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THE RELATIONSHIP BETWEEN ATTRACTIVENESS AND FEMININITY IN FEMALE GAIT

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ABSTRACT

The evaluation of physical attractiveness has been reported to be related to the psychological process for detecting associated physiological health and fertility features. The femininity of the female gait is also associated with its attractiveness. However, it is unclear whether femininity is always attractive in female gait and what physical characteristics are perceived as being attractive and/or feminine. In this study, we aimed to understand the root of the attractiveness of human movement by examining the relationship between perceived attractiveness and femininity in female gait. First, we created 30 s gait animations by using 3D motion capture data of 10 female nonmodels and seven female runway models, where they walked either barefoot or in high heels. Then, 60 observers evaluated the attractiveness and femininity of each animation. We compared the scores of attractiveness (A-scores) and femininity (F-scores) of the models and nonmodels, and we examined the factors related to the evaluation (A-scores and F-scores), namely, the walkers' height, weight, BMI, and the characteristics of movements. Consequently, both the A-score and the F-score were high for the models' gait in high heels. Conversely, in the other conditions, there were two types of attractiveness–femininity relationships—a linear relationship (high A-score and F-score, or low A-score and F-score) and an unequal relationship (high F-score but low A-score). Most physical and motion factors correlated with both the A-score and the F-score; however, BMI, flexibility at the thoracolumbar joint, stride time CV, and toe-off angle were related to either the A-score or the F-score.

Keywords: *locomotion, attractiveness, femininity, high-heel walking*

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1 INTRODUCTION

Physical attractiveness is a key factor in our social communication. The perception of beauty in human beings is associated with the detection of specific physiological health-related (Symons, 1995; Thornhill & Gangestad, 1999; Gangestad & Scheyd, 2005; Singh & Singh, 2011; Sugiyama, 2015) and sociocultural (Berscheid & Walster, 1974; Langlois et al, 1987) features. Mate attractiveness in nonhuman species is also known to be related to survival and reproduction (Norris, 1993; Petrie, 1994; Birkhead & Fletcher, 1995; Weiss, Kennedy, Safran, McGraw, 2011). A female lumbar curvature similar to that observed during pregnancy (approximately 45.5°) has been reported to be the most attractive to men (Lewis, Russell, Al-Shawaf, & Buss, 2015; Lewis et al, 2017), which supports the idea that female attractiveness is ultimately related to fertility. From these previous studies, it is believed that the observer's evaluation of the attractiveness of human movement is also related to the observed actor's health-related or sex-specific physical/motion characteristics.

Walking is a basic human movement, and gait kinematics is one of the cues for female attractiveness (Guéguen, 2015; Fink, Apalkova, Butovskaya, & Shackelford, 2021). Morris, White, Morrison, and Fisher (2013) reported that shortened stride length and greater hip rotation were key factors for the attractiveness of females walking in high heels. They suggested that the gait can be manipulated to alter female attractiveness by using female sex-specific or feminine body motion. However, femininity in motion is believed to embody multiple factors—motion factors such as pelvic obliquity, arm swing, and torso rotation (Bruening, Frimenko, Goodyear, Bowden, & Fullenkamp, 2015) and sex-specific physical factors such as the shape of the bosom and buttocks, height, and weight. Considering that tall fashion models are attractive targets in the media, femininity and attractiveness in motion are not always thought to be the same. By clarifying the relationship between gait attractiveness and femininity, it is possible to further deepen our understanding of psychological processes in human perception of attractiveness.

Additional contributors to gait attractiveness may include the features of runway walking, which can be believed to embody an aesthetically optimal gait, and include waist rotation, leaning backward, the alignment of the upper torso, and the reduction of the arm swing (Or, 2012). Even in nonmodels, a gait like that of a fashion model may be the standard of attractiveness. However, unlike the nonmodel gait, the model's gait has the purpose of making clothes look attractive rather than the walker herself, so the standard for evaluating attractiveness may differ between the model and nonmodel gait. By examining the observer's recognition of the attractiveness and femininity of the model's gait, it becomes possible to understand the influence of the walker's aesthetic intention on gait kinematics.

In this study, we aimed to investigate the physical and motion factors that are the standard for the observer's evaluation of the attractiveness and/or femininity of female gaits (including models) and to explore the relationship between gait attractiveness and femininity. Height, weight, and BMI were candidates for inclusion as salient physical factors. Additionally, because lumbar curvature and whole-body silhouettes are believed to be linked to gait attractiveness and/or femininity, we calculated the flexibility of the upper body, the forward–backward silhouette of the limbs, and gait parameters related to aging, disability, and health condition as candidates for inclusion as motion factors. The results of this study will contribute to the artificial generation of feminine or attractive gait in the future.

2 METHODS

All procedures involved in this study were conducted according to the Declaration of Helsinki and were approved by the Ethics Committee of Nagoya University. The individuals participating in this study provided written informed consent to participate in this study and for us to publish these case details. Informed consent continued throughout the study via a dialog between the researcher and participants.

2.1 Experiment for creating gait animation

We recruited seven professional runway models (age, 42.4 ± 7.0 years; height, 170.6 ± 3.7 cm; and weight, 55.6 ± 3.4 kg) and 10 nonmodels (age, 34.0 ± 7.2 years; height, 162.0 ± 5.4 cm; and weight, 54.7 ± 7.7 kg). They walked on a treadmill in high heels or barefoot (two trials for each footwear condition) at a speed of 1.0 m/s. We used a three-dimensional (3D) optical motion capture system (OptiTrack V100—R2; NaturalPoint, Corvallis, OR) with a sampling frequency of 100 Hz to obtain the position of the following feature points during gait: the top of the head, the ears, the acromions, the elbows (calculated as the middle point between the humerus-medial epicondyle and the humerus-lateral epicondyle), the wrists, the upper margin of the sternum, the sternum-xiphoid process, the lowest edge of the ribs, the c7 vertebra, the t8 vertebra, the t12 vertebra, the anterior superior iliac spine, the posterior superior iliac spine, the greater trochanter, the lateral and medial knee joint space, the malleolus lateralis and medialis, the toe and calcaneus, and the bottom of the heel for the high-heel condition.

The time series data for the joint center coordinates were then passed through a fourth-order Butterworth low-pass filter with a cut-off frequency of 6 Hz, which was used to create a 30 s gait animation. During those 30 s, we rotated the viewpoint of the animation at a constant speed from the front right to the back left of the walker (Figure 1 illustrates the beginning and end of the animation). The number of animations was 68 (17 participants, two footwear conditions, and two trials for each). Additionally, we calculated the 3D joint angles for the ankle, knee, hip, lumbosacral joint, thoracolumbar joint, neck, shoulder, and elbow. These joint angle data were used to investigate the motion factors that affect the observer's judgment of attractiveness and femininity (see Section 2.3). All signal processing was conducted using Matlab R2021a.

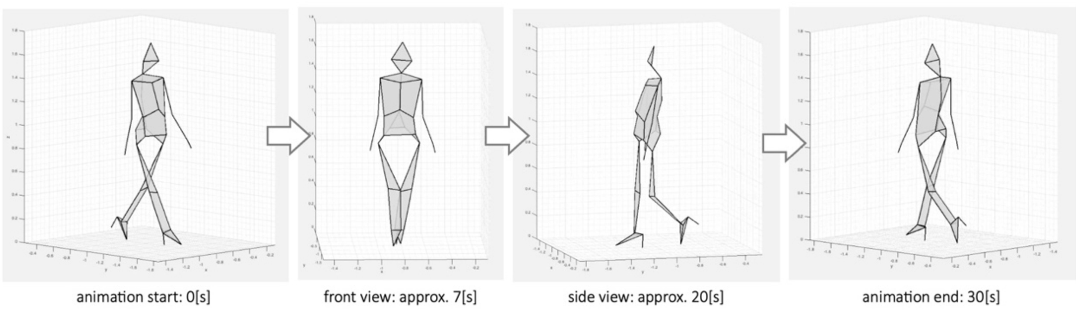


Figure 1. The flow of animation (in this sample, high-heel condition)

2.2 Experimental protocols and measurements

Thirty healthy women (age: 20–59 years) and 30 healthy men (age: 24–58 years) participated in the attractiveness/femininity evaluation experiment. Participants viewed the 30 s walking animations presented on a standard computer monitor (EIZO FlexScan EV2480). The order of presentation was randomized, and they were asked to keep their eyes on the animation while it was moving. Within 30 s after each animation stopped, participants judged the attractiveness and femininity on a 7-point Likert scale: 1 low to 7 high attractiveness/femininity. We gave no information about walkers (e.g.,., age, sex, and occupation) to the participants. Participants took a break after every 17 animation evaluations.

2.3 Data analysis

First, we qualitatively observed the relationship between the attractiveness score (A-score) and the femininity score (F-score) in model/nonmodel × barefoot/high-heel conditions. After that, to determine the factors that affect the A-score and the F-score, we investigated the relationship between each score and the walker's appearance factor (height, weight, and BMI) or motion factors. Motion factors were calculated as the flexibility of the upper body and limb silhouette. The flexibility of the upper body per unit time was calculated as follows:

$$F_i = \left|\theta_i - \bar{\theta}_i\right|$$

where *i* represents the lumbosacral and thoracolumbar joints and $\bar{\theta}_i$ is the mean joint angle. We calculated F_i for each 3D plane (the sagittal, frontal, and horizontal planes) separately. F_i of the null represents the complete immobility of the joint. We then calculated the mean value of each upper body joint's flexibility during the single stance phase (20%—40% and 70%—90% gait cycle) as the representative value for each joint's flexibility. We focused on flexibility during the single stance phase because, in our preliminary experiment, we had observed the greater flexibility of upper body joints during the single stance phase in models (who could be the embodiment of physical attractiveness) compared with nonmodels.

Additionally, we calculated the limb and head silhouette in a forward—backward direction as follows:

$$S_i = r_i \cdot \sin\theta_i$$

where θ_i represents the joint angle at the knee, shoulder, and neck in the sagittal plane. r_i is the segment length of the shank, upper arm, and head. S_i of positive and negative directions represents backward and forward deviation of the limb silhouette. The reason we focused on those three body parts (legs, upper arm, and head) is that push-off motion at the knee is related to the walker's youth and health (Hamrin et al., 1982; Nakamura et al., 1985; Bohannon, 1997), the head forward/backward silhouette is a cue to emotional expression/perception (Gross et al., 2011; Venture et al., 2014), and backward orientation of the upper arm during walking could have the effect of emphasizing the breasts, which are one of the biological characteristics of females. The mean value of S_{neck} and $S_{shoulder}$ during all gait cycles and the mean of S_{knee} during the push-off phase were calculated as the representative value of each animation. Additionally, we calculated the following general gait parameters—stride time CV (coefficient of variation of time required for one gait cycle), symmetry (ratio of left and right swing time), cadence (steps per minute), heel-contact angle, toe-off angle, and minimum toe clearance (minimum height at which the toes are off the floor during the swing phase).

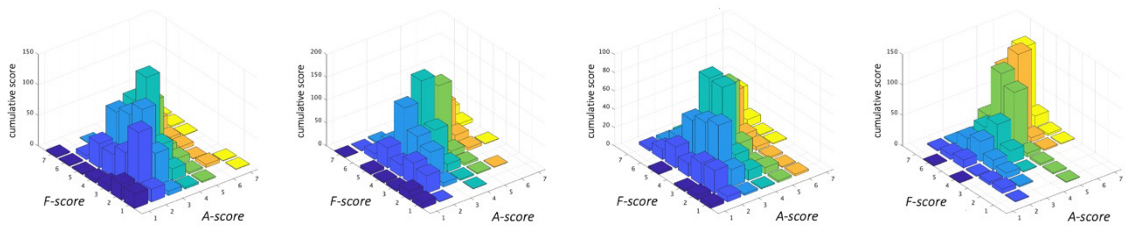
Finally, we investigated the physical and motion factors that affect the observer's attractiveness and/or femininity evaluation using Pearson's correlation coefficient test between A-/F-score and the abovementioned factors. We focused on differences in factors related to evaluation between A-score and F-score.

3 RESULTS

We first observed the relationship between A-score and F-score qualitatively for female gait in model/nonmodel × barefoot/high-heel conditions. Then, we investigated the physical and motion factors that affect the A-score and/or the F-score.

3.1 Are attractiveness and femininity the same in female gait?

To address the question of whether attractiveness and femininity in female gait always coincide, we investigated the relationship between the A-score and the F-score for each group and each footwear condition. Figure 2 illustrates the cumulative score from all the observers for (a) the nonmodels' barefoot gait (20 animations), (b) the nonmodels' gait in high heels (20 animations), (c) the models' barefoot gait (14 animations), and (d) the models' gait in high heels (14 animations). We obtained the following findings through qualitative analysis: 1) both the A-score and the F-score were high for the models' gait in high heels (Figure 2d), and 2) for the other conditions, there were two types of relationship—one is linear (high A-score and F-score, or low A-score and F-score) and the other is an unequal relationship (high F-score but low A-score). These results suggested that high attractiveness is associated with femininity, but low attractiveness is not associated with femininity, that is, femininity is a necessary but not sufficient condition for attractiveness in female gait.



(a) non-model/barefoot (b) non-model/high-heel (c) model/barefoot (d) model/high-heel

Figure 2. Attractiveness and femininity relationship in female gait

3.2 Physical and motion factors that affect the evaluation

Next, we investigated the physical and motion factors that are related to the A-score and/or the F-score. Correlation coefficients were calculated for each walker group (N, nonmodel; M, model) and the footwear condition (barefoot, high heels). Table 1 and Table 2 show the results of Pearson's correlation coefficient test between the physical/motion factors and the A-score or the F-score, respectively. Only items with statistically significant correlations are summarized in the table. The abbreviations of F_{thor_s}, F_{thor_f}, S_{head}, S_{arm}, and S_{shank} in the table represent flexibility at the thoracolumbar joint in the sagittal and frontal planes and the silhouette of the head, arm, and shank in the forward (negative value) and backward (positive value) directions, respectively. Additionally, ST CV and TO angle in the tables stand for stride time coefficient of variation and toe-off angle, respectively. Items with a statistically significant correlation ($r > 0.4$ and $P < 0.05$) are shown in bold. Additionally, factors that showed significant correlation both with the A-score and the F-score are shaded. The factors not listed in the tables, namely, the flexibility of the thoracolumbar joint in the frontal plane, flexibility of the neck in the horizontal plane, gait symmetry, cadence, heel-contact angle, and clearance, did not correlate with either the A-score or the F-score.

The A-score of nonmodels was negatively correlated with their weight (barefoot: $r = -0.519$, heel: $r = -0.484$). It was also correlated with flexibility at the thoracolumbar joint in the sagittal plane (F_{thor_s}) only under barefoot condition ($r = 0.519$). Additionally, the A-score of nonmodels was negatively correlated with the silhouette of the head (S_{head}) (barefoot: $r = -0.568$, heel: $r = -0.776$) and shank (S_{shank}) during the push-off phase (heel: $r = -0.671$) and was positively correlated with the silhouette of the arm (S_{arm}) (barefoot: $r = 0.691$, heel: $r = 0.522$). Among general gait parameters, only the stride time CV showed a negative correlation with the A-score of nonmodels when they wore high heels. For models, only flexibility at the thoracolumbar joint in the sagittal plane (F_{thor_s}) and silhouette of the arm (S_{arm}) showed a positive correlation with the A-score.

Table 1. Pearson's correlation between A-score and physical/motion factors

	N-bare		N-heel		M-bare		M-heel	
	r	P	r	P	r	P	r	P
Height	-0.381	0.0970	-0.409	0.0733	0.102	0.729	0.0196	0.947
Weight	**-0.519**	**0.0191**	**-0.484**	**0.0306**	-0.400	0.157	-0.300	0.298
BMI	-0.428	0.0600	-0.359	0.120	-0.487	0.0771	-0.326	0.255
F_{thor_s}	**0.519**	**0.0189**	-0.0173	0.942	**0.560**	**0.0374**	0.370	0.193
S_{head}	**-0.568**	**0.00903**	**-0.776**	**<0.001**	-0.368	0.196	-0.115	0.696
S_{arm}	**0.691**	**<0.001**	**0.522**	**0.0181**	**0.698**	**0.00551**	**0.798**	**<0.001**
S_{shank}	-0.137	0.565	**-0.671**	**0.00119**	-0.266	0.358	0.149	0.611
ST CV	-0.275	0.24151	**-0.448**	**0.0477**	-0.492	0.0739	-0.333	0.245
TO angle	0.0127	0.958	0.413	0.0707	0.377	0.184	0.281	0.331

Table 2 shows the correlation coefficients between the F-score and each factor. The F-score of nonmodels was negatively correlated with their height (barefoot: $r = -0.520$, heel: $r = -0.513$), weight (barefoot: $r = -0.656$, heel: $r = -0.609$), and BMI (barefoot: $r = -0.520$, heel: $r = -0.456$). Similar to the A-score, it was correlated with flexibility at the thoracolumbar joint in the sagittal plane only under the barefoot condition ($r = 0.465$). The F-score of nonmodels showed a strong negative correlation between the silhouette of the head (barefoot: $r = -0.720$, heel: $r = -0.714$) and the shank (heel: $r = -0.620$). It was also positively correlated with the silhouette of the arm (barefoot: r = 0.445, heel: r = 0.551). For models, their silhouette of the arm also positively correlated with the F-score (barefoot: r = 0.645, heel: r = 0.684). Additionally, the models' toe-off angle during the barefoot condition showed a strong positive correlation with the F-score.

Table 2. Pearson's correlation between the F-score and physical/motion factors

	N-bare		N-heel		M-bare		M-heel	
	r	P	r	P	r	P	r	P
Height	**-0.520**	**0.0188**	**-0.513**	**0.0208**	0.283	0.326	0.178	0.544
Weight	**-0.656**	**0.00169**	**-0.609**	**0.00436**	-0.128	0.663	-0.246	0.396
BMI	**-0.520**	**0.0188**	**-0.456**	**0.0434**	-0.348	0.222	-0.388	0.171
F_{thor_s}	**0.465**	**0.0387**	0.0855	0.720	0.528	0.0521	0.351	0.219
S_{head}	**-0.720**	**<0.001**	**-0.714**	**<0.001**	-0.449	0.108	-0.363	0.201
S_{arm}	**0.445**	**0.0493**	**0.551**	**0.0119**	**0.645**	**0.0127**	**0.684**	**0.00699**
S_{shank}	-0.364	0.114	**-0.620**	**0.00355**	-0.199	0.496	0.0198	0.946
ST CV	-0.307	0.187	-0.427	0.0605	-0.350	0.220	-0.442	0.114
TO angle	0.0640	0.789	0.276	0.239	**0.700**	**0.00529**	**0.527**	**0.0530**

In summary, the differences between the F-score and the A-score were found in the following factors: 1) height and BMI: short and low BMI nonmodels' gait was evaluated as feminine, but not attractive; 2) low stride time CV of nonmodels' gait was evaluated as attractive, but not feminine; and 3) models' gait with large toe-off angle during the barefoot condition was evaluated as feminine, but not attractive.

4 DISCUSSION

In this study, we addressed the question of whether femininity and attractiveness are equivalent in female gait. We obtained attractiveness and femininity evaluation scores for 3D animations of walking barefoot and in high heels from 60 participants who included fashion models and nonmodels. There were no gender or age differences between the observers for attractiveness and femininity ratings. In addition to a matched relationship between attractiveness and femininity, we observed gait with high femininity and low attractiveness in both the nonmodel gait and the model barefoot gait. A link between female attractiveness and femininity had been reported (Buss, 1989; Perre et al, 1998); however, in this study, it was suggested that feminine gaits are not always attractive. Stride length and hip rotation and tilt have been demonstrated to be related to gait femininity and, hence, to female gait attractiveness (Morris et al, 2013). In this study, we examined the physical and motion factors that affect each of the A- and F-scores.

We calculated the Pearson's correlation between the A- and F-scores and physical and motion factors—height, weight, and BMI were candidates for physical factors, and flexibility of the upper body in the sagittal and frontal planes, forward—backward silhouette of the limb, and gait parameters related to aging and disability (stride time CV, symmetry, cadence, heel-contact angle, toe-off angle, and minimum toe clearance) were candidates for motion factors. As a limitation of this study, we do not understand the causal relationship between variables because we focused on correlations. Among the nonmodels, the walkers who were lighter, leaned their head forward, and pulled their upper arm backward were evaluated as more attractive in both the barefoot and high-heel conditions (Table 1). Additionally, barefoot gait with high flexibility at the thoracolumbar joint in the sagittal plane and high-heel gait with knee extension during the push-off phase were evaluated as attractive for nonmodels (Table 1). These results were also the same for the evaluation of femininity (Table 2). Because a backward swing of the upper arm could have the effect of emphasizing the breasts, and because the flexibility at the thoracolumbar joint could construct a lumbar curvature that mediates fertility information (Lewis et al, 2017), such sexuality information may induce a perception of charm and femininity. Additionally, the association between health and knee extension has been observed in studies of patients with spastic hemiparesis, whose walking capacity is related to the muscle strength of knee extension (Hamrin et al, 1982; Nakamura, Hosokawa, & Tsuji, 1985), and in studies of aging itself that demonstrate a correlation between knee extension and age-related declines in maximum gait speed (Bohannon, 1997). From these results in this study, it is considered that the criteria for the perception of gait attractiveness and femininity are mostly common in that they are manifestations of walkers' health and reproductive function, which is consistent with previous studies (Symons, 1995; Thornhill & Gangestad, 1999; Gangestad & Scheyd, 2005; Singh & Singh, 2011; Sugiyama, 2015).

In comparison, a difference between the evaluation criteria of femininity and attractiveness was found in nonmodels' height and BMI—shorter height and smaller BMI are evaluated as feminine but not as attractive. This result suggests that the short and thin body shape may be evaluated as feminine in comparison with males, but it may not be evaluated as attractive because the low BMI is inconsistent with the health of walkers. Additionally, less stride time CV was evaluated as attractive but not as feminine in nonmodels' high-heel gait. Stride CV is associated with fall risk (Hausdorff, Rios, & Edelberg, 2001), and this result also supports the idea that the health-related factors affect the judgment of female attractiveness. For models' gait, the toe-off angle was positively correlated with only the F-score in both footwear conditions. Since the toe-off angle is considered to be linked to the knee extension during the push-off phase, it may be related to the health of the walker. Because there may be factors that affect the A-score and F-score other than the factors focused on in this study, to comprehensively detect factors that affect the judgment of attractiveness and femininity in female gait, we could use the method of machine learning to classify female gait in the context of attractiveness or femininity.

In this study, it was clarified that attractiveness and femininity in female gait did not always match each other—sometimes, it was perceived as feminine but not as attractive. This nonuniformity of gait attractiveness and femininity could be due to the balance between factors involved only in femininity or attractiveness (that is, the weight of factors for evaluation). To examine the weight of each factor for the A-score and F-score, we conducted a multiple regression analysis using physical and motion factors as a candidate for explanatory variables under each group and condition; however, we could not obtain a high multiple correlation coefficient (*R* = 0.3 ~ 0.4). Although we could not obtain a significant multiple regression model to explain the A- and F-scores, factors that showed a statistically significant correlation in this study tended to be significant explanatory variables in multiple regression analysis. To obtain a more accurate multiple regression model, in a future study, we should collect a large amount of data on the A-score and the F-score for classifying attractive or feminine gait by using a bottom-up method of machine learning. Additionally, other biomechanical factors may be related to the A-score or F-score among the factors not suggested by previous studies. Such an exhaustive search makes it possible to generate feminine or attractive gaits artificially in the future.

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