AN ANALYSIS OF THE SEXUAL DIMORPHISM OF HANDS:

ATTRACTIVENESS, SYMMETRY AND PERSON PERCEPTION

BY

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B.A., Psychology, Simon Fraser University, 1999
M.A., Psychology, Simon Fraser University, 2002

DISSERTATION

Submitted in Partial Fulfillment of the
Requirements for the Degree of

Doctor of Philosophy
Psychology

The University of New Mexico
Albuquerque, New Mexico

December, 2009

DEDICATION

I dedicate this dissertation to my family and friends. A special note of gratitude goes to Bea and Mike Hicks, Gerald Paetz and to Howard whose love, support and understanding throughout the completion of this work has been invaluable. Thank you also to Chris and Lorna Dane who have been great cheerleaders.

ACKNOWLEDGMENTS

I would like to acknowledge my supervisors Geoffrey Miller and Steve Gangestad for all of their support, insight, and critiques of my work as well as their theoretical contributions to the study of sexual selection in humans. I would like to thank Randy Thornhill whose rigorous research over several decades has been an inspiration. Thank you also to my committee member Mike Dougher for his support and perspective.

I am extremely grateful to all of my research assistants whose help made this project possible. Specifically I would like to acknowledge Cisco Martinez, Levi Orban and Aman Bassi for their hard work and dedication.

Finally I would like to acknowledge Charles Crawford for always being willing to read drafts and for staying on my case until the end.

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ABSTRACT

Like faces, hands and forearms may provide cues to quality and sex-typical hormone exposure used in mate choice. To date second-to-fourth digit ratio is the only measure that has been used to evaluate hand attractiveness. Two sexually dimorphic components were extracted from measurements taken on 62 male and 68 female hands and forearms. These components were combined to create an objective hand masculinity index. Sex-typical scores on this objective measure were associated with sexually dimorphic facial features, greater symmetry, sex typical 2D:4D (low for men and high for women) in Anglo participants and low finger ridge counts in both sexes. Attractiveness ratings and attribute judgments were made on photographs of the dorsal view of target hands and arms. Additional ratings of hands only and arms only were obtained for comparison. Subjectively rated and objectively measured masculine hands and arms were judged most attractive in men, while feminine hands and arms were preferred in women. Within men, an analysis of separate hand and arm ratings indicated that a combination of masculine hands with less masculine forearms was most attractive, possibly indicating a trade-off between quality and parental investment by the opposite sex. Men with male typical hand index scores, low 2D:4D and high ridge counts were rated as more masculine, dominant, intelligent, healthy and as good parents. Women with feminine hands, high 2D:4D and high ridge counts were rated as more feminine. Results were mostly consistent with similar research on faces. Interesting findings regarding female dermatoglyphics are discussed along with limitations and future directions.

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Introduction

Research on physical attractiveness, for the past few decades, has focused predominately on faces and a few bodily features (i.e. height, waist-to-hip ratio, voices). In men's faces, averageness, symmetry, and exaggerated secondary sexual characteristics (i.e. jaws and brows) have been found to increase ratings of attractiveness (Grammer & Thornhill, 1994; Johnson, Hagel, Franklin, Fink, B. & Grammer, 2001; Little, Burt, Penton-Voak, Jones, Little, Baker, Tiddeman, Burt, & Perret, 2001; although see Rhodes, 2006 and Rennels, Bronstad & Langlois, 2008 for conditions where more feminine faces are preferred). In women, feminine facial features are preferred by men (Johnson & Franklin, 1993; Perrett, May & Yoshikawa, 1994). Although bodies have historically been less often studied, researchers have found preferences for tall men (Pawlowski & Koziel, 2002), larger optimal waist-to-hip ratios (around 0.9) in men as compared to women (Singh, 1995), larger shoulder to hip ratios in men (Dijkstra & Buunk, 2001), smaller feet relative to body size in women (Fessler et al., 2005), and vocal masculinity in males (Feinberg, DeBruine, Jones, & Little, 2008). Body morphology, like parts of the face, is sexually dimorphic and therefore, because of its dependence on sex typical hormones, may convey important information regarding sex, fertility, or condition to potential mates.

The word *hand*some was originally used to refer to someone who was "dexterous", "manually apt", "honest", and "straight forward". Today we use the word to represent an attractive individual – an attractive "masculine" individual to be precise. The word 'handsome' probably does not refer to an actual judgment about the hands of an individual but that may not be such an absurd idea. Hands and forearms are two very sexually dimorphic parts of the human body and I propose that if sex-typical faces, voices and body types are preferred, then we may also find a preference for sex-typical hands and arms.

Next to the face, the hands arguably communicate more information than any other body part. When the mouth and vocal chords cannot be used (as with the deaf), the hands are the next vehicles for communication. Even when they are not used as the primary communicative tool, the hands are often used to gesture along with speech. Iverson and Goldin-Meadow (1998) found that blind speakers use gestures even when speaking to a blind listener. This type of gesturing along with speech is evident even in children as young as six months (Petitto, Holowka, Sergio & Ostry, 2001). Although babies at this young age are at the babbling stage of speech, their hands show distinct patterns of linguistic babbling that develop along with their speech. Positioned at the end of the upper appendages, the hands are highly visible, and when moved are likely to draw more attention than any other body part, aside from the face. This attention is accentuated by the fact that in most clothed societies (extremely cold climates not withstanding) the hands are typically exposed. Hand evaluation can also be made through handshakes or the touch and exploration of courtship.

Another form of communication is what we can 'read' from hands. Cues to aging in skin are given by loss of hydration and elasticity, an increasing presence of wrinkles and age or 'liver' spots. Joints can also become arthritic, hair darker and muscles disused. In hierarchical societies, calluses, scars and signs of heavy usage of hands can provide information about the social status of an individual. In addition to features of hands indicating age or occupation, they also can provide information about disease and personality (Napier, 1993). Signs of nutrition, hormones, and immune function are evident in skin and nail quality, and mental health has been associated with certain common skin diseases (Dalgard, Svensson, Sundby & Dalgard, 2005). The amount of care put into the cleanliness of hands and nails could possibly indicate levels of conscientiousness or even neuroticism in the case of constant nail biting.

Not only do the hands and arms have a high communicative function but they also have high anatomical complexity. The hand alone has more bones (22) and more muscles (40) than the face (bones = 14, muscles = 27), legs (bones = 4, muscles = 14) or feet (bones = 26, muscles = 15; Gray, 1918). This complexity allows the hands to perform highly specific and intricate movements. As I will argue, features of the hands and forearms are highly hormone dependent. This complexity and hormone dependency may provide a perfect canvas on which the effects of age, sex, condition, and environment can be painted. Just as people can differentiate a child's face from an adult, and a man's face from a woman's so, I suggest, one can see the differences in age, sex, and possibly condition in hands.

As detailed later there is very little research on what makes hands attractive to the opposite sex. There are likely functional and anatomical features of human hands that are found attractive regardless of sex (e.g. number and relative length of digits, lack of webbing, and thumb-digit opposition). There are also many aspects of skin texture and color that undoubtedly influence attractiveness judgments. Some preferences may be species-typical, others sex-specific, some culturally dependent and others idiosyncratic. Desires for certain features, which reliably co-varied with reproductively relevant qualities may be expressions of evolved psychological adaptations interacting with local ecologies (e.g. preferences for masculine traits in males, which may vary across societies dependent on marriage systems, parasite prevalence or other life history factors). Preferences for other characteristics may not have been selected over time but may be culture-, generation- or climate-specific (e.g. desire for female thinness in recent decades). The present study cannot investigate all aspects of hand attractiveness but begins by focusing on sexually dimorphic hormone markers and their links to quality.

Prenatal Hormones and the Development of Hands

Hands and arms may be as sexually dimorphic as jaws and brows. The effects of sex-differentiated hormone exposure are quite evident in both muscle and bone development of the limbs. Homeobox (Hoxa and Hoxd) genes are required for the development of both the growth and patterning of the digits as well as the formation of the gonads (and therefore the production of sex steroids in utero). This has led some researchers to use the ratio of the length of the second (index) finger to the length of the fourth (ring) finger as a window into the early hormonal environment of the fetus (Manning, 2002). In men the fourth digit (ring finger) tends to be longer than the second (index) therefore producing a lower second digit to fourth digit (2D:4D) ratio. Women tend to have higher 2D:4D ratios with the index finger being slightly longer than or equal to the ring finger. In a sample of Jamaican women, high waist-to-hip ratios (a proposed correlate of testosterone) in mothers were associated with low 2D:4D ratios in their children (Manning, Trivers, Singh, & Thornhill, 1999). This could suggest that a prenatal environment high in testosterone or a shared genetic tendency, between mother and fetus, for increased testosterone production may be associated with male-like 2D:4D ratio. Manning, Scutt, Wilson, & Lewis-Jones (1998) found the 2D:4D ratio to be negatively correlated with adult testosterone levels in men and positively correlated with estrogen and LH levels in both men and women. Evidence for a relationship between finger ratios and adult sexual dimorphism has been mixed. Fink et al. (2005) reported an association of masculine lip, jaw and nose shape with low 2D:4D ratios, which was supported by Burriss, Little & Nelson (2007) who found links between feminine 2D:4D ratios and objective measures of facial femininity in women. Several other studies have failed to find the same results (Koehler, Simmons & Rhodes, 2004; Pound, Penton-Voak & Kampe, 2005).

Humans are also sexually dimorphic in the number and pattern of dermal ridges on their palms, soles, and digits (Holt, 1968). In general men tend to have higher mean finger ridge counts than women (Holt, 1955). Total ridge counts are partially related to the sex chromosome complement (Penrose, 1967). Individuals with only one X chromosome (Turner's Syndrome) have the highest ridge counts, while individuals with supernumerary sex chromosomes have the lowest (Penrose, 1967; Netley & Rovet, 1982). Most individuals have more ridges on their right hand than their left but women have a higher incidence of leftward asymmetry than men (Kimura & Carson, 1994). Although R > L ridge count asymmetry is more common in males than in females, men with higher circulating testosterone levels have higher counts on their left hands and men with lower testosterone had higher counts on their right hands (Jamison, Meier & Campbell, 1993). Dermatoglyphic abnormalities or asymmetries have been used to provide information regarding congenital malformations (Penrose, 1968), schizophrenia (Murphy & Wig, 1997), sex chromosome abnormalities (Reed, 1981) and cognitive performance (Kimura & Clarke, 2001). Ridge patterns on the fingers and palms are first evident during weeks 14-22 of gestation at the sites where embryonic volar pads subside (Okajima, 1975). Ridge patterns remain unchanged after the second trimester and are highly influenced by genetics with total ridge count being correlated 0.96 in monozygotic twins [Hall, 2000; Medland et al., 2007; although heritability is lowest (approx. 0.50) for the thumb and little finger]. Individual differences in prenatal environment (androgen exposure and stress) and developmental stability also play a role in ridge formation (King, Mancini-Marie, Brunet, Walker, Meaney & Laplante, 2009).

Although the sex difference in finger ridge counts is robust (higher counts more common in males) the detailed relationship between prenatal hormones and individual differences in ridge counts is unclear. Ridge counts are influenced by both the type and size of finger ridge patterns. These patterns are in turn affected by the timing of the involution of localized elevations of tissue found on the fingertips called volar pads (Medland et al., 2007). If ridge patterns develop early, before volar pads have completely subsided, whorl patterns (which lead to higher ridge counts) will develop. Later development of ridges result in arch patterns, and loops are formed from development at intermediate stages (Babler, 1978). A comparison of early and late pubertal maturation found that late maturing adult males had more complex ridge patterns while late maturing females had more complex palmar patterns (Meier, Goodson & Roche, 1987). The authors speculated that a generalized delay in development within some individuals would result in a delay in volar pad regression as well as a delay in pubertal maturation. Some suggest that a slower developmental rate associated with the effects of fetal and environmental androgens (Geschwind & Galaburda, 1985; Jamison, Jamison & Meier, 1994) is responsible for the differences in ridge pattern formation. While direct tests of this hypothesis are unlikely in humans due to ethical concerns, experimental administration of testosterone to pregnant rhesus monkeys showed an effect of early dosage on total ridge counts of the offspring (Jamison, Jamison & Meier, 1994). Early exogenous testosterone exposure *decreased* the ridge counts and ridge complexity in the rhesus offspring. The authors also noted that the period within which testosterone affected dermatoglyphics began and ended before the time ridges actually began to form. This implies that although human ridge formation can be seen by week 14 of gestation (Okajima, 1975), the period of effect for environmental androgens may be much earlier.

While the 2D:4D finger ratio and ridge counts are examples of early hormonal and developmental effects on male and female hand morphology, other later differences in bone, muscle and fat development are also of interest.

Sex-linked Physical Development and Body Fat Distribution

Across the lifespan sex-steroid hormones affect the growth of bone, muscle and body fat composition (Veldhuis et. al., 2005). Particularly during adolescence, testosterone has both androgenic (masculinizing) and anabolic (building up of lean muscle tissue) effects (Dabbs & Dabbs, 2000). At male puberty, facial features (e.g. cheekbones, chin, eyebrow ridges and mandibles) sexually differentiate, voices lower, and musculature increases (Thornhill & Gangestad, 1999a). In a study developed to obtain reliable reference values for grip strength, Peolsson, Hedlund, and Oberg (2001) found that women's handgrip strength was 63% of that for men. Weber, Chia and Inbar (2006) added evidence that men outperform women in anaerobic tests of arm and leg power. After allometric scaling to control for body mass the authors found that there were no differences in performance between men and women in leg power, however, men were still more powerful in an arm-cranking task. These effects are undoubtedly due to differences in both muscle and bone density/size between the sexes. Androgen receptors are expressed in bone cells (both osteoblasts and osteocytes) and influence both height and bone size (Veldhuis et. al., 2005). As for muscle mass, Bashin et al. (1996) conducted one of the only fully blind and randomized tests of the effects of high doses of testosterone on muscle size and strength in normal men. Participants were randomly assigned to one of four groups: placebo with no exercise; placebo with exercise; testosterone with no exercise; and testosterone with exercise. Results showed that both body weight and fat-free mass increased in both of the testosterone conditions. There were also significant increases in the size of the men's triceps and quadriceps for the testosterone alone and the testosterone with exercise groups.

Homo sapiens have a unique sexually dimorphic body fat distribution compared to other primates. Higher levels of estrogen increase fat deposition on women's breasts, hips, buttocks, and thighs, while testosterone causes men to store fat around their abdomen. Like other primates, human males tend to have a more muscular and developed upper body while females tend to carry most of their body mass in their lower torso (Dabbs & Dabbs, 2000). Although the majority of the sex differences in fat and fat-free mass (muscle and water) distributions are influenced by the increase in sex hormones at puberty, He et al. (2002) found that even before the physical signs of puberty were evident, girls had greater relative gynoid (pelvis and legs) and extremity (legs and arms) fat deposition than boys. This trend carries over into adulthood where women are found to have a larger proportion of calories stored as fat (higher percentage of body fat) than men, regardless of body weight (Rosenbaum & Leibel, 1999). Storage of extra calories as fat in women provides more stable food storage during pregnancy and breastfeeding (Lassek & Gaulin, 2006), while the storage of fat in the abdominal region in men can be readily mobilized for use as energy needed in strenuous muscle work. This sexually dimorphic pattern of fat deposition is reflected in the generally more smooth and round appearance of women's forearms versus a more vascularized and muscular appearance in men.

Increased abdominal obesity is associated with negative health effects in both men and women (Reeder, Angel, Ledoux, Rabkin, Young & Sweet, 1992). While abdominal obesity can be related to an excess of free testosterone in women, the same is not true in men (Evans, Hoffman, Kalkhoff & Kissbah, 1983; Tsai, Boyko, Leonetti & Fujimoto, 2000). Low testosterone in men is associated with increased abdominal fat deposits, particularly intra-abdominal fat as opposed to subcutaneous fat (Tsai, Boyko, Leonetti & Fujimoto, 2000). Excess accumulation of intra-abdominal or visceral fat puts men at risk for cardiovascular disease and insulin resistance (Boyko, Leonetti, Bergstrom, Newell-Morris & Fujimoto, 1995). Although there are many obvious ways to observe an accumulation of visceral fat, Ken'ichi et al. (2003) found that, in non-obese men, waist circumference and the fat mass of the arms both significantly correlated with visceral fat levels as measured by computed tomography. Vascular arms with low body fat might not only provide general information about sex, they might also provide individual difference cues to higher testosterone levels and lower risks of some diseases in men.

Hormone-Mediated Traits and Sexual Selection

The sex differentiation in muscle size, fat deposition, face morphology and hand structure is primarily a result of the interaction between sex-steroid hormones (androgens and estrogens), growth hormones and other systems. The increased level of testosterone present in men versus women was likely driven by sexual selection (i.e. aided in intra-sexual contests and/or had a mating function). Physically and behaviorally, testosterone mediates resource and energy allocation to features that augment male ability to compete for reproductive opportunities (Ellison, 2003). Testosterone's effects on masculine features along with increased social dominance, and risky behavior are hypothesized to have benefited men in intrasexual contests for mates (Apicella, Dreber, Campbell, Gray, Hoffman & Little, 2008; Mehta, Jones & Josephs, 2008; Archer, 2006; Thornhill & Gangestad, 1993).

In order for preferences for a trait to evolve, the overall benefits gained from the choice must outweigh the costs. Within direct benefits models of sexual selection the trait of interest either benefits the chooser directly with increased fecundity (i.e. increased resources, parental care or higher fertility) or in some way reduces the cost of reproduction (i.e. decreases search time or lowers chance of infection by disease). In sexually reproducing species, the chooser may also obtain indirect benefits through the acquisition of a mate with "good genes", which through sexual recombination may increase the survival or reproductive advantage of offspring (Trivers, 1972). These genetic benefits can be in the form of "intrinsic good genes" (alleles associated with high fitness regardless of the chooser's genetic make-up), "compatible genes" (alleles that, in combination with the chooser's specific genes, would increase fitness of the offspring), or "diverse genes" (alleles from mates who could diversify the genetic make-up of multiple offspring; Thornhill & Gangestad, 2008; Jennions & Petrie, 2000).

Female Mate Choice: Direct Benefits. In an ancestral environment women's preferences for testosterone-mediated traits in men may have garnered direct benefits, such as protection or material resources. Winners of intra-sexual contests could potentially acquire high status and increased resources, which could then be transferred to potential mates and their offspring. However, in mating systems with internal gestation and without absolute monogamy, males potential rate of reproduction exceeds that of females and attractive males may benefit from increasing mating opportunities (Clutton-Brock, 1991), which would mean investing less in each mate. Due to the biparental nature of most human mating systems, men must make trade-offs between two types of reproductive effort: mating effort and parental care. Archer (2006) provides an argument for testosterone's role in mediating this trade-off. The hypothesis is that higher testosterone levels facilitate mating effort and lower testosterone in married men and fathers facilitates an increase in parental care and a decrease in the likelihood that time and energy will be spent on competing or acquiring additional mates. In support of this, men with more masculine bodies, and with higher levels of testosterone report increased access to sexual partners (Bogaert & Fisher, 1995; Rhodes, Simmons & Peters, 2005; Peters, Simmons, & Rhodes, 2008). Several studies have shown that testosterone levels are lower in married (or partnered) men than in single men (Mazur & Michalek, 1998; Gray, Kahlenberg, Barrett, Lipson & Ellison, 2002; Van Anders, 2008) and among married men, those with higher testosterone invest less in and spend less time with their wives (Gray et al., 2002).

Given that testosterone has been found to modulate mating behavior in many vertebrates (O'Neal, Reichard, Pavilis, & Ketterson, 2008; Hirschenhauser & Oliveira,

2006) and there is support for this being true in humans (Van Anders, 2008; Peters, Simmons, & Rhodes, 2008; Archer, 2006) behavioral and physical traits affected by androgens could have provided some information to ancestral women about men's relative investment in parental care and mating effort. Body fat distribution, bone growth, muscularity, hairiness and skin tone could all potentially reflect individual differences in testosterone levels [although Peters, Simmons & Rhodes (2008) found no association between rated masculinity of faces and bodies and morning saliva testosterone levels]. If masculine physiology does reflect this trade-off, women in search of long-term relationships, ones that require more cooperation and possibly parental behavior, may not find highly exaggerated masculine traits attractive. In support of this hypothesis several studies have found that women prefer more feminized faces for long-term partners than for short-term partners (Penton-Voak et. al., 1999; Penton-Voak, Jacobson & Trivers, 2004; Scott, Swami, Josephson & Penton-Voak, 2008).

Female Mate Choice: Indirect Benefits. Masculine traits may also provide information regarding mate quality or condition (Thornhill & Gangestad, 2008; Penton-Voak et.al., 2001). If the elaboration of masculine traits co-varied with quality, and a portion of this quality was heritable, then preferential mating with such males would provide genetic benefits to offspring in terms of intrinsic good genes. How would masculine traits become reliable indicators of mate quality? Given that resources are finite, trade-offs are required between somatic maintenance, growth and reproductive effort. Individuals with higher genetic quality could possibly afford to invest more overall in masculine behavioral and physical characteristics (that aid in intra-sexual and inter-sexual competition). Individuals of poor quality have fewer resources to allocate and optimal trade-offs would likely lead to less overall investment in sexually selected traits. Based on this reasoning, an exaggeration of testosterone-mediated morphological (and possibly behavioral) traits could potentially be used by males to honestly signal aspects of quality to same-sex rivals or to opposite-sex potential mates. The system is kept honest by the metabolic and survival costs of diverting resources away from cell repair and immunity as well as the social costs of displaying an ability or willingness to engage in intra-sexual contests, which are particularly high for individuals unable to win such contests (Rohwer & Rohwer, 1978; Thornhill & Gangestad, 1999a).

Developmental instability is one construct that researchers have used to provide indirect evidence for intrinsic good genes sexual selection. Bilateral symmetry or low fluctuating asymmetry (FA) is the most common measure of developmental stability in human and non-human research, (Gangestad & Thornhill, 1997; Koehler, Simmons, Rhodes & Peters, 2004; see Møller, 1997 for a review of non-human research). To the extent that developmental stability is partly heritable, low FA may be a marker of genetic quality (or a specific component of genetic quality). Fluctuating asymmetry (FA) results when a bilateral trait, symmetrical at the population level, develops asymmetrically in an individual. The detailed mechanisms that cause perturbations in development responsible for asymmetry are not known but, theoretically, anything that can affect development (e.g. parasites, mutations, or environmental stressors), and/or heritable differences in ability to ward off these disruptions can lead to asymmetry. If, as hypothesized, androgenized male traits reflect aspects of intrinsic good genes then we would expect masculine male features to co-vary with FA. In support of this, Gangestad and Thornhill (2003) and Scheib, Gangestad and Thornhill (1999) found that masculinity in male faces was related to FA. Men with more symmetrical features tended to have more masculine features (although see Penton-Voak, Perrett, Castles, Burt, Koyabashi, & Murray, 1999 and Koehler, Simmons, Rhodes & Peters, 2004). Although Gangestad and Thornhill (2003) did not find an association between FA and masculinity in women, Koehler et al. (2004) did find a small, but significant, positive relationship between body FA and female facial masculinity.

Although the link between masculine traits and good genes is indirect, conditional preferences for masculine faces add additional support. If masculine traits are linked to heritable quality and if men with such traits focus more on mating effort than parenting effort, then selection pressures may have shaped women's desires for such traits to be conditional on situations when heritable benefits would be maximized. As previously mentioned, women's preferences for masculinity tend to increase when judging men's faces as potential short-term sexual partners (when the benefits or possibility of paternal investment is low). In addition to mating context, women's desires are also conditional on fertility risk and parasite prevalence. The benefits of a mate with intrinsic good genes are maximal when conception is likely and in ecologies where heritable immunity can aid offspring survival. Several studies have found women's preferences for masculine traits and scents of symmetrical men increase in phase of the menstrual cycle where conception would be most likely (Thornhill & Gangestad, 1999b; Penton-Voak & Perrett, 2001; Johnston, Hagel, Franklin, Fink, & Grammer, 2001; Little, Jones & Burriss, 2007). Cross-culturally, individuals in societies with greater pathogen risk place greater importance on physical attractiveness when choosing a mate (Gangestad & Buss, 1993). Pathogen prevalence and decreased medical care alter the costs and benefits of choosing a mate with heritable quality and immunity. Penton-Voak, Jacobson, and Trivers (2004) found that in a Jamaican population, where there was decreased paternal investment in first children, higher parasite loads and decreased medical care, women preferred more masculinity in faces than women from a British population.

Male Mate Choice. Estrogen-mediated phenotypic traits may have offered men information regarding the direct benefits of reproductive value (youth) and fertility as well as indirect benefits of genetic quality (Grammer, Fink, Juette, Ronzal, & Thornhill, 2002; Thornhill & Gangestad, 2008). In humans, compared to other primates, there is a considerable amount of paternal care and long-term pair bonding, which is suggested to be facilitated by female concealed ovulation and an extended period of sexuality when not fertile (Geary & Flinn, 2001; Thornhill & Gangestad, 2008). Long-term pair bonding increases the selective advantage for men of pairing with a mate who has the potential to reproduce not just now (fertility) but also well into the future (reproductive value). Due to women's relatively concealed ovulation, selection likely favored men who were attracted to aspects of a woman's phenotype that may be related to her reproductive value. Thornhill and Gangestad (2008) have argued that a number of women's estrogen-mediated characteristics (femoral-gluteal storage of gynoid fat, breasts and feminized faces) act as signals of reproductive value.

Signals or ornaments can be distinguished from other phenotypic characteristics that may be by-products of adaptations, which were not directly selected for the function of communication (Thornhill & Gangestad, 2008). A signal is a trait that was selected for (or elaborated from its original form) because it transmitted information to others, which led to the increased survival or reproduction of the sender. By-products are associated with adaptations, but did not provide benefits that drove selection for the adaptation. Thornhill & Gangestad (2008) suggest that, among other feminine traits, gynoid fat distributions may have originally been attended to by men as by-product cues to women's relative hormone levels (and associated fertility). The preferential mating of men with such women would increase the benefits to individual women of allocating more effort to the growth of these traits. The increased sexually selected pressures on distribution of gynoid fat on the hips, butt and thighs leaves those women in best condition better able to divert resources to these reproductively relevant traits. The estrogen-mediated trait now acts as a signal of quality or condition.

Given the limited amount of research on hands it is premature to suggest that sex-differentiated hand features were exaggerated by sexual selection to function as signals. If preferences do exist, certain characteristics of hands and arms may have simply been acting as by-product cues. Cues to youth and health may be found in skin texture and color (Fink & Matts, 2008; Fink, Grammer & Matts, 2006; Jones, et al., 2004). Female-typical bone growth may provide cues to quality (attractiveness linked to symmetry in faces; see Rhodes, 2006) relative hormone levels in utero (2D:4D) or at puberty, but may also reflect youth as bone structure changes with age (Schaefer, et.al., 2006; Johnston & Franklin, 1993).

Judgments of Hand Attractiveness

To date only three known studies have addressed hand attractiveness, all focusing on second digit or fourth digit length and their relation to attractiveness. Manning and Crone (in Manning, 2002, pp. 47-50) had photocopies of dorsal (back) and ventral (palm) surfaces of hands rated by opposite-sex participants and found fourth digit length was positively associated with hand attractiveness in both sexes. The authors also found that the hands of younger women, taller men and thinner individuals of both sexes were rated as sexy.

Saino, Romano, and Innocenti (2006) asked participants to rate ventral (palm) surface computer scans of opposite-sex hands for attractiveness. Specifically, they asked participants how sexually attractive they would find the man or woman who's hands were portrayed in the scans. For both men and women, unmanipulated hand images were rated as belonging to attractive individuals if they had a longer second digit or fourth digit. The authors found no significant relationship between 2D:4D ratio and attractiveness. By digitally manipulating individual scans to have longer or shorter second or fourth digits, Saino et al. (2006) found that men disliked shortened second digits, whereas women preferred elongated fourth digits in opposite-sex targets. Interestingly, Saino et al. (2006) reported that, in an unpublished survey, undergraduates rated hands as important when making overall judgments of sexual attractiveness.

A third study by Voracek and Pavlovic (2007) had participants rate gray scale printouts of male and female palms on attractiveness, health and several other attributes. One major difference from the previous two studies was that the participants were blind to the sex of the hand in the printout. The majority of results were in the opposite direction to what the authors had originally predicted. Sex-atypical hands were judged to be more attractive and healthier for both men and women. Although the authors state that 75 to 80 percent of their target hands were correctly identified as belonging to a male or female, the participants' ratings of masculinity, femininity and dominance in men were all related to 2D:4D in the opposite direction than one would predict. That is, male hands with female typical (higher) 2D:4D ratios were perceived as more masculine, less feminine, and more dominant in males. It is possible that the findings in this study were a result of the raters not knowing the sex of target hands.

Current Study

The current study examined sexually dimorphic traits of hands and forearms and their relation to sexual dimorphism of the face, measures of developmental instability, indirect measures of prenatal hormone levels, as well as ratings of the attractiveness, masculinity, dominance, health and intelligence of hands. The aim of the first set of analyses (part 1) was to create an objective hand and forearm dimorphism measure (hereafter referred to simply as "hand masculinity index") akin to those that have been developed for faces (Penton-Voak et al., 2001; Gangestad & Thornhill, 2003). While other objective, sexually dimorphic measures such as 2D:4D potentially reflect prenatal hormone exposure, some sex-hormone dependent phenotypic characteristics are only present, in adult form, after puberty. The relationship between traits set prenatally and sexually dimorphic adult features is also not clear. Dermatoglyphic asymmetries have been related to adult testosterone (Jamison et al., 1993). Some evidence supports a relationship between 2D:4D and adult levels of testosterone or dominant facial characteristics (Manning et al., 1998; Neave, Laing, Fink & Manning, 2003), but others show no relationship between digit ratio and facial masculinity (Burriss et al., 2007; Koehler, Simmons & Rhodes, 2004). The proposed objective hand masculinity measure broadens potential analyses involving hand dimorphism to include development influenced by sex hormones at all stages of life. In order to relate the newly developed hand masculinity index to commonly used indirect measures of developmental disruptions, prenatal hormones and circulating hormones; measurements of fluctuating asymmetry, second-to-fourth-digit ratio, finger ridge counts, ridge count asymmetries and objective facial masculinity were taken.

Part 1 Predictions. *The first set of predictions pertains to relationships between objective hand masculinity, objective face masculinity, prenatal hormone measures, ridge count asymmetry and fluctuating asymmetry.*

Prediction 1. Objective hand masculinity will be positively related to objective face masculinity. Both men and women with more masculine faces should also have more masculine hands

Prediction 2. If finger ridge counts and 2D:4D both, to some degree, reflect the effects of prenatal environment on sex-typical growth ridge counts should be negatively related to 2D:4D in both men and women.

Prediction 3.1. Objective hand masculinity will be negatively related to 2D:4D in both sexes. That is, higher hand masculinity scores will be associated with lower 2D:4D ratios.

Prediction 3.2. Higher (male-typical) finger ridge counts are predicted to be associated with higher hand masculinity.

Prediction 3.3. Based on research linking dermatoglyphic asymmetry to adult testosterone in men, objective hand masculinity is predicted to be associated with finger ridge asymmetry (Jamison, Meier & Campbell, 1993). Men with more masculine hands will have higher ridge counts on the left hand than on the right.

Prediction 4.1. Theoretically, if sexually dimorphic hand morphology conveys information about quality then objective masculinity in hands and arms should relate to fluctuating asymmetry. An interaction between sex and FA is predicted, with hand masculinity being negatively related to FA in males and positively related to FA in females.

Prediction 4.2. If such an effect exists, follow-up analyses will explore the relationship between fluctuating asymmetry and the individual items that were combined to create the hand masculinity index.

In part 2, previous research on the attractiveness of hands was expanded in several ways. Color photographs of the dorsal (back) view of target hands were judged on attractiveness, masculinity, dominance, health, intelligence and likelihood of being a good parent. Unique to the current study, judges rated photographs of hands and forearms together. Including the forearm in photographs is hypothesized to make available more of the context in which hands would naturally be viewed. In line with past research, a second set of target photographs presented target hands cropped at the wrist while in a third set of photographs the forearm was judged alone. A fourth set of photographs displayed the target's face so judgments of attractiveness and masculinity-femininity could be compared across traits.

While past research focused solely on how attractiveness related to second and fourth digit lengths, part 2 of the present study explored a wider range of characteristics that may have provided individuals with mate choice relevant information. Judgments of hands and forearms were used to determine if, within each sex, ratings of attractiveness were related to objective hand masculinity, subjective ratings of masculinity, 2D:4D, finger ridge count and ridge count asymmetry. To partially replicate and extend past research, attractiveness was assessed with respect no only to second and fourth digit lengths, but to lengths of all digits as well as digit length relative to height. It is possible, given the experimental findings of Saino et al. (2006), that the shape of hands represented by sex-typical digit ratios is attractive to the opposite sex, though longer female fingers in general may also be attractive. Anecdotally this seems plausible and the observation is supported if those chosen as hand models can serve as examples of what is viewed as attractive. According to one hand modeling agency the suggested requirement for female models is to have long, straight fingers, with unblemished skin (Hand Models 1, 2009). The grooming standard of women wanting long nails (to the extent of purchasing fake "enhancements") may also reflect female competition for mate attention.

Predictions Part 2. *Though part 2 of this study is largely exploratory there are a few general predictions that can be made based on theory and past research on faces.*

Prediction 5. Based on facial research, opposite-sex raters are predicted to find sex-typical hands and forearms attractive (although female preference for masculinity may be conditional on relationship context or menstrual cycle phase).

Prediction 6. Hands of younger women will be judged attractive.

Prediction 7. Masculine hands will be judged as dominant in men (Neave et al., 2003).

Method

Participants

This study was approved by the University of New Mexico IRB. The sample consisted of 68 women and 62 men enrolled in Introductory Psychology courses at the University of New Mexico. Women averaged 21.95 years of age (SD = 0.6; RANGE = 18-43); men averaged 21.18 years (SD = 0.6; RANGE = 18-45). Approximately 75% of participants were of Anglo origin, 20% Hispanic, 2.5% Asian and 2.5% African-American origin. Participation was voluntary and participants received minor extra credit in one of their Psychology classes.

Procedure

Part 1

Data were collected in two separate sessions. In the first session, participants consented to participate, and were asked to indicate consent to have their facial pictures either: not taken at all (n = 3), only used to calculate objective masculinity (n = 6), or used for all measurements and subjective ratings (n = 121). Participants self-reported their age, sex, current GPA, as well as verbal and quantitative SAT scores (82.5% and 86.1% remembered respectively). Participants then had their fluctuating asymmetry measured, and fingerprints and physical measurements taken. In the second session, participants completed additional paper and pencil tests (not reported on here), and had photographs of their faces and hands taken.

Physical Measurements. Body fat (bioelectrical impedance; 0.1% increments) and weight (0.2 lb increments) were obtained using a Tanita Body Fat Monitor scale (model TBF-681; Ilinois). A standard tape measure was attached to the wall, and height (feet/inches) was judged using a straight ruler placed, perpendicular to the wall, at the top of each participant's head.

Fluctuating Asymmetry (FA). Digital calipers were used to measure the size of ten bilateral traits: ear length, ear width, elbow width, wrist width, ankle width, foot width and 2nd (index) to 5th (little) finger length. Each trait was measured twice on the right side and twice on the left by one of four trained measurers. The absolute value of the right – left difference, for each trait, was divided by the size of the trait and summed across the ten measures. This was done separately for the first and second set of measurements in order to test reliability. For these composites intra-rater reliability between the two sets of measurements was acceptable (alpha = 0.882). As described in Gangestad and Thornhill (2003), to obtain a total measure of relative FA the absolute value of each bilateral trait difference (summed across the two measurements) was divided by the average size of the trait. To create a composite FA score all ten traits were summed for each participant separately. Participants were also asked about any breaks or sprains that may have occurred to any of the ten trait areas. Breaks or sprains can potentially skew FA and reflect non-heritable phenotypic variation in symmetry. If a participant did report an injury, and their asymmetry was greater than the mean then the value of their right-left asymmetry was adjusted to an average value.

Second to Forth Digit Ratio (2D:4D). Measurements from the basal crease (bottom) to the tip of the second digit (index finger) and fourth digit (ring finger) were obtained, using digital calipers, during the measurement of FA. The length of the second digit was divided by the length of the fourth digit for each hand separately. Two measurements of each finger were taken and reliability (Cronbach's alpha) was .972 for left hand 2D:4D and .963 for right hand 2D:4D. The two right ratio measurements were averaged together and the two left ratio measurements were averaged for each participant.

Dermatoglyphic Ridge Count. Participants' fingers were individually rolled on an inkpad and then rolled onto standard fingerprint forms. A tripod magnifying glass was used to enhance the prints and aid in counting ridges. Two thin straight pins were used, one as a guide-line between points, and the other to pass along the ridges to help guide the rater. Finger print patterns and ridge counts were determined according to the method described in Holt (1968), and Cummins and Midlo (1961). Fingerprints follow three basic patterns, arches, loops and whorls. Ridge counts are determined, in part, by locating the triradii (ridges come together to form a triangle) and core points of these patterns. Arches are made up of slightly curved ridges and have no triradii, loops have one triradius, and whorls typically have two triradii. A line (in this case with a straight pin) was set up connecting the triradus and the core (or center point) of the print. Ridges were counted between these two points excluding triradial and core points. As arches do not have triradii they automatically have a count of zero. Following methods used in Kimura and Carson (1995), ridge count totals for each hand were computed using only digit I (thumb) and digit V (little finger) counts. Two trained, independent raters counted ridges on all thumb and little fingerprints. Inter-rater reliability (intra-class correlation) was high for all ridge counts: left thumb count $r = .988$, right thumb count $r = .984$, left pinky count $r = .965$, and right pinky count $r = .993$ (all $F_s > 5.38$, $p < .02$). Due to smudging, some ridge patterns were not visible: ridge counts were calculated for 65 females and 60 males.

Ridge count asymmetry. Dermatoglyphic asymmetry was calculated by subtracting the left ridge count from the right ridge count for each homologous finger. The digit I and V asymmetries were then added together to create a total ridge count asymmetry variable. Positive values of this variable represent greater right asymmetry while negative values represent greater left asymmetry. Calculating asymmetry using total right counts minus total left counts did not alter the results.

Hand Photographs. Digital Photographs were taken of 114 participants' hands and forearms from 6 feet away with a Fuji Film FinePix camera mounted on a tripod (optical zoom = 6X). Arms were positioned horizontally on a wall and color photos were taken from the elbow to the fingertips with palms down (dorsal view) as well as palms up (ventral view; although ventral photographs were not rated in the current study). Digital images were imported into Photoshop Elements 2.0 (for Macintosh) and the participant number was cropped out of the frame. Three sets of target photographs were created. The first set of photos included images of each participant's hand and forearm (up to the elbow; Fig. 1 (a)). In the second set, target photographs were cropped at the wrist and only the hand was visible (Fig. 1 (b)), while the third set included just the forearms (from wrist to elbow; Fig. 1 (c)). For most participants (n = 97) right hand photographs were used. The right hand photographs for the nine female and eight male participants were either missing (n = 1) or out of focus (n = 16) so left hand photographs were used.

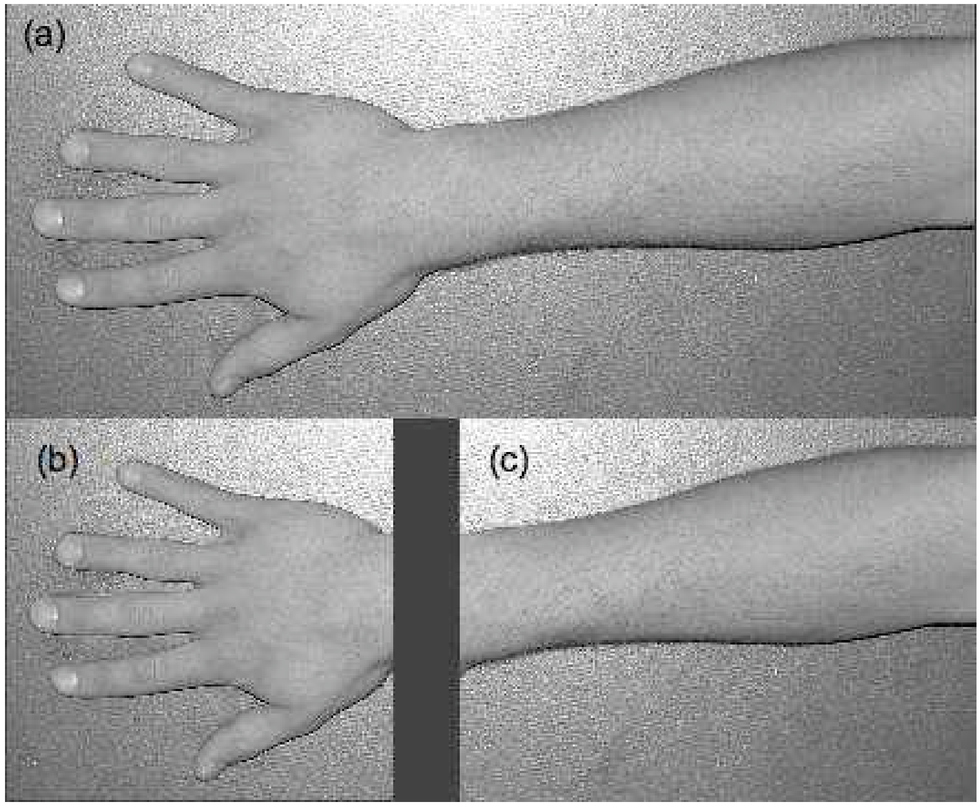


Figure 1. Examples of Three Sets of Target Photographs. (a) Hands and forearms; (b) hands only; and (c) arm only. Judges rated each set separately for each sex of target hand.

Face Photographs. Digital photographs were taken of 113 participants' faces from ten feet away with a Fuji Film FinePix camera mounted on a tripod (optical zoom = 6X). Participants were asked to look straight ahead at the camera with a neutral facial expression. Digital images were then imported into Photoshop Elements 2.0 (for Macintosh).

Face Masculinity Measure. Photographs were imported into the Macintosh version of NIH Image 1.63, and 25 standard points were placed on each face based on methods from Grammer, Fink, Juette, Ronzal, and Thornhill (2002), and Gangestad and Thornhill (2003). Seven facial traits that were potentially sexually dimorphic were measured from digitized photographs: chin length (distance from the mouth to the bottom of the chin), jaw width (distance side-to-side across the face at the level of the mouth), eye height (mean height of the eye, from bottom of upper lid to top of lower lid), eye width (mean width from corner to corner), lip height (top of upper lip to bottom of lower lip), mouth width (corner to corner) interpupillary distance (pupil to pupil). To standardize measures for overall face size, “height measures” (e.g., chin length, eye height) were divided by overall face length (hairline to bottom of chin) and “width measures” (e.g., jaw width, interpupillary distance) were divided by face width (distance between outermost extensions across the cheekbones). Prior to measurement, all faces were aligned such that the center of the pupils were on the same horizontal axis. All variables were measured in pixels.

A principal components method was used to extract two factors (first two eigenvalues = 2.51 and 1.38) from the seven ratio measures and a non-orthogonal (OBLIMIN) rotation of the factors was performed. The first component was defined by jaw width (-.82), chin length (-.81), eye height (.80) and eye width (.52). Positive values on this component represent female-typical dimorphic growth (e.g. larger eyes, smaller jaws and shorter chins) while negative values reflect male-typical growth. The second component was defined by mouth width (.72), interpupillary distance (.63), eye width (.57) and lip height (.45). Factor scores for each participant were estimated using a regression-based method. The two sets of factor scores were entered into a discriminant analysis and were able to predict sex correctly 75.7% of the time. The standard discriminant function coefficients were 1.005 for the first factor and -.224 for the second factor. Discriminant function scores (weighted combinations of the two factor scores) were calculated for each participant and multiplied by -1 so that higher scores reflect more masculine facial characteristics.

Hairiness. Two raters independently judged the subjective hairiness of all target forearms (full hand/arm photographs). Ratings were made on a nine-point scale (*1=light and sparse in appearance; 9 = dark and thick in appearance*). Inter-rater agreement was high (*alpha* = .961) so scores for each target hand were averaged together.

Length of Nails. Given that the length of an individual's fingernails may influence attractiveness of hands each hand was rated on a three-point scale (1 = short, 2 = medium, 3=long) for length of nails by the principal investigator.

Ethnicity. A question regarding ethnicity was absent from the demographic information questionnaire. Since facial photographs were available the principal investigator subjectively evaluated ethnicity. Due to the possible errors of classification to specific ethnic categories participants were judged dichotomously as either Anglo (n = 92) or non-Anglo (n = 30). The non-Anglo sub-sample consisted predominantly of Hispanic individuals, most of whom likely have mixed ancestry.

Part 2

A small number (n = 10) of research assistants were asked to judge each face and hand photograph on several attributes. The decision to use a few research assistants as opposed to a large number of participants was made due to the novelty of this research topic at the time of conception and the large number of photographs to be rated (six attributes on 112 faces and 113 hands). The higher level of commitment among research assistants allowed for time and consideration to be taken when ratings were made. The judges were free to take as much time as needed to make decisions about attributes, but they could not go back to change previous choices. Six female and four male research assistants from Kwantlen Polytechnic University (KPU; British Columbia, Canada) initially rated the target faces and full hand and forearm photographs. This group of judges was not informed of the sex of the target hand. When judging hand attractiveness, not knowing the sex of the target can be problematic as a feminine hand may be rated differently if belonging to a man versus a woman. To account for this a second set of five research assistants from Douglas College (British Columbia, Canada) were informed of the sex of the target and asked to judge hand and forearm photographs as well as hand only and arm only photographs. Hand and arm rating from this second set of judges and face ratings from the first (slightly larger) set of judges were used in the final analyses.

Hand Judgments. Two male and three female research assistants from Douglas College (New Westminister, British Columbia, Canada) judged each of the three sets of digital hand photographs (full hand and arm, hand only and arm only) on six attributes: attractiveness, masculinity, dominance, intelligence, health and good parent. The judges were told the sex of the target hand or arm, but were blind to the study hypotheses at the time of rating. Digital photographs were presented sequentially on a computer screen and the order of presentation was randomized within each of the three sets of target photographs for each judge. All attributes were rated on a nine-point scale (*1=low, 9=high*, except for masculinity, *1 = feminine* and *9 = masculine*). Scores for each attribute were z-transformed within-rater to control for any biases in scale usage before averaging. For attractiveness and masculinity, judgments of opposite-sex targets were used so composite (average) scores were constructed for female and male judges separately. Inter-rater reliability (Cronbach's alpha) for female (n = 3) and male judges (*n* = 2) is displayed in Table 1. The two male judges were inconsistent for judgments of female hand/arm masculinity, so ratings from four Kwantlen Polytechnic University male judges (who were blind to the sex of the target hand) were used instead (*alpha* = .578). Reliabilities for judgments of the other four attributes as well as attractiveness and masculinity judgments of hand only and arm only photographs are displayed in Table 1. Due to low reliability for male ratings of health (*alpha* = .012), scores from all five judges were averaged (new *alpha* =.504). Inter-rater reliabilities for hand only attractiveness ratings were alpha = .500 and .290 for female and male judges respectively, and for masculinity ratings were alpha = .444 and .338. For arm only photographs, reliabilities for attractiveness ratings were alpha = .368 and .611 for female and male judges respectively, and for masculinity ratings were alpha = .750 and .734.

Table 1.
Inter-rater Reliabilities for Ratings of Full Hand and Arm Photographs

Judges	Attractiveness	Masculinity	Dominance	Health	Intelligence	Good Parent
Female	.471	.776	.613	.433	.577	.403
Male	.494	.578[a]	.412	.504[b]	.519	.603

Note: Reliabilities are based on n = 3 female and n = 2 male judges. [a] reliability for ratings made by a different set of four judges; [b] reliability for all five male and female judges.

Although several of the reliability scores for hand and forearm judgments were below traditional levels for acceptability (alpha = 0.7), the correlations between raters were comparable to those in past research. In their study, Saino et al. (2006) reported the range of z-transformed correlation coefficients between all possible pairs of male raters of female palms to be from .213 to .737 (*M* = .458). The smaller number of judges in the present study does decrease the reliability of the ratings, so a follow-up study with more judges is necessary.

Face Judgments. Attractiveness, masculinity, and femininity were judged on a nine-point scale (*1=low, 9=high)* by six female and four male research assistants. Judges were from Kwantlen Polytechnic University (KPU; British Columbia, Canada) and were unfamiliar with the target individuals (UNM; New Mexico, U.S.A). Target photographs were presented randomly and all judges rated all target faces. Given that rated masculinity and femininity were inversely related in this sample (r = -.948 male judges; r = -.947 female judges) and that they, theoretically, are at opposite ends of a continuum a masculinity-minus-femininity difference variable was created. Each judge's rating of femininity was subtracted from his or her rating of masculinity. Inter-rater reliability, measured by Cronbach's alpha, for attractiveness judgments by female judges (n = 6) was 0.826 and by male judges (n = 4) was 0.783. For masculinity – femininity ratings inter-rater reliability was 0.717 for female judges and 0.823 for male judges. Within each judge, scores were z-transformed, to control for scale usage. Although judgments were made on all target photographs by all judges, only opposite-sex ratings were averaged to create a score for each target photo.

Results

Descriptive Statistics, Transformations and Eliminations

All analyses were conducted with SPSS version 17 for Mac. Table 2 displays the mean, minimum score, maximum score, standard deviation and number of participants for all measures. Hairiness was positively skewed (.72) so a log10 transformation of the variable was computed. One male participant was removed from the hand masculinity calculations and all subsequent analyses because he suffered from Alopecia, which led to a complete lack of hair on his face, head and arms. The presence of nail polish may also be a factor, which influences the subjective evaluation of hands, therefore all analyses involving hand judgments were run with and without participants wearing nail polish (n = 3). The analyses did not show any significant differences so all participants were included in the reported analyses.

Sex Differences

Independent samples *t*-tests were conducted on the hand masculinity index, face masculinity measure and the indirect measures of prenatal hormone exposure to test whether the expected sex differences existed in the current sample (see Table 3). As expected, men scored higher than women on both hand masculinity and face masculinity. There were no sex differences in either right or left hand second-to-fourth digit ratio. Men had a greater number of ridge counts on both hands and more right hand asymmetry in ridge counts compared to women.

Table 2.
Descriptive Statistics

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Left 2D:4D Ratio	127	.91	1.08	.98	.04
Right 2D:4D Ratio	127	.90	1.06	.97	.03
Average 2D:4D Ratio	127	.92	1.06	.98	.03
Left Ridge Counts	126	0	85	34.33	17.87
Right Ridge Counts	126	0	89	37.37	18.14
Average Ridge Counts	126	0	87	35.94	17.43
Ridge Count Asymmetry (R-L)	122	-19	33	3.14	8.36
Facial Masculinity Measure	107	-2.97	2.48	-.07	1.07
Hand Masculinity Index	113	-3.25	3.93	.00	1.99
Fluctuating Asymmetry	127	7.70	37.40	19.11	5.20
Face Attractiveness	112	-1.70	1.76	-.06	.80
Face Masculinity	112	-1.59	1.57	-.04	.88
Hand Attractiveness	113	-1.93	1.81	-.03	.77
Hand Masculinity	113	-1.74	2.13	-.05	.87
Hand Dominance	113	-1.50	1.64	-.06	.75
Hand Health	113	-1.88	1.61	-.13	.70
Hairiness	116	1.00	9.00	4.14	2.21
Age	126	18	45	21.58	4.82
Body fat (%)	126	6.90	46.80	23.39	9.46
Height (feet & inches)	127	4.93	6.33	5.63	.32
Weight (pounds)	126	94.40	295.20	157.57	39.41
Elbow Width (mm)	126	53.09	81.46	66.21	6.54
Wrist Width (mm)	126	46.20	65.07	54.39	4.51

Note: Face and hand ratings are averages of opposite-sex ratings which have been z-scored within judge.

Table 3.
Sex Differences

	Men		Women				
Variable	*M*	*SD*	*M*	*SD*	*df*	*t*	*p*
Hand Masc	.56	.87	-.58	.94	105	6.43	.000
Face Masc	1.8	1.09	-1.61	.91	111	18.23	.000
Right 2D:4D	.97	.03	.98	.03	124	-.79	.430
Left 2D:4D	.98	.03	.99	.04	124	-1.26	.209
Right RC	43.25	18.49	31.83	16.17	123	3.68	.000
Left RC	37.64	19.16	31.00	15.87	122	2.11	.037
RCA (R-L)	5.49	8.05	.877	7.4	122	3.32	.001

Note: RC = ridge counts, RCA = ridge count asymmetry

Part 1:

Hand Masculinity Index. Five measures were considered in constructing an objective measure of hand masculinity: wrist width, elbow width, finger lengths, body fat, and hairiness of arms (with men hypothesized to have higher scores on all characteristics except body fat). Given the influence of sex hormones on bone growth (Veldhuis et al., 2005), wrist, elbow and finger length measurements seemed appropriate. These measurements were also readily available from the data previously collected on FA. To stay consistent with the hand displayed in target photographs, right elbow, wrist and finger measurements were used. For those 17 participants whose left hand photographs were rated, left arm and hand measurements were analyzed. Standardized scores were calculated for each of the four finger lengths and these were summed to create a finger length composite. Although second to fourth digit ratio was considered as a possible component of objective hand dimorphism it was not included in the measure for several reasons. First, having an objective measure independent of 2D:4D allows for comparisons and analyses of interactions between the two measures. Second, in this sample there were no significant differences between men (M = .978, SD = .03) and women's (M = .986, SD = .04) left hand 2D:4D [$t(124)$ = -1.24, p = .215, Cohen's d = -.22] or between men (M = .973, SD = .03) and women's (M = .978, SD = .03) right hand 2D:4D [$t(124)$ = -.792, p = .430, Cohen's d = -.14].

Theoretically, the variables used to create a hand dimorphism factor should each, themselves, be sexually dimorphic. To assess this, sex differences in wrist width, elbow width, finger length sum, body fat, and hairiness of arms were examined with separate ANCOVAs using age and age squared as covariates, as dimorphism can change with age.

Compared to women, men had significantly wider wrists ($F[1,120] = 193.05$, $p < .000$, $\eta^2 =.62$), wider elbows ($F[1,120] = 140.62$, $p < .000$, $\eta^2 = .54$), and longer fingers ($F[1,120] = 89.07$, $p < .000$, $\eta^2 = .43$). Men had lower body fat levels ($F[1,120] =35.93$, $p < .000$, $\eta^2 = .23$), and were rated as having more hair on their arms ($F[1,120] = 45.77$, $p < .000$, $\eta^2 = .29$). There were no significant effects of age or age squared in any of the above analyses.

Although men on average have longer fingers than women in absolute terms (due to their overall larger size), longer fingers are hypothesized to be an attractive trait in women. In their study on digit length and hand attractiveness, Saino et al. (2006) reported finding a positive allometric relationship between digit length and height for both men and women. They also reported similar positive relationships between attractiveness and absolute length as between attractiveness and finger length relative to height. To derive a measure of finger length controlling for body size the finger length sum was regressed on height ($F[1, 124] = 189.12$, $p < .000$, $B = .78$) and unstandardized residual scores were computed. The residuals from this analysis represent the proportion of finger lengths not explained by height. Although there were no sex differences in this new finger length variable [$t(123) = .974$, $p = .33$, Cohen's $d = .17$], it was considered for inclusion as a feature that may load on a female-typical factor.

The five variables were entered into a principal components analysis to reduce the data to a smaller number of factors. The *r*-matrix showed that most variables correlated fairly well with each other but no correlation was over .9 (determinant = .264). Bartlett's test of sphericity was significant [$\chi^2(10) = 145.89$, $p < .000$], indicating the correlation matrix was significantly different from an identity matrix where all variables are uncorrelated. The Kaiser-Meyer-Olkin measure of sampling adequacy (Kaiser, 1970) indicates whether the pattern of correlations among variables is diffuse or compact. The KMO ranges from 0 to 1, with values below .5 suggesting that the variables included in the analysis may not be appropriate for a factor analysis. The overall KMO statistic (.612) was higher than the suggested minimum of 0.5 so all variables were kept in the analysis. Based on the scree plot (Cattell, 1966) and eigenvalues larger than 1.0 (Kaiser, 1960), two factors were extracted (eigenvalues = 2.2, 1.16, .86, .59, .20). The two factors accounted for approximately 64% of the combined variance of the five variables. A direct OBLIMIN rotation was used because there was no theoretical reason to expect factors to be independent. The factors correlated $r = 0.035$ and a VARIMAX rotation yielded similar results. Based on the pattern matrix (labeled "component" in Table 4, elbow width, wrist width, and hairiness defined the first factor. Primarily finger length residuals and body fat defined the second factor.

Table 4.
Pattern Matrix Factor Loadings for Hand Dimorphism PCA

	Component	
Variable	1	2
Elbow Width	.88	.20
Wrist Width	.91	.06
Hairiness	.69	-.29
Unstandardized Finger Length Residuals	.23	.73
Body Fat	-.21	.70

To assess whether these two factors discriminated between males and females in this sample, regression-based, estimated factor scores were entered into a discriminant analysis. Both the first factor ($F[1,111] = 248.85$, $p < .000$) and the second factor ($F[1,111] = 8.75$, $p = .004$) significantly discriminated between the sexes. On the first factor, males averaged higher ($M = .88$, $SD = .56$) than females ($M = -.78$, $SD = .55$), while on the second factor, females averaged higher (*M* = .25, *SD* = .1.02) than males (*M* = -.29, *SD* = .91). The standardized discriminant function coefficients (which are the same as standardized beta weights in a regression) were 1.05 for the first factor and -.54 for the second factor. The canonical variate correlation coefficients (which are similar to factor loadings) from the structure matrix were .86 for the first factor and -.16 for the second factor. A discriminant function score, a weighted combination of the two sexual dimorphism factor scores, was produced for each participant. When these discriminant function scores were used to predict the sex of each participant a correct classification was made 94.7% of the time. Figure 2 shows examples of male and female hands with high and low discriminant function scores. These discriminant function scores were labeled the "hand masculinity index".

Prediction 1: Objective hand and face masculinity. Theoretically, an objective measure of the sexual dimorphism in hands should be positively related to an objective measure of face masculinity. There may be differences in the sex-typical development of faces and hands if, however, facial dimorphism predominantly reflects pubertal growth while hand dimorphism reflects combinations of prenatal hormone exposure and pubertal growth. To test the relationship between hand and face masculinity a univariate GLM was conducted using the hand masculinity index as the dependent variable, sex as a between-subjects factor and objective face masculinity as a covariate. Age, ethnicity and the face masculinity × sex interaction were also included. In an initial analysis the interaction between ethnicity and face masculinity was added to the GLM to test for homogeneity of regression slopes. The interaction was not significant [$F(1,98) = .291$, $p = .591$, $\eta^2 = .003$] which suggested that any effect of face masculinity would not differ

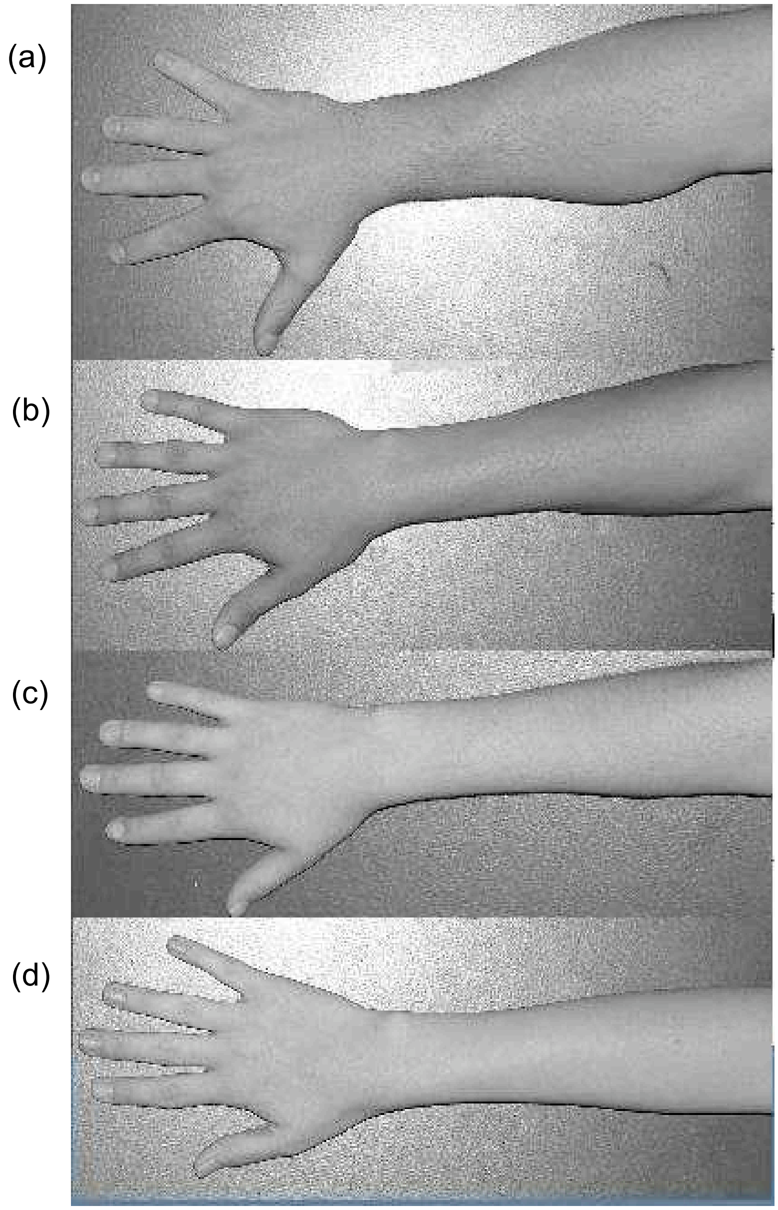


Figure 2. Example Photographs of Hands and Arms Scoring High or Low on the Hand Masculinity Index. (a) High masculinity male hand; (b) low masculinity male hand; (c) high masculinity female hand; (d) low masculinity female hand. Color versions of photographs were presented to judges.

depending on ethnicity. This interaction term was removed from the model and the GLM run again. As expected, the effect of sex on objective hand masculinity was significant [F(1,96) = 198.56, p < .000, η^2 = .67]. Ethnicity had a significant effect on hand masculinity scores [F(1,96) = 18.20, p < .000, η^2 = .16], but there was no effect of age [F(1,96) = .003, p = .953, η^2 = .000]. The relationship between face masculinity and hand masculinity was significant [F(1,96) = 4.12, p = .045, η^2 = .04] with no face masculinity × sex interaction [F(1,96) = .064, p = .801, η^2 = .001]. As seen in Figure 3, individuals with more masculine hands, as defined by this new objective index, also had more masculine faces (r = 0.200, p = .047, controlling for sex, age and ethnicity).

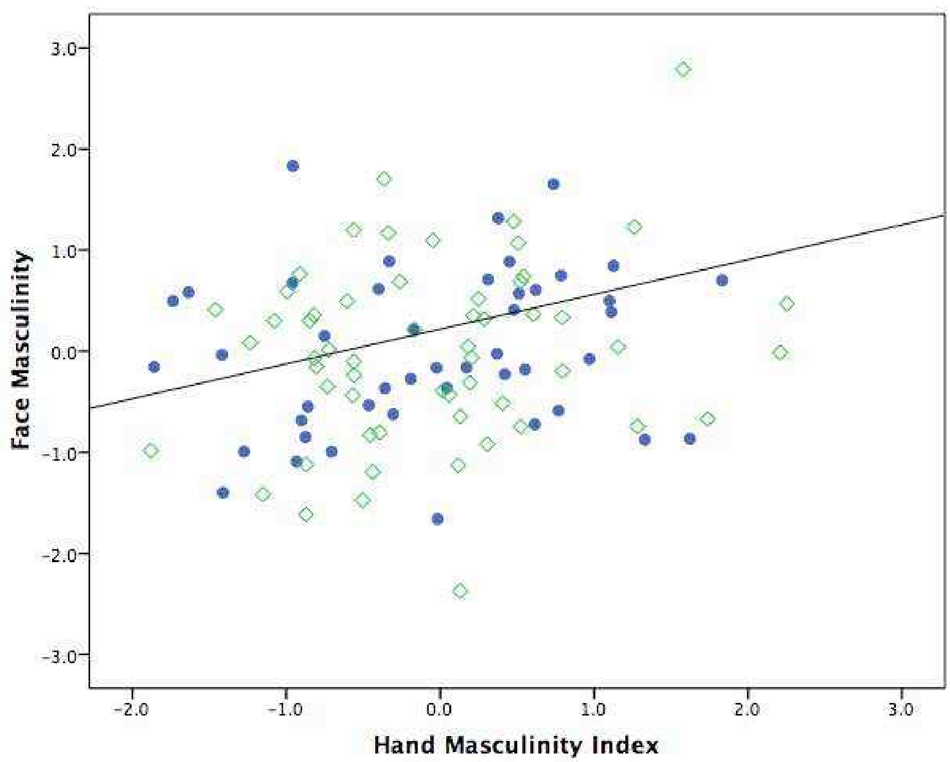


Figure 3. Scatterplot of the Relationship Between Face Masculinity and Hand Masculinity Controlling for Sex, Age and Ethnicity. Plotted on the x- and y-axis are the unstandardized residuals of hand and face masculinity, respectively, regressed on age, sex and ethnicity. Men are represented by filled circles and women by diamonds.

Prediction 2: Relationships among prenatal hormone measures. In this sample, controlling for ethnicity, there were no statistically significant relationships between right hand or left hand 2D:4D and dermatoglyphic ridge counts or ridge count asymmetries in men, although findings were in the predicted direction. Men with lower (masculine) right digit ratios tended to have higher ridge counts and more ridges on the left hand as compared to right. In women there was a positive relationship between right 2D:4D and left ridge count (see Table 5). Women with high (feminine) right digit ratios tended to have high left ridge counts. This runs counter to prediction 2 which hypothesized the association between the two indirect prenatal hormone measures would be the same for women as for men.

Table 5.

Correlations between 2D:4D, Dermatoglyphic Ridge Counts and Ridge Count Asymmetry

	2D:4D			
	Men		Women	
Ridge Count	Right	Left	Right	Left
Right	-0.126	-0.098	0.171	0.107
Left	-0.169	-0.049	0.248*	0.109
Asymmetry (R-L)	0.116	-0.093	-0.196	-0.076

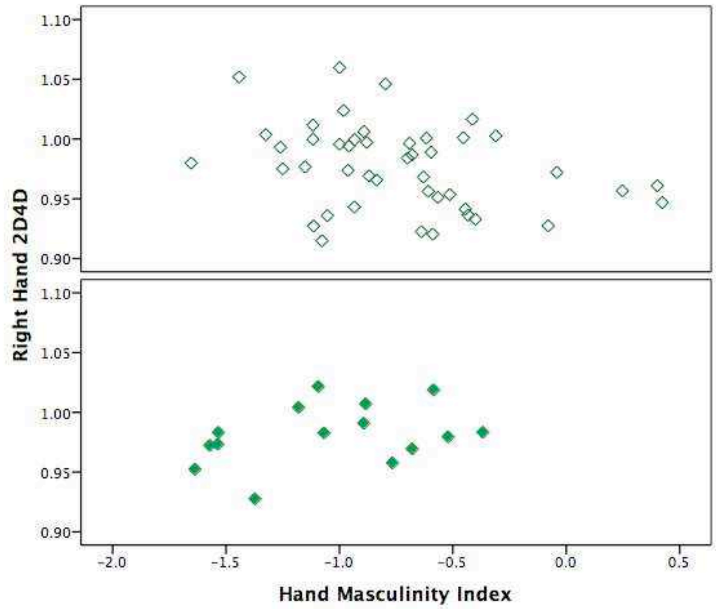
Note. Based on 59 men and 64 women. *$p = 0.052$ (2-tailed).

Prediction Set 3: Hand masculinity index and prenatal hormone measures. To test whether the hand masculinity index was related to either 2D:4D, ridge counts or ridge count asymmetry, univariate GLM's were conducted with sex as a between-subjects factor and each hormone measure (right 2D:4D, left 2D:4D, average ridge count, and ridge count asymmetry) serving as dependent variables individually. Given that 2D:4D and ridge counts have been shown to vary across populations (Manning, 2002; Kamali, Mavalwala, Khaneqah & Bhanu, 1991) ethnicity and the ethnicity × hand masculinity interaction were initially added as factors in each model. If the effect of ethnicity or its interaction with hand masculinity were not significant, the model was run again with the covariate removed from the model.

3.1: Second-to-fourth-digit ratio. In the initial analysis for right hand 2D:4D there was a significant interaction between hand masculinity and ethnicity, indicating that the relationship between digit ratio and hand masculinity differed depending on ethnicity [$F(1, 105) = 12.18$, $p = .001$, $\eta^2 =. 104$]. Given this, the analysis was re-run separately for Anglos and non-Anglos. For Anglo participants there was a significant main effect of hand masculinity on 2D:4D [$F(1, 80) = 10.99$, $p = .001$, $\eta^2 = .121$] and no significant interaction with sex [$F(1, 80) = 0.007$, $p = .933$]. Both women and men with higher hand masculinity scores had lower (or more masculine) right 2D:4D scores [$r = -.326$, $p = .003$, $n = 81$, 2-tailed controlling for sex; see Figure 4 (a) and (b)]. There was no significant curvilinear effect [$F(1, 78) = 0.703$, $p = .404$].

The analysis for non-Anglo participants also revealed a significant linear main effect of hand masculinity on 2D:4D [$F(1, 25) = 4.55$, $p = .043$, $\eta^2 = .154$] and no significant interaction with sex [$F(1, 25) = 0.264$, $p = .612$]. As Figure 4 shows, the direction of the effect was reversed for this sub-set of the sample [(a) and (b), filled symbols]. Non-Anglo men and women with low (masculine) 2D:4D tended to have lower hand masculinity scores ($r =.383$, $p = .044$, $n = 26$; 2-tailed controlling for sex). There were no significant effects in the univariate GLMs of hand masculinity on left hand 2D:4D, however the pattern of results in men was consistent with the right hand ratio.

(a)



(b)

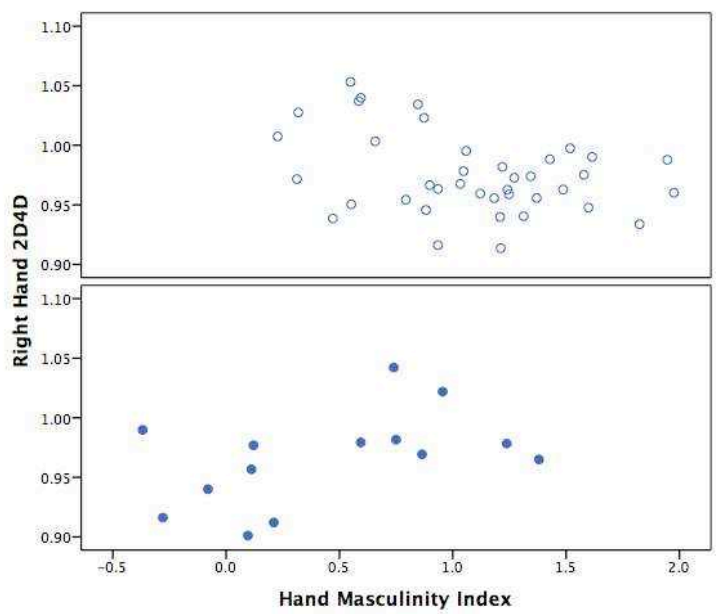


Figure 4. The Relationship Between Right Hand 2D:4D and Hand Masculinity. On the x-axis are plotted the z-transformed hand masculinity scores. (a) The negative relationship in Anglo women (top panel, empty diamonds) and positive relationship in non-Anglo women (bottom panel, filled diamonds); (b) The negative relationship in Anglo men (top panel, empty circles) and positive relationship in non-Anglo men (bottom panel, filled circles).

3.2: Finger ridge counts. In the initial GLM for average ridge counts, there was no effect of ethnicity [$F(1, 105) = .931$, $p = .337$, $\eta^2 =. 009$] and no interaction between ethnicity and the hand masculinity measure [$F(1, 105) = 1.35$, $p = .247$, $\eta^2 =. 013$]. The analysis was then re-run without ethnicity as a factor. For finger ridge counts averaged across both hands there was a main effect of hand masculinity which exceeded traditional significance at $p < 0.05$ [$F(1, 107) = 3.45$, $p = .066$, $\eta^2 =. 031$] and no interaction between hand masculinity and sex [$F(1, 107) = .057$, $p = .813$, $\eta^2 =. 001$]. As can be seen in Figure 5, when controlling for sex there is a negative relationship between finger ridge counts and hand masculinity ($r = -.196$, $p = .04$, $n = 108$; 2-tailed controlling for sex). Men and women with more masculine hands tended to have lower ridge counts. There was no curvilinear relationship between hand masculinity and ridge counts.

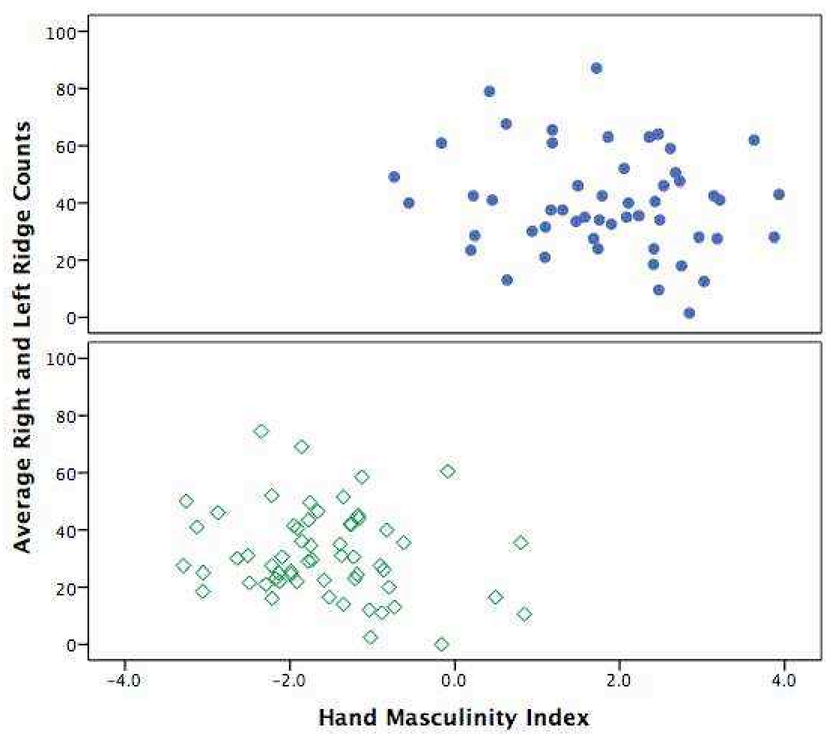


Figure 5. Association Between Finger Ridge Counts and Hand Masculinity. Men are represented in the top panel (filled circles) and women in the bottom panel (diamonds).

3.3: Finger ridge count asymmetry. Age, ethnicity and the ethnicity × hand masculinity interaction were not significant predictors of ridge count asymmetry. The linear effect of objective hand masculinity on ridge count asymmetry varied by sex [F(1, 103) = 4.32, p = .040, η^2 =. 040]. The zero order Pearson correlation, within men, was negative as predicted (r = -.267, p = .028, n = 52; 1-tailed), and was positive but not significant within women (r = .129, p = .165, n = 59; 1-tailed). The asymmetry measure was calculated by subtracting left ridge counts from right ridge counts; therefore positive values on this variable represent a higher ridge count on the right hand versus the left. According to past research men with higher circulating testosterone had more ridges on their left hand than their right (Jamison, Meier & Campbell, 1993). Men, in the current sample, with higher hand masculinity scores (which may reflect the effect of androgens on development) had lower ridge count asymmetry scores. This means that men with masculine hands had more ridges on their left fingers compared to their right.

Prediction 4.1: Hand masculinity index and FA. To investigate the relationship between FA and hand/arm masculinity, I conducted a GLM using sex and ethnicity as fixed factors, FA as a covariate and the hand masculinity index as the dependent variable. Height and age were included as covariates along with the ethnicity × FA and FA × sex, interactions. Based on similar research on faces, I predicted an interaction between FA and sex (Gangestad & Thornhill, 2003). Specifically I predicted that higher hand/arm masculinity would be associated with lower FA in men, but not in women.

Sex, height and ethnicity were significantly related to hand masculinity (see Table 6) however age was not. As table 5 shows, the interaction between ethnicity and FA was also significant. Ethnicity moderates the relationship between FA and hand masculinity across the sexes. The overall effect of FA on masculinity was not significant, but as expected the interaction between FA and sex was significant even after controlling for height and ethnicity.

Table 6.
GLM Analysis for the Effect of FA on Hand Masculinity Index

Source	Sums of Square	*DF*	*F- Ratio*	Partial Eta Squared
Sex	81.67	1	117.77***	.536
Ethnicity	6.41	1	9.24**	.083
Age	.52	1	0.75	.007
Height	10.95	1	15.79***	.134
FA	0.379	1	0.54	.005
FA x Sex	3.22	1	4.64*	.044
Ethnicity x FA	4.64	1	6.37*	.059
Error	70.73	102		

Note: *$p < .05$, ** $p < .01$, ***$p < .001$

Separate analyses within each sex revealed that among women (n = 57), FA was positively correlated with hand masculinity after controlling for ethnicity (r = .231, p = .078; 2-tailed), while for men (n = 49) the relationship was negative (r = -.181, p = .203; 2-tailed controlling for ethnicity). Women with feminine hands and men with masculine hands tended to be more symmetric (see Figure 6).

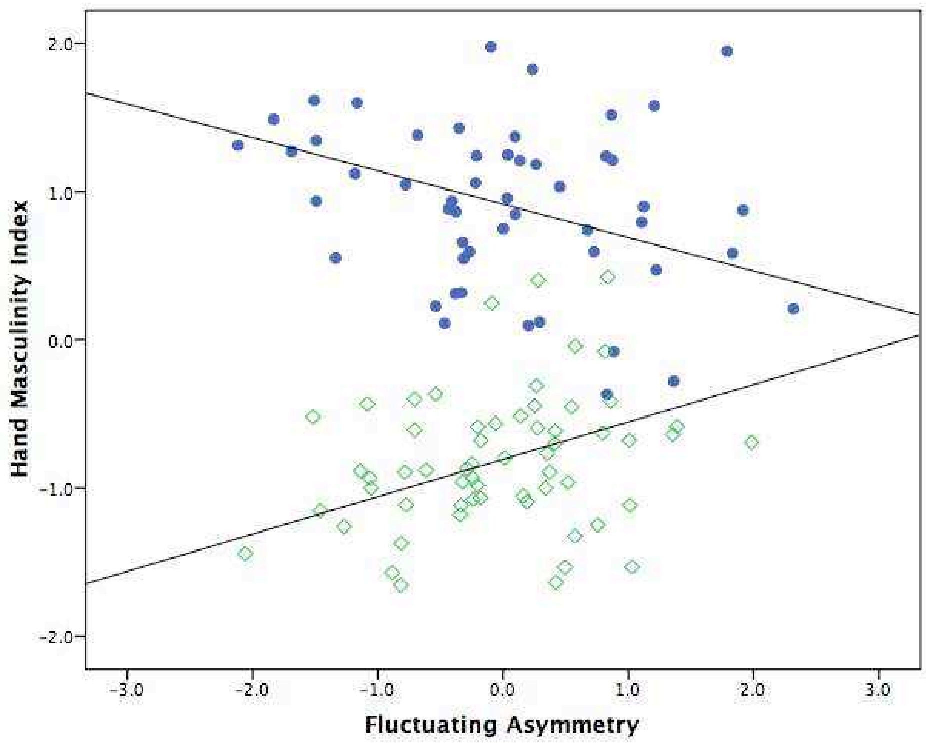


Figure 6. Scatterplot of the Relationship Between Hand Masculinity and FA by Sex. Values on the x-axis and y-axis have been converted to z-scores. Men are represented by filled circles and women by diamonds.

Prediction 4.2: To explore this relationship further, individual univariate GLM's were run on each of the five variables that made up the masculinity index (see Table 7). Height and age were again used as covariates, along with all possible interactions between height, FA, and sex. When the same model was run with ethnicity added as a factor the results did not vary.

The interaction between sex and FA was significant for only one variable: elbow width [$F(1, 113) = 4.87$, $p = .029$]. The relationship was not significant in men, but in women elbow width was positively related to FA ($r = .338$, $p = .004$). Women with larger elbows were relatively more asymmetric than their smaller boned counterparts.

Table 7.
GLM Analyses for Individual Hand Masculinity Index Measures and FA

		Elbow Width	Wrist Width	Finger Length Residuals	Hairiness	Body fat
Variable	*df*	*F*	*F*	*F*	*F*	*F*
Sex	1	18.06***	26.79***	1.79	6.08*	41.03***
Age	1	0.77	5.25*	1.68	2.48	8.72**
Height	1	31.97***	40.66***	0.92	3.81+	9.94**
FA	1	3.68+	0.03	0.11	2.54	6.92*
Sex × Height	1	0.20	1.49	0.01	1.04	1.88
Sex × FA	1	4.87*	0.68	0.66	2.53	0.62
Height × FA	1	9.28**	0.31	0.07	0.93	4.89*
Sex × Height × FA	1	1.03	0.69	0.10	0.68	4.49*

Note: All analyses based on denominator degrees of freedom = 104 except hairiness df_{den} = 102.
+$p < .10$, *$p < .05$, ** $p < .01$, ***$p < .001$

The main effect of FA (p = .01) and a sex × height × FA interaction were significant for body fat (see Table 7, p = .036). Separate GLM's within each sex for body fat revealed that the height and FA interaction was only significant in women [$F(1, 59) = 6.80$, p = .011]. For men, individuals with higher body fat tended to be more asymmetric (r = .288, p = .014). To analyze the interaction in women, a dichotomous variable was created based on a median split for height. For women who scored below the median height, body fat was negatively related to FA (r = -.239, p = .09), while the reverse was true for women who scored above the median in height (r = .224, p = .10). In shorter women, having higher body fat was associated with being more symmetric. Amongst taller women, however, lower body fat was associated with increased symmetry. This should be qualified by adding that in this sample there were more cases of women with very low body fat in the below median height group (25% of cases below 19.67% body fat) as opposed to the above median height group (10% of cases below 20.72% body fat). There were also more women with high body fat percentages in the taller group (10% of cases above 42.6% body fat) compared to the shorter group (5% of cases above 41.75% body fat).

Part 2:

Overall, attractiveness judgments of the three different sets of photographs (hand/arm, hand only, arm only) were modestly related to each other (see Table 8). Surprisingly, attractiveness ratings of full hands and arms were only weakly related to attractiveness ratings of hands alone or arms alone in men. Judgments of masculinity were also positively related regardless of which part of the hand or arm was being rated (hand/arm-hand, $r = 0.824$, $p < .000$; hand/arm-arm, $r = .372$, $p = .020$; hand-arm, $r = .566$, $p = .015$). All other judgments of characteristics (dominance, good parent, and health) were significantly positively correlated across sets of photographs except for the relationship between ratings of intelligence in hands and ratings of intelligence in arms (hand/arm-hand, $r = .482$, $p < .001$; hand/arm-arm, $r = .173$, $p = .033$; hand-arm, $r = .017$, $p = .429$).

Table 8.
Correlations of Attractiveness Between Photograph Sets

Attractiveness Ratings		Hands Only	Arms Only
Hands And Forearms			
	All	.329***	.192*
	Men	.110	-.139
	Women	.614***	.526***
Hands Only			
	All	-	.212*
	Men	-	.425***
	Women	-	.246*

Note: *$p < .05$, **$p < .01$, $p < .001$ (1-tailed).

Prediction 5: Hand attractiveness and sex-typical hormone measures. Univariate GLM's were conducted to test whether sex-typical features of hands were found attractive within each sex. The attractiveness judgments for each of the three sets of photographs were entered individually as dependent measures, sex served as a between-subjects factor and each of the masculinity measures (hand masculinity index, 2D:4D, dermatoglyphic ridge count and ridge count asymmetry) were entered separately as covariates. Age, ethnicity and length of nails were also added as covariates.

Objective hand masculinity. For all analyses involving the hand masculinity index the interaction between ethnicity and hand masculinity was entered into the model. This interaction was not significant for any of the three photograph sets so the interaction term was removed and the analyses re-run.

Full hand and arm photographs. There were no significant effects of age or length of nails and no main effect of objective hand masculinity on attractiveness judgments of full hand and arm photographs (see Table 9). Hand and forearm attractiveness did vary with ethnicity. Non-Anglos hands (M = 0.455, SD = 0.65) tended to be rated as more attractive than Anglo hands (M = 0.169, SD =0 .69; t = 1.97, p = .051). As predicted, there was a significant interaction between sex and hand masculinity when predicting attractiveness. Controlling for age, ethnicity and nail length, more masculine hand and arm combinations were judged as attractive in men (r = .331, p = 0.010, df = 47; 1-tailed) and more feminine hand and arm combinations were judged as attractive in women (r = -.204, p = .065, df = 54; 1-tailed, see Figure 7).

Table 9.
GLM Analysis for the Effect of Objective Hand Masculinity on Full Hand and Arm Photographs

Source	Sums of Square	*DF*	*F- Ratio*	Partial Eta Squared
Sex	0.47	1	0.28	.011
Ethnicity	3.05	1	7.79**	.070
Age	0.72	1	1.83	.017
Nail Length	0.57	1	1.45	.014
Hand Masculinity	0.38	1	0.96	.009
Hand Masculinity x Sex	5.24	1	13.37***	.115
Error		103		

Note: *$p < .05$, ** $p < .01$, ***$p < .001$

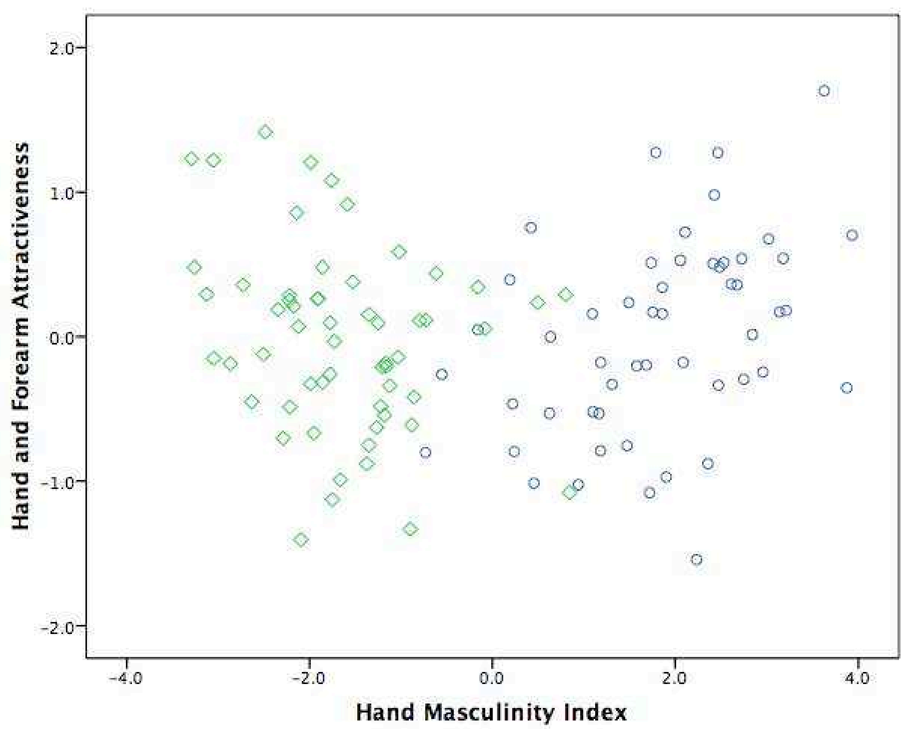


Figure 7. Relationship Between Objective Masculinity Scores and Attractiveness Ratings of Full Hand and Forearm Photographs. Plotted on the y-axis are the unstandardized residuals of attractiveness ratings regressed on age and length of nails. Men's hands are represented by filled circles and women's hands by diamonds.

Arm Photographs. Neither age, length of nails or ethnicity predicted arm attractiveness. There was a significant main effect of objective hand masculinity on arm attractiveness [$F(1, 102) = 4.75$, $p = .032$, $\eta^2 = .04$; see Figure 8] but the interaction between sex and hand masculinity was not significant for arms alone [$F(1, 102) = 2.04$, $p = .156$]. Although the interaction with sex was not significant, the tendency for individuals with less masculine arms to be judged more attractive was stronger for female arms ($r = -.368$, $p = .003$, $df = 54$; 1-tailed) than for male arms ($r = -.048$, $p = .370$, $df = 47$; 1-tailed) when controlling for age, length of nails and ethnicity.

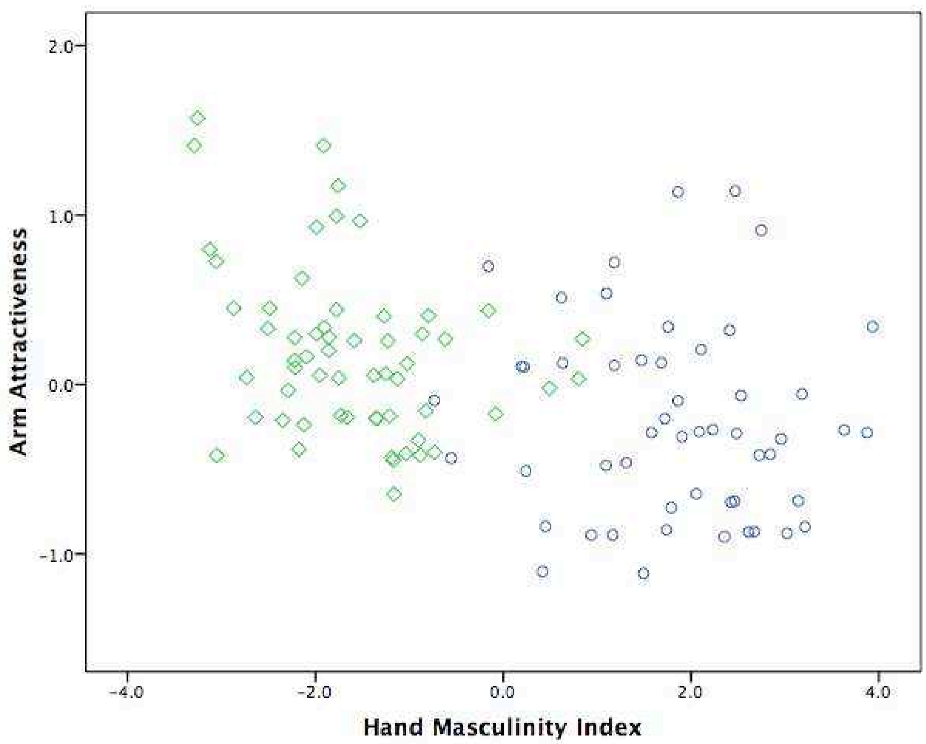


Figure 8. Relationship Between Objective Masculinity Scores and Attractiveness Ratings of Forearms. On the y-axis are plotted the unstandardized residuals of arm attractiveness ratings regressed on age, ethnicity and length of nails. Men’s hands are represented by filled circles and women’s hands by diamonds.

Hand Photographs. Attractiveness judgments of hands alone were not significantly related to objective hand masculinity [$F(1, 94) = 2.73$, $p = .101$, $\eta^2 = .02$] nor did they vary by sex [$F(1, 94) = .669$, $p = .768$, $\eta^2 = .008$].

Second-to-fourth-digit ratio. There were no significant effects of either left or right 2D:4D ratio on the three sets of attractiveness judgments. Controlling for age, ethnicity and length of nails the only significant relationship was between right 2D:4D and attractiveness of male hands/arms ($r = -.271$, $p = .029$, $df = 48$, 1-tailed). In full hand and arm photographs men with more masculine (lower) 2D:4D were rated as more attractive.

Finger ridge counts and ridge count asymmetry. None of the univariate GLM's for ridge counts or ridge count asymmetry were significant.

Relative Contributions. To test whether objective hand masculinity, 2D:4D and ridge count asymmetry account for unique variance in attractiveness ratings once the other measures are controlled for, a univariate GLM was constructed with sex as a between subjects factor, attractiveness ratings of full hand and arm photographs as the dependent measure and hand masculinity index, right hand 2D:4D, and ridge count asymmetry as covariates. The interactions of each covariate with sex were also entered into the model. There were no significant main effects of any of the three covariates nor was the interaction between sex and ridge asymmetry significant (all F's < 2, $p > .1$). The interaction with sex was significant for objective hand masculinity [$F(1,102) = 9.93$, $p = .002$] and the 2D:4D × sex interaction just exceeded significance [$F(1,102) = 2.99$, $p = .086$]. Controlling for 2D:4D and ridge asymmetry, men's hands scoring high on the masculinity index were rated as attractive ($r = .334$, $p = .018$, $n = 48$; 2-tailed) and women's hands with low masculinity were rated attractive (*r* = -.299, *p* = .024, *n* = 55; 2-tailed). Holding objective hand masculinity and ridge asymmetry constant, judges rated hands of men with low 2D:4D as attractive (*r* = -.276, *p* = .052, *n* = 48; 2-tailed) but there was no association between hand attractiveness and 2D:4D in women (*r* = .041, *p* = .760, *n* = 55; 2-tailed).

Masculinity ratings. Since separate masculinity judgments were made on the three sets of photographs, univariate GLM's within each photograph set were run with judgments of masculinity as a covariate, sex as a fixed factor and attractiveness ratings as the dependent variable. Age, ethnicity and length of nails again served as covariates.

Hands and forearms. For judgments of full hand and forearm attractiveness there was no main effect of masculinity but, the masculinity × sex interaction was significant [$F(1, 105) = 28.19$, $p < .000$, $\eta^2 = .18$]. Consistent with predictions, controlling for age, ethnicity and length of nails, men with masculine hands/arms were rated as more attractive (*r* = .357, *p* = .022, *df* = 39, 2-tailed) and women with more feminine hands/arms were rated as attractive (*r* = -0.417, *p* = .001, *df* = 55, 2-tailed).

Hands. For judgments of hands only, there was once more an interaction between masculinity and sex [$F(1, 96) = 34.58$, $p < .000$, $\eta^2 = .26$]. Men were judged as more attractive if they had masculine hands (*r* = .353, *p* = .024, *df* = 49, 2-tailed) while women were more attractive with more feminine hands (*r* = -.774, *p* < .000, *df* = 54, 2-tailed).

Arms. There was no main effect of rated masculinity on arm attractiveness [$F(1, 107) = .153$, $p = .696$] but the masculinity × sex interaction was significant [$F(1, 107) = 7.993$, $p < .000$, $\eta^2 = .26$]. Partial correlations, controlling for age, ethnicity and length of nails, within each sex showed that women with feminine arms were found attractive

(r = -0.551, $p < .000$, df = 56, 2-tailed) while men with masculine arms were attractive (r = .493, $p < .000$, df = 48).

Attractive features of hands. To partially replicate and extend finding from Siano et al. (2006) I calculated correlations between attractiveness and individual features of hands [second digit length (2D), fourth digit length (4D), 2D divided by height, 4D divided by height] as well as new features previously unexplored [third digit length (2D), fifth digit length (5D), age, length of nails, and the individual features that factored into the hand masculinity index]. Table 9 displays the first order Pearson correlations for attractiveness ratings from each set of photographs for men and women separately.

Male Hand Attractiveness. In men an interesting picture emerged. First, hairiness was negatively related to attractiveness when women were judging men's hands or arms separately. However, when rating full photographs of hands and arms the tendency was reversed and women tended to prefer men with hairy arms. A curvilinear regression was run on each of the photograph sets, and in addition to the linear relationships there were significant curvilinear relationships between hairiness and attractiveness for ratings of full hand and arm photographs [$F(2, 51) = 4.60$, $p = .015$, $b_1 = 0.565$, $b_2 = -0.044$] as well as for ratings of hand only photographs [$F(2, 51) = 4.35$, $p = .019$, $b_1 = 0.635$, $b_2 = -0.073$]. The quadratic relationship for attractiveness ratings of arm only photographs was in the same direction but did not reach significance with $\alpha = 0.05$. In this sample, men with an intermediate level of hairiness were considered most attractive, while those with less hairy or very hairy hands and arms were less attractive.

When judging photographs of men's hands only, women in this sample found younger hands with shorter fingernails and smaller wrists to be attractive (Table 10).

Table 10.
Attractiveness of Hand Features by Sex of Hand and Set of Photographs.

	Attractiveness ratings of					
	Men			Women		
Feature	Hand/ Arm	Hand	Arm	Hand/ Arm	Hand	Arm
2D	.	.	-.304*		.292*	
3D	.	.	-.277*	.103	.324*	
4D	.	.	-.178	.168	.346**	
5D	.	.	-.284*	.121	.333**	
2D/Height	-.117	.	-.248+	.302*	.214	-.123
3D/Height	.	.	-.195	.361**	.231+	
4D/Height	.	.		.406**	.267*	-.103
5D/Height	.	.	-.181	.388**	.279*	-.102
Age	.152	-.313*	-.146	-.244+	-.150	
Length of Nails	.	-.276	-.144	.208	.114	-.171
Elbow Width	.	-.198	-.363**	-.256+	-.293*	-.334**
Wrist Width	.118	-.251+	-.143			
Finger length Residuals	.	.	-.191	.367**	.267*	-.112
Hairiness	.300*	-.266+	-.238+	-.176	-.111	-.489**
Body fat	-.231+	-.203	-.393**	-.387**	-.344**	-.204

Note. Correlations less than 0.10 suppressed. Based on 53 men's and 60 women's hands.
+ p <.10, *p <.05, **p <.01 (2-tailed).

There were no significant relationships between hand attractiveness and digit length. This failed to replicate the findings from Siano et al. (2006) that longer second and fourth digits were preferred in both men and women.

It was likely hardest, in the present study, for individuals to rate photographs of forearms without the surrounding context of a hand, elbow or shoulder. Surprisingly, in men, ratings of forearm attractiveness were associated with several features of the hand.

It appeared that women preferred men with shorter fingers (except for the fourth digit), however, the photographs only included forearms from the wrist to the elbow so judges could not actually be basing their ratings directly on finger length. In the present dataset, wrist width, elbow width and the lengths of all digits, except for the fourth digit, were positively correlated with body fat and height. Partialing out either body fat or height reduced the correlations between attractiveness and finger lengths (2D, 3D, and 5D) but the relationships remained significant. The relationship between arm attractiveness and finger lengths disappeared, however, when both body fat and height were controlled. It may be possible, then, that women raters inferred some aspect of overall size from the forearms of men. If this were true, in this sample, women showed a preference for smaller men when judging forearms alone.

Female Hand Attractiveness. In women, younger hands with longer fingers (2D, 3D, 4D or 5D), longer finger to height ratios, smaller elbows and longer nails were judged as attractive. The preference for youth supports the general prediction that younger women's hands will be found more attractive. When full photographs of hands and forearms were rated, absolute finger lengths were not associated with attractiveness, however finger lengths relative to height were. Women's hands with longer fingers for their particular height were found more attractive. As in men, body fat and height were both positively related to wrist and elbow size as well as finger lengths in women. Contrary to men, longer fingers remained attractive in women even after controlling for body fat and/or height. The strength of the relationship actually increased. In this sample, women's hands with longer fingers than are typical for their height were rated as attractive.

In addition to a significant linear relationship between body fat and rated attractiveness of hands and forearms, there was a significant curvilinear effect [$F(2, 56) = 7.202$, $p = .002$, $B_1 = 1.033$, $B_2 = -1.415$). Hands and forearms belonging to women with moderate levels (between 20% and 30%) of body fat were found most attractive.

Additional Results and Analyses

Person perception of hands. In addition to attractiveness, photographs of target hands were rated on five attributes: masculinity, dominance, intelligence, health, and good parent. As with faces, first impression judgments of individuals' may be made based on physical traits. The following analyses were run to assess whether trait attributions of target hands were related to the three objective sexually dimorphic measures. In the current data set attractiveness ratings of men's hands were positively related to all five rated attributes: (all r's > 0.45, all p's < .001, $df = 50$). In women, attractive hands were rated high on intelligence, health, and good parent (all r's > 0.55, all p's < .001, $n = 55$) but low on masculinity ($r = -.338$, $p = .01$, $df = 55$), while dominance was not significantly related to attractiveness. In the following analyses results are provided for judgments of photographs of full hands and forearms only controlling for ethnicity.

Objective hand masculinity. In men, masculine hands were positively related to all five attribute ratings (see Table 11). High objective masculinity was associated with hands rated as masculine, dominant, healthy, intelligent, and as good parents. There was a trend for women's hands scoring high on the hand masculinity index to be rated as higher in masculinity but lower in parenting qualities.

Table 11.
Relationship Between Objective Hand Masculinity and Hand Perception by Sex

	Hand Masculinity Index	
Hand Judgments	Men	Women
Masculinity	.445**	.187
Dominance	.314*	-.010
Health	.293*	.026
Intelligence	.268+	-.018
Good Parent	.312*	-.106

Note: Entries are partial correlations with the effect of ethnicity removed. Based on *df* =40 (men) and *df* = 54 (women). + *p* <.10, **p* <.05, ***p* <.01 (2-tailed).

Second-to-fourth-digit ratio. How does hand perception relate to 2D:4D? Table 12 displays the Pearson correlations between left and right 2D:4D and the five subjective attribute ratings of full hands and forearms from men and women separately. Although not reaching significance at traditional levels in this two-tailed test there was negative association between rated masculinity and right hand 2D:4D in both men and women which is what one would predict if processes involved in prenatal development were associated with adult sexually dimorphic development. Hands with masculine right 2D:4D ratios were judged to be more masculine and hands with feminine ratios were judged to be more feminine. Lower right digit ratios in men were also judged more dominant, healthier, more intelligent, and as better parents. Women with feminine left digit ratios were rated higher on the qualities of good parent and intelligence.

Table 12.
Relationship Between 2D:4D and Hand Perception by Sex

	2D:4D			
	Men		Women	
Hand Judgments	Left	Right	Left	Right
Masculinity	-.062	-.209	-.093	-.157
Dominance	-.068	-.245+	-.066	.035
Health	-.130	-.332*	-.052	-.055
Intelligence	-.275*	-.216	.280*	.003
Good Parent	-.256+	-.236+	.262*	.150

Note: Entries are partial correlations with the effect of ethnicity removed Based on *df* =49 (men) and *df* = 54 (women). + *p* <.10, **p* <.05, ***p* <.01 (2-tailed).

Finger ridge counts and ridge count asymmetry. Dermal patterns and ridges were not visible in the dorsal views of hands presented to judges in this study (and finger ridges are generally not visible) so it is unlikely that individuals actually judge hands using cues from dermal ridges. In men, ratings of masculinity, dominance, health, and the attribute of good parent were all positively correlated with finger ridge count (see Table 13). Higher values on all of these attributes were ascribed to hands with greater ridge counts. For ridge count asymmetry, there was a trend for male hands with more ridges on the left hand to be rated as masculine, which is what one might expect based on past research (Jamison, Meier & Campbell, 1993).

Table 13.
Relationship Between Ridge Counts and Hand Perception by Sex

	Ridge Count					
	Men			Women		
Hand Judgments	Left hand	Right hand	Asymmetry (R-L)	Left hand	Right Hand	Asymmetry (R-L)
Masculinity	.336*	.259+	-.193	-.202	-.129	.116
Dominance	.324*	.301*	-.076	.035	.117	.136
Health	.345*	.382**	.055	-.147	-.072	.108
Intelligence	.071	.016	-.129	-.023	.000	.058
Good Parent	.269+	.223+	-.129	-.021	-.063	-.070

Note: Table entries are partial correlations with the effect of ethnicity removed. Based on *df* =50 men and *df* =56 women. + *p* < .10, **p* < .05, ***p* < .01 (2-tailed).

Hand and face judgments. In this study, independent sets of raters made judgments of faces and hands. If sexually dimorphic hormone markers of the face and hands convey similar information we should find ratings of attractiveness correlate positively across traits. Table 14 shows the partial correlations for attractiveness and masculinity of faces and hands, controlling for age. In both men and women, ratings of attractiveness of faces correlated positively with independent ratings of the attractiveness of hands. Individuals with attractive faces tended to also have attractive hands and forearms. In addition, independent ratings of masculinity co-varied positively across features. Men with subjectively masculine faces were likely to be rated as having masculine hands, while women with feminine faces were judged as having feminine hands.

Table 14.
Partial Correlations Between Face and Hand Judgments by Sex.

	Face Judgments			
	Men		Women	
Hand Judgments	Attractiveness	Masculinity	Attractiveness	Masculinity
Attractiveness	**0.305***	0.279*	**0.253***	-0.117
Masculinity	0.329**	**0.298***	-0.214*	**0.226***

Note. Based on df = 55 (women) and df = 49 (men), controlling for age. *p <.05, **p <.01 (1-tailed).

Discussion

Summary

Altogether these results provide preliminary evidence that adult sexual dimorphism, in hands and forearms, is somewhat related to prenatal growth or hormone levels and the resulting sex-typical morphology is viewed as attractive. A composite measure, the "hand masculinity index", was constructed to objectively quantify the sexual dimorphism of hands and forearms. Individuals with sex-typical hands tended to have sex-typical facial features as measured by a methodologically similar, objective facial dimorphism composite (Thornhill & Gangestad, 2003). Sex-typical hand morphology was also related to fluctuating asymmetry, which is used as a measure of developmental stability. Individuals with fewer developmental disruptions tended to have hands that developed more typically for their sex. More specifically, men with lower FA have more masculine hands and women with lower FA have more feminine hands.

By approximately the fourth month of fetal life genetic and environmental factors set the growth patterns of second-to-fourth digit ratio and finger ridge patters differentially between the sexes. Although several studies have not found associations between 2D: 4D and facial or body masculinity (Burriss et al., 2007; Koehler, Simmons & Rhodes, 2004; Neave et al., 2004), the present study did find relationships between hand masculinity and both digit ratio and dermatoglyphic ridge counts. In Anglos, masculine hands were associated with lower 2D: 4D while the relationship was reversed in the mixed heritage non-Anglo sub-sample. The prediction that higher ridge counts (which are more common in men) would be associated with greater hand masculinity was not supported in this sample. In both sexes lower ridge counts were associated with greater hand masculinity scores.

Results from part 2 of this study support the hypothesis that sex-typical hands are attractive to the opposite sex. Neither finger ridge counts nor 2D: 4D alone predicted attractiveness, but sex-typical scores on the new masculinity index were associated with attractiveness in photographs of hands including forearms. When ridge counts and objective hand masculinity were statistically controlled, a trend toward sex-typical 2D:4D predicting attractiveness emerged. Ratings of three separate sets of photographs (hands and forearms together, hands alone and arms alone) allowed for a comparison of attractiveness across traits. In general, arms of both sexes were preferred it they were less hairy and smaller in size. Younger women had attractive hands and in general women's hands with longer fingers were preferred. Contrary to previous research (Saino et al., 2006; Manning, 2002), longer fourth digits were not preferred in men. There was a tendency for longer second digits to be disliked in male hands.

Discussion of Results

Hand Masculinity Index. An objective measure of hand and forearm sexual dimorphism was created using direct measurement of features available from the assessment of fluctuating asymmetry (elbows, wrists and finger lengths) along with other aspects of physiology hypothesized to be involved in the perception of sex-typical hands (body fat and hairiness). Quantification of the degree masculinity or femininity in hands could be achieved in several other ways including measurement from photographs or the morphing together of images to create sex-typical prototypes. One benefit to direct measurement is the ability to construct a composite using absolute trait sizes as opposed to constructing ratios. This can be done with measurement from photographs, however extra care must be made to ensure the photographs are standardized. Partial validation of the hand masculinity index came with a positive association between objective hand masculinity scores and objective face masculinity scores within each sex. Granted, this relationship only adds validity to the measure if we make the assumption that the relationship between adult face and hand masculinity is positive at the population level. As will be discussed, the hand masculinity index was also related to two other measures (2D:4D and finger ridge counts) known to be sexually dimorphic from birth.

One limitation of the current hand masculinity index was the choice of variables added to the PCA. A measure of finger lengths controlling for height was added to the model even though it likely did not contribute the discrimination between males and females in this sample (i.e. there were no difference between the sexes in finger length residuals). The finger length residuals did load, as expected, on the second "feminine" component along with body fat. Several other factors pertaining to hands could have been included in the masculinity index. Second-to-fourth digit ratio, hand length-to-width ratio, and a measure of skin coloration or elasticity could all have theoretically contributed to an objective measure of sexual dimorphism. The exclusion of 2D: 4D from the present conceptualization of the index allowed for comparisons between traits influenced by prenatal hormones and those dependent on sex hormones later in life.

Symmetry. As predicted, individuals with greater symmetry had more sex-typical hands, even after controlling for size and ethnicity. A similar result was found in previous research with male faces (Gangestad & Thornhill, 2003; but see Koehler et al., 2004). Together these findings provide support for the hypothesis that the growth of sexually dimorphic hormone-facilitated features is associated with quality in both men and women.

2D: 4D and Ridge Counts. Surprisingly, there are only two other known studies that have examined the relationship between indirect measures of prenatal growth or hormone exposure: 2D: 4D and finger ridge counts. In an unpublished manuscript Manning, Stevenson, Bundred and Pharoah (as cited in Manning, 2002, pg. 9-11) reported low digit ratios were associated with higher ridge counts on the second and fourth digits in a group of low birth weight children. Daly, Gooding, Jessen and Auger (2008) also found a small negative correlation between right 2D: 4D and total ridge counts. Interpretation of these findings is difficult, though, because neither of the previous studies controlled for sex. In the present study, the relationship between right 2D: 4D and finger ridge count tended to be negative in men and positive in women. Second digit and fourth digit growth reach relative proportions similar to adults by about week 14 of prenatal life. The ratios are hypothesized to be influenced differentially by prenatal hormones with a higher testosterone to estrogen ratio leading to a lower second-to-fourth digit ratio (Manning, 2002). Finger ridges begin to develop around the 10th week of gestation and are countable by around week 13 (Okajima, 1975; Babler, 1987). Since men have higher average counts than women it is generally expected that higher levels of androgens will lead to an increased complexity in ridge patterns and a higher ridge count (Mustanski, Bailey & Kaspar, 2002). Given the close ontogenetic timing and sexual dimorphism of these two traits it is expected that they would be negatively correlated with each other regardless of sex. Results of the current study provide support for this hypothesis in men, but the positive association in women requires explanation.

One explanation for the positive relationship between 2D:4D and ridge counts in women is sampling or measurement error. The methodology of using ridge counts from two fingers (digit I and V) as opposed to counting all of the fingers may have driven this spurious result. Given that digit V has the highest likelihood of containing an arch (Robert Meier personal communication), which has a ridge count of zero, the combined count of these two fingers may not accurately reflect the total count of all fingers. Having said this, digit I and digit V ridge count asymmetry has been successfully used to predict cognitive performance in several studies (Kimura & Clarke, 2001; Kimura & Carson, 1995). Digit I and V also have the lowest heritability of all five digits (approximately 0.5; Medland et al., 2007). This suggests that if there are non-genetic factors influencing prenatal growth these two digits would most likely be affected.

If the measurements in this sample do reflect population trends then there is another explanation that may account for the positive relationship between 2D: 4D and ridge counts in women. Abnormal androgen exposure in women may actually result in a *decrease* in ridge counts. The detailed effects of differential androgen exposure (either from the fetus or an external source) on the timing of ridge development are largely unknown. Much of the current research on individual differences in dermatoglyphic traits involves clinical populations (e.g. dyslexics, schizophrenics or individuals with chromosomal abnormalities), which may also reflect additional underlying genetic differences. As mentioned earlier, when pregnant rhesus mothers were exposed to testosterone their offspring tended to have *fewer* dermal ridges than controls (Jamison, Jamison & Meier, 1994). The authors speculated on reasons why the effects in humans may be different (including effects of experimental androgen exposure vs. natural exposure and species difference in the timing of natural testosterone secretion). One suggestion to explain species differences was that earlier testosterone secretion in humans compared to rhesus monkeys delayed ridge development until after volar pads had begun to recede (Jamison, Jamison & Meier, 1994). In support of this, Babler (1987) suggested volar pad involution begins around prenatal weeks 10 to 11 in humans, which is also when primary ridges begin to form. Ridges that develop while volar pads are still prominent tend to be whorls or loops (which result in higher ridge counts, typical of men) while arches (with counts of zero) tend to form after volar pads have regressed (Babler, 1987). If the typical onset of female ridge development is after volar pads begin to regress and the effect of excess androgens on a female fetus is to *delay* ridge development then this might actually lead to decreased finger ridge counts.

Speculatively, a less-feminine developmental pattern leading to lower ridge counts in women may also explain the current finding that women with more masculine hands tend to have lower ridge counts. Indirect support for the hypothesis comes from a study of the ridge counts of monozygotic twins who were either concordant or discordant for sexual orientation (Hall, 2000). Among female twins concordant for sexual orientation there were no significant differences in finger ridge counts. The same was not true for female twins discordant for sexual orientation. Homosexual females had lower ridge counts than their heterosexual co-twin. Even though evidence only indirectly supports a connection between female homosexual behavior and prenatal androgen exposure (Hall, 2000; Cohen-Bendahan, van de Beek & Berenbaum, 2005) the direction of this result is theoretically consistent with the present argument.

What about the relationship between 2D: 4D, ridge counts and hand masculinity in men? Although the effect was small and not statistically significant in this sample, there was a trend for low 2D: 4D men to have high finger ridge counts. This result is in the same direction as those reported by Manning (2002) and Daly et al. (2008) and is consistent with what is predicted based on chromosomal sexual dimorphism. Men with low 2D: 4D also tended to have more ridges on their left hands than their right hands (a positive correlation between digit ratio and ridge count asymmetry). Men with L > ridge counts have been shown to have higher adult levels of testosterone (Jamison et al., 1993) than their R > counterparts. In the current sample, low 2D: 4D was also associated with higher objectively measured and subjectively rated masculinity in male hands. This is what would be predicted if a sex-typical developmental trajectory existed early on and was carried throughout adult development.

As with women, however, men with higher scores on the hand masculinity index tended to have lower ridge counts. Although it is possible that either this or the negative association between 2D:4D and ridge counts is a spurious finding, there may be an alternative explanation. Meier et al. (1987) hypothesized that "a relatively constant tempo of [androgenized] growth that was set down early in prenatal life" (p. 369) leads to both more complex ridge patterns and more dimorphic pubertal growth. In their study the operational definition of "masculine" pubertal growth was late maturation, since boys tend to mature on average later than girls. The authors did find that late maturing men had higher ridge counts than early maturing men. The present operational definition of "masculine" pubertal growth is male-typical hand morphology. However, would later maturing men necessarily be expected to have sexually dimorphic phenotypes as well?

An evolutionary life history perspective might predict not. Given the costs of androgenization, a delayed on-set of pubertal growth may be ideal to make use of a longer-term strategy within a longer lifespan, while an earlier on-set of growth may actually be associated with a more masculine phenotype in order to maximize reproductive success in an uncertain environment or shorter expected lifespan. In support of this, early male puberty has been associated with an unrestricted sociosexual orientation, higher testosterone levels, higher ratings of facial masculinity and dominance, and lower 2D: 4D (Ostovich & Sabini, 2005; Lawson, 2008).

Could it be possible then that early prenatal stress or androgen exposure leads to decreased complexity in ridge patterns, lower 2D: 4D, and a more sexually dimorphic adult phenotype? The small but negative correlations between 2D:4D and ridge counts in men suggest not, but the finding that early maturing males have lower ridge counts (Meier et al., 1987) is consistent with this view. In addition, Jamison et al. (1993) reported negative correlations between total male ridge counts and adult testosterone levels implying higher adult testosterone tended to be found in men with lower ridge counts. Finally, evidence (not reported in here) from the present data indicates men with more objectively masculine faces tend to also have lower ridge counts ($r = -.249$, $p = .091$, $n = 47$). More research is needed on the developmental timing of prenatal growth. Since ridge pattern complexity is dependent on the shape of volar pads, ridge counts could either be increased or decreased by developmental disruptions depending on changes in the onset, offset, or developmental rate of either pad or ridge growth. More information is needed on the effect of early androgen exposure on normal human finger ridge counts. Although digit ratio and dermatoglyphics have both been used as indirect measures of prenatal androgen exposure they are not highly associated in adults. The windows of effect for developmental disruptions may differ for each trait and are in need for further investigation (Putz, Gaulin, Sporter & McBurney, 2004).

In men, the relationship between objective hand masculinity and 2D: 4D was moderated by ethnicity. Anglo men with masculine hands tended to have low 2D: 4D while in non-Anglo men the effect was reversed. Caution should be taken when interpreting this result among non-Anglo men since the grouping combines several different ethnicities into one (Hispanic, Asian, North and African American). It is interesting to note that individuals at the lower end of the male hand masculinity distribution tended to be non-Anglo. Phenotypically these men tended to have lighter or less hair on their arms and were slighter in bone size, however they still tended to have low, male-typical digit ratios.

Hand Attractiveness. Unique to the present study was the use of photographs of hands and forearms as target stimuli. Although hands themselves are sexually dimorphic, there are several features of forearms in particular that are hormone dependent and likely add to an overall evaluation of attractiveness. Consistent with facial research, sex-typical hands and forearms, measured both objectively and subjectively, were rated as most attractive by the opposite sex. Both 2D:4D and objective hand masculinity accounted for unique variance in hand attractiveness ratings within each sex.

Among both men and women, younger hands were rated as attractive. For women this result is consistent with research on faces and makes sense, theoretically, as younger women (to a point) tend to have higher reproductive value. The preference for younger men was most pronounced in ratings of hands alone. It is difficult to speculate about male age preferences without being able to control for the raters' own ages. In the present study, target males ranged from 18 to 45 years of age. Given that female judges were all undergraduate students, a preference for younger male hands in this sample would likely indicate a preference for individuals of similar age.

Consistent with past reports on hand attractiveness, longer second and fourth digits were attractive in unmanipulated hands of women (Manning, 2002; Saino et al., 2006; Voracek and Pavlovic, 2007). While previous authors focused solely on 2D and 4D lengths, it appears that, in the current sample, this preference also extends to the third and fifth digits as well. In women, these preferences remained significant even after controlling for height and weight.

I did not replicate previous results suggesting longer second and fourth digits were attractive in men's hands (Saino et al., 2006; Voracek and Pavlovic, 2007). When rating photographs of full hands and arms, female judges did show a slight aversion to longer second digits. Surprisingly, female judges' ratings of male forearms were negatively associated with 2D, 3D and 5D lengths, again showing an aversion to longer digits except for the fourth digit. Saino et al. (2006) speculated that longer digits were preferred because opposite sex raters were using relative scaling cues in hands to judge the target's height. The current findings suggest that cues to size may be so ubiquitous in the hands and arms that ratings of the target's forearm alone were able to drive an association with finger length. When both height and weight were controlled, the relationship between arm attractiveness and digit length disappeared in men.

Although men's hands and arms with high masculinity scores were found attractive, men with a moderate amount of arm hair were most preferred in this North

American sample. Recent research has shown the same association in faces with light stubble being judged most attractive in male faces (Neave & Shields, 2008). The thickness and coloration of body hair is sexually dimorphic and may signal dominance and age (among other traits) in males. In the present sample, males with very little hair and males with an abundance of think dark hair were rated less attractive than the intermediate option. A similar curvilinear relationship has been observed with male facial masculinity when morphing techniques were used (see Rhodes, 2006 for a summary). The unaltered photographs used in the current research did not include male hands covering the whole possible range of variation from extremely masculine to extremely feminine hands. Future possibilities might include the creation of composite photographs of hands, which could then be experimentally morphed to high and low extremes. Based on the present set of results I predict extremes of femininity in male hands would be considered unattractive with the most preferred hand being masculine but not hyper-masculine.

Another related but unanswered question is what are subjective ratings of hand masculinity based on? In men, high objective hand masculinity scores, masculine 2D:4D and high ridge counts were all related to subjective judgments of masculinity. In women these associations were weak. Although simplified in this study, sexual dimorphism may not be definable by a single linear dimension between masculine and feminine extremes. Future research could quantify what constitutes sex-atypical development in men and women's hands.

A unique finding came from the comparison of the three different photograph sets in part 2 of this study (hands and forearms, hands only and arms only). In men, attractiveness ratings for their hands and forearms were not highly related to ratings for hands alone and were even slightly negatively associated with ratings of their arms alone. In addition, masculine features (both subjectively rated and objectively measured) were preferred in photographs of male hands and forearms together. The same was not true for judgments of men's forearms alone. Attractiveness ratings for women were positively related across all three photograph sets, and feminine features in women were preferred regardless of whether judges were rating hands or forearms or both. Among both men and women, individuals with attractive faces also tended to have attractive hands.

Researchers have put forth several hypotheses as to how multiple features of faces and bodies relate to each other and to attractiveness (Møller and Pomiankowski, 1993; Grammer, Fink, Juette, Ronzal, & Thornhill, 2002). The redundant signal hypothesis suggests each feature reflects overall fitness, therefore evaluating several traits together can provide reliable information about an individual. This hypothesis predicts mate choice relevant traits should be positively related to one another. In women, this hypothesis has been supported by several studies revealing positive correlations between separate features such as faces, nude fronts, nude backs and body scents (Thornhill & Grammer, 1999; Rikowski & Grammer, 1999; Grammer et al., 2002). My findings add support for this model of female attractiveness. Women with attractive hands also tended to have attractive arms and faces. Theoretically this makes sense, as women do not generally have to make the same trade-offs between mating effort and parenting effort as men do. Physically, features that make women attractive as good mates also tend to make them attractive as good parents.

The multiple messages hypothesis proposes that different features may communicate different aspects of fitness relevant information. As mating effort often interferes with parental effort in men, attractive traits in a good genes mate may not be the same traits that are ideal in a long-term partner. Cunningham, Barbee and Pike (1990) found that separate features of men's faces signaled neoteny, expressivity, and maturity and that a combination of all three of these traits was maximally attractive. Evidence that women's mate preferences for masculinity in faces are dependent on mating context or menstrual cycle phase suggests female interest in a mixture of qualities (Penton-Voak et. al., 1999; Johnston, Hagel, Franklin, Fink, & Grammer, 2001). Men who might be able to optimize signals of multiple qualities may be maximally attractive. The present analysis did not provide a direct test of this hypothesis but certain results suggest further exploration may be warranted. While masculine hand and arm combinations were found attractive in men, some feminine features (less hair, smaller elbows) were preferred when women were rating men's arms alone. This may suggest multiple messages. Masculine hands may communicate high prenatal androgen exposure and a genotype able to support sex-typical life history of growth. Less masculine forearms (smaller bone growth, higher body fat, lower muscularity and less course, dark hair) may provide cues to lower levels of dominance, aggressiveness and higher relative investment in parental care versus mating effort. An alternative hypothesis is that judging photographs of arms alone may be such a novel task that judges are less certain of what an attractive arm would look like. Although this possibility cannot be ruled out entirely, the inter-rater reliability for attractiveness ratings of arms alone was relatively similar to ratings of hands only or hands and arms combined.

Person Perception of Hands. In addition to attractiveness, judges rated full hand and forearm photographs on masculinity/femininity, dominance, health, intelligence and the attribute good parent. There was a trend for women's hands with low right 2D:4D, low ridge counts, and high objective hand masculinity to be rated as masculine. Judgments of masculinity and dominance in male hands were associated with high objective hand masculinity, low right hand 2D:4D, and high finger ridge counts, as predicted. This suggests that early sex-typical development is related to and reflected in adult hand morphology, which is subjectively evaluated as masculine or feminine.

In the present sample men's hands with lower 2D:4D were rated higher in health, and intelligence as well as being rated as better parents. In their study on hand attractiveness, Voracek and Pavlovic (2007) found relationships among male participants that contradicted their predictions and that were in the opposite direction to the present findings. The authors reported mostly positive correlations between male 2D:4D and rated masculinity, dominance, and health, which suggests that men's hands with feminine ratios were perceived as more masculine, dominant and healthy. The differences in findings between studies may be due to random error or may be due to methodological differences. Voracek and Pavlovic (2007) had participants rate palm photographs, while dorsal photographs of hands were used in the current investigation. Another distinction between studies was whether the judges were informed of the sex of the target hand (no in the previous study, yes in the present study). As mentioned before, this is important particularly if subjective ratings are hypothesized to be dependent on sexually dimorphic morphology. An androgynous hand might be rated as masculine if belonging to a woman but rated as feminine if belonging to a man. An alternative explanation is that the discrepancies are due to the added information provided by forearms in the current set of photographs. When photographs of the dorsal view of the hand without forearms were analyzed, the relationships between 2D:4D and attribute judgments for men in the present sample tended to be similar to those reported by Voracek and Pavlovic (2007) (positive) although effect sizes were small and not statistically significant (results not provided for brevity).

Although not specifically predicted, sex-typical male hands were rated as healthier in this sample. Whether measured by 2D:4D, objective hand masculinity or ridge counts, masculine male hands tended to be rated as healthier. This adds support to findings by Scott et al. (2008) who found sex-typical faces were rated as healthier in a Malaysian population.

A limitation to part 2 of this study was that only a few judges rated each photograph. Due to this, inter-rater reliability for hand judgments tended to be lower than typically accepted. The average correlation between pairs of raters for hand attractiveness was, however, comparable to what has been reported in past research (Saino et al., 2006). An increase in the number of judges could increase reliability and allow for an investigation of rater contexts (e.g. relationship status, menstrual cycle phase or own mate value) that may influence ratings of hand attractiveness. Attribute ratings in the present study also did not differentiate between short-term and long-term preferences for mates. Based on research with faces and bodies, preferences for masculine hands would be expected to be greater when women judges are at peak fertility, when rating potential short-term partners, when women are higher in mate value, or when women's own long-term partners are lower in mate value (Penton-Voak & Perrett, 2001; Scott et al., 2008).

As one of the first exploratory studies of hand attractiveness, these results suggest interesting directions for future research. While the focus of the present research was directed toward the attractiveness of sex hormone mediated traits in hands, a host of other traits could carry mate choice relevant information. Particularly for the hands, various levels of grooming and cleanliness could indicate status, health, conscientiousness, and neuroticism. Also, we do not live in a two-dimensional world. There are two types of movements that our hands are generally designed for: the precision grip (e.g. holding a pen to write) and the power grip (e.g. grasping a doorknob). Hands depicted in these gripping motions could provide added information about functionality and age-related degeneration (Carmeli, Patish & Coleman, 2003). Research on skin coloration, health and age cues in hands would be an interesting extension of the current work with facial stimuli (Fink & Matts, 2007; Fink, Matts, Klingenberg, Kuntze, Weege & Grammer, 2008). Age spots, loss of elasticity, wrinkles, sagging and nail bed thinning are just a few of the results of natural aging. The effects of aging on attractiveness would likely be greater for women's hands because reproductive value is more closely tied to aging in women. Given the increasingly older, active population in Western Cultures, the number of anti-aging hand products available may not be surprising.

Conclusion

This is the first study to compare multiple objective measures of sex-typical growth to subjective ratings of attractiveness and masculinity in hands and forearms. The newly created hand masculinity index not only reflected sexually dimorphic development at puberty, but was also related to sexually dimorphic traits set early in prenatal development. Associations between fluctuating asymmetry and sexually dimorphic hand growth support the hypothesis that high quality enables increased investment in both reproductive effort and somatic maintenance. Opposite sex preferences for sex-specific hormone-mediated traits may reflect a history of selection for both direct benefits (e.g. reproductive value) and indirect benefits (e.g. intrinsic good genes) in both men and women.

Attractiveness ratings in women suggest consistent preferences for feminine features across multiple traits. Women's fertility fluctuates more than men's, varying with hormonal levels across monthly cycles throughout adulthood until menopause. Sex-hormone dependent traits in women may therefore provide helpful cues to potential mates. If results from this study can be replicated and extended, they suggest men's traits may provide multiple messages within a mating system where both genetic quality and paternal investment are valued. In species where bi-parental care enhances offspring survival, the male with the most exaggerated androgen-mediated behavior and morphology may not be the ideal mate for the long term.

Future research is needed to clarify the relationship between putative prenatal hormone measures, which would allow for better analyses of development throughout the life course. Applied research could focus on the enhancement of dimorphic features and the moderation of age related processes to enhance hand attractiveness.

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