the stance phase knee flexion was greater (15.96° vs. 10.03°) and during the swing phase knee flexion was less (51.48° vs. 62.25°), when wearing high heels compared to flats. Significantly more pelvic rotation and tilt were also found during high-heeled gait compared to flat-shoed gait (4.16° vs. 3.06° and 14.57° vs. 12.34°).

Variations within-participants over the five gait cycles were low and ranged between 1.44 CV% and 1.46 CV% for the stride data, between 0.67 CV% and 1.15 CV% for the knee angle data and between 2.19 CV% and 2.96 CV% for the hip angle data. Between-participants variance ranged between 4.03 CV% and 5.09 CV% for the stride data, between 2.5 CV% and 4.41 CV% for the knee angle data and between 12.05 CV% and 13.3 CV% for the hip angle data. Variance between-subjects of the mean pelvic rotation ranged between 22.6 CV% and 32.5 CV%, between 18.4 CV% and 21.9 CV% for lateral pelvic tilt and between 44.07 CV% and 56.4 CV% for shoulder rotation. The increased variability in kinematics at the pelvis and shoulders was expected due to the larger ranges of motions at these joints (Rau, Disselhorst-Klug & Schmidt, 2000). When walking in high-heels women take smaller and more frequent steps, they bend their knees and hips less, and more rotation and tilt occur at the hip.

5.2. The relationship between judgements of attractiveness and biomechanical measures

The mean attractiveness score for individual walkers in both the flat shoes and heels conditions was correlated with the biomechanical measures in each condition (see Table 2). There were only two significant results and no consistent picture of the relationship between the biomechanical measures and the judgement data emerged.

6. Discussion

Participants rated the point-light displays of the walkers in high heels as significantly more attractive than the same walkers in flat shoes (with a large effect size). Females wearing flat shoes were also more likely to be incorrectly identified as males. There were also significant effects of wearing high heels on the pattern of gait, most with large effect sizes. Relative to the flat heels condition the females in the high heeled shoe condition walked in a fashion more characteristic of female gait; the walkers in high heels took smaller more frequent steps, had less knee bend but had greater hip rotation and tilt. Walkers with lower BMI scores were judged to be more attractive. However, there was no consistent pattern to the correlations between attractiveness ratings of individual walkers and their biometric measures. It is also worth noting that our results suggest that high heels are an important part of the contemporary female wardrobe as the minimum number of high heeled shoes owned was four and the maximum 25.

The results of the rating study shows that the female walk is perceived as much more attractive when wearing high heels than not. Therefore we suggest that one, conscious or unconscious, motivation for women to wear high heels is to increase their attractiveness. Women are also more likely to be correctly identified as female when walking in high heels. Furthermore, the effect seems highly consistent for each individual walker (i.e. all walkers were judged to be more attractive in the heels condition). The biomechanical results are also consistent with the hypothesis that wearing high heels makes women look more attractive by making them more feminine as the effect of heels was to exaggerate some sex specific elements of female gait including: greater transverse plane hip rotation (pelvic rotation); increased vertical motion at the hip in the coronal plane (lateral pelvic tilt); shorter strides and higher cadence (Murray et al., 1970; Troje, 2002; Cho, Park, & Kwon, 2004; Pollick et al., 2005).

We observed a modest effect of sex on the judgements of attractiveness with females rating the stimuli as more attractive than the males. However, there was no sex condition interaction and no sex walker interaction, indicating that both males and females judged the walkers to be more attractive when wearing high heels and that there was no difference between male and female judges in the rank order of the attractiveness of the walkers. In a large meta analysis of attractiveness studies Langlois et al., (2000) reported a striking lack of sex differences in judgements of attractiveness. However, the

Table 2
Correlations between the mean rating of attractiveness and biomechanical measures.

Biomechanical measure	Mean rating femininity in high heels	Mean rating femininity in flat shoes
Stride duration (s)	−.03	.69*
Cadence (steps/min)	.04	.13
Stride length (m)	−.11	−.13
Knee flexion/extension		
Heel strike (°)	.25	.44
Stance max flexion (°)	.62*	.52
Toe-off (°)	.15	..39
Swing max flexion (°)	.05	.07
Hip flexion/extension		
Heel strike (°)	.29	.11
Toe-off (°)	−.04	−.01
Swing max flexion (°)	.35	.15
Pelvic rotation (°)	.22	−.23
Lateral pelvic tilt (°)	−.17	.27
Shoulder rotation	−.03	..28

* Sig .05 level.

studies reviewed focus on the rank order of attractiveness of different stimuli rather than absolute differences in judgements of attractiveness. Therefore our findings are consistent with the conclusions of Langlois et al. However, the result that females are in general more generous in their judgements is worthy of further investigation.

It was perhaps surprising that there was no consistent pattern of correlations between the biomechanical measures and the judgements of attractiveness of the individual walkers. We would have predicted positive correlations between biomechanical indicators of the femininity of the walkers and judgements of attractiveness i.e. walks that would be judged to be most attractive would be the most feminine biomechanically. We can only speculate that such within group differences may be quite subtle in comparison to the large effects we observed in the between group comparisons of shoe conditions.

From a historical perspective one way to interpret the wearing of high heels is that they may act in a similar way to a super releaser. In ethological studies of non human animal behaviour one method to establish what aspect of a stimulus is eliciting a particular behaviour is to systematically exaggerate the various features of a stimulus. For example, oystercatchers prefer large artificial eggs that they cannot even sit on, to their own normal size eggs (Tinbergen, 1951). The phenomenon has been observed in a diverse range of animals including insects (Magnus, 1958), fish (Rowland, 1989), birds and mammals (Bielert & Anderson, 1985). However, there is some ambiguity in the use of the term. From a historical perspective the term super releaser has been used to describe an artificially created stimulus. However, it has been used more recently to describe naturally occurring morphological features that are at the end of a normal distribution. Bielert and Anderson (1985) found that female Baboons with exaggerated perineal swellings (in layman's terms a larger than normal swelling of the bottom associated with the sexually receptive period of their oestrous cycle) aroused greater sexual interest in males as indexed by masturbatory seminal emissions. However, we use the term in its historical sense of an artificially created stimulus. Our results indicate that both males and females judge women walking in high heels as more attractive. We suggest that high heels may exaggerate the sex specific aspects of the female walk which could cause sexual arousal in males and make women aware of potential competitors for mates. The normal stimulus of a woman walking is exaggerated by the wearing of high heels producing a supernormal stimulus. We do not, however, propose that these responses are instinctual as Lorenz and Tinbgergen did when describing super releasers. Perhaps an alternative metaphor is that of the extended phenotype (Dawkins, 1982), which is the effect of any gene outside the body in which it resides. Other fashions can be explained in this context; for example, the female corset has been seen as a method of emphasising the difference between the width of the waist and the width of the hips (Etcoff, 1999), and makeup can change the perception of facial symmetry, skin texture and colour, and featural contrast (Etcoff, Stock, Haley, Vickery, & House, 2011). There are also other examples of cultural artefacts, such as the teddy bear, being subject to artificial selection to produce supernormal stimuli (Morris, Reddy, & Bunting, 1995). The difference between the teddy bear and high heels is that the teddy bear is selected directly whereas high heels are selected via the effect of heels on female gait.

There have been numerous fashions that have not been congruent with an evolutionary model. For example, female shoulder pads in the 1980s emphasised a particularly male aspect of the body. Flapper dresses in the 1920s did little to emphasise the female figure. However, we suggest that there may also be some artificial selection of fashion. Fashions by their very nature are ephemeral, but fashions that endure (such as high heels for females) may emphasise sex specific aspects of the body. Other fashions such as shoulder pads may occur from time to time but may reoccur infrequently over time as they are poorly matched with our biology.

We cannot preclude the explanation that it is not the wearing of high heels per se that affects the way women walk, but they walk differently simply because of the way they think about high heels, however, this then begs the question of why the association between high heels and female sexuality had been established in the first place. We suggest the parsimonious explanation is that the effects of high heels on gait are biomechanical in the first instance.

We have suggested that evolution may partly explain the continuing popularity of high heels as an article of the female wardrobe. However, high heels could simply be an indicator of social status as they are often more expensive than other types of shoe (Smith, 1999). However, high heels are also imbued with a cultural significance. Wearing heels or corsets (or other fashions that can actually be painful to wear) can be seen as comparable to more permanent body modifications such as tattoos, piercings, scarification or implants. Anthropologists have argued that such modifications can have a variety of functions including group identifiers, social control or rite of passage (Rush, 2005). For example, many girls are not allowed to wear high heels by their parents until they have gone through puberty as high heels are regarded as part of the adult world (Morton, 2005). It is also a possibility that high heels are an indicator of status as they are more expensive than many other types of shoe and women wear high heels to indicate status (Smith, 1999). It is beyond the scope of this paper to investigate the relative importance of the various motivations for wearing high heels but it is almost certainly the case that the effect of heels on female gait is only one of many motivations for wearing heels.

In summary we suggest that a woman walking in high heels is a supernormal stimulus and the results of the studies reported here form part of a growing body of evidence that emphasises the complex relationship between evolution and culture.

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