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# Hand Grip Strength in Relation to Morphological Measures of Masculinity, Fluctuating Asymmetry and Sexual Behaviour in Males And Females

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## 1. Introduction

Human evolutionary history is, as that of any other species, characterized by phenotypic and genetic changes as a result of natural and/or sexual selection. In spite of the fact that we live in relatively unnatural environments (especially in our Western culture), signals of this evolutionary history are tractable and allow gaining insights in ancestral processes of selection. One important aspect that has received a lot of attention is the process of mate selection and attractiveness (e.g., Thornhill & Gangestad, 1999). The central working hypothesis is that particular morphological features correlate with 'genetic' quality or mate value. Selection would then favour preferences for these features (i.e., evaluated to be attractive) such that choosing a mate baring these features would increase reproductive success. This has driven research in evolutionary psychology, and the main focus has been on attractiveness, secondary sex characteristics as hormone markers, hormone levels and fluctuating asymmetry (e.g., Thornhill & Gangestad, 1999).

Overall, there is growing evidence that (especially) women evaluate sex-typical characteristics of the face, body and voice in men and that their preference may vary across the menstrual cycle. Also in women, typically feminine characteristics are judged to be more attractive. Although the adaptive value of these preferences is much more difficult to study, it appears reasonable to assume that more masculine characteristics in males correlate with increased circulating testosterone levels which in turn positively associate with dominance and physical performance while feminine characteristics reflect oestrogen levels which associate with increased fertility. Thus, there is evidence that these hormone-mediated characteristics bare information that, at least ancestrally, are important for mate selection and expected fitness. An interesting and open question then is why the sexual dimorphism in humans has not evolved to be more extreme. Most likely, some cost is associated to develop more masculine for males and/or more feminine for females. Alternatively, there is some evidence of an intra locus sexual conflict affecting fitness of siblings (Garver-Apgar et al., 2011). Most attention in the literature has been devoted to the association between masculinity and other measures of health, like fluctuating asymmetry (FA). Three possible outcomes have been proposed. More masculine or feminine features are (assumed to be) associated to higher testosterone or oestrogen levels, respectively, which, in turn, may act as an immunosuppressant (Little et al., 2008). It has, therefore, often been argued that larger secondary sexual characteristics should be related to a healthier immune system because only healthy individuals can afford the high sex hormone handicap (Little et al., 2008). On the other hand, Getty (2002) and Kokko et al. (2002) have noted that, because of trade-offs between investment in reproductive traits and somatic investment (e.g., immune defences), high quality individuals may, under intense sexual selection, be 'forced' to invest in reproduction to such a large degree that they actually have worse health and poorer survival prospects than individuals of low quality. Thus, if both symmetry and masculinity/femininity signal quality, both should be positively correlated where high quality males can grow symmetric and masculine and high quality females can grow symmetric and feminine (e.g., Little et al., 2008). However, if sexual selection drives high quality individuals to display extreme masculine/feminine features, these may come at the expense of health. Under such a scenario, high quality individuals preferred for mating, with high circulating sex hormones (testosterone or estrogens) and/or associated morphological expression of masculinity/femininity would develop a less symmetric body relative to individuals with lower circulating hormones and less extreme morphological expression of masculinity/femininity. Recently, Puts (2010) argued that androgen-dependent masculine traits may be produced in proportion to inherited immunocompetence, so that good-gene males end up little healthier than average. The regulation of androgen levels and the response to them may thus have evolved as a means of producing sexually selected traits in proportion to a male's ability to safely bare them. If so, little or no relationship between sexual dimorphism and FA is expected, as individuals would trade inherited immunocompetence for sexual competitiveness (masculinity in males, femininity in females). A recent review found little evidence for an association between FA and sexual dimorphism, supporting Puts (2010) view, but further research was clearly recommended (Van Dongen submitted manuscript). Clearly, there is a need for an integrative approach studying associations between masculinity/femininity, health and sexual behaviour simultaneously. Furthermore, the associations between different measures of masculinity/femininity are not well understood.

Indeed, measures of masculinity and femininity can be obtained in many different ways. Body masculinity is often measured objectively by the shoulder-to-hip ratio (SHR), while femininity is reflected by the well known waist-to-hip ratio (WHR). Facial masculinity/femininity can be expressed by facial shape (Little et al., 2008) and recently one study suggested that the eye-mouth-eye (EME) angle would also reliably reflect masculinity/femininity (Danel & Pawlowski, 2007). Next to these objective measurements, masculinity/femininity is often studied through ratings of pictures by the opposite sex. To evaluate the fitness-relevance of variation in masculinity/femininity, some have studied associations with sexual behaviour, like age of first sexual contact and number of sexual partners (or promiscuity). Others have studies associations with dominance. More recently, associations with physical stress have been of interest and more specifically, hand-grip strength (HGS) appears to be very relevant in this context. Physical strength, and its closely related HGS, may play an important role in male-male competition, and also appears to be, albeit weakly, related to survival (e.g., Gallup et al., 2008). Results from several recent studies are summarized in Table 1, and suggest that HSG is a promising measure of masculinity, yet, also shows some heterogeneity. In addition, there seems to be a lack of studies investigating associations between HGS and other objective measures of masculinity/femininity.

In this study we present data on relationships between HGS and i) objective measures of facial masculinity/femininity; ii) fluctuating asymmetry; iii) attractiveness and vi) sexual behaviour in a population of young males and females. The dataset presented here was not very large (total sample size of 100). Therefore, it cannot provide strong conclusions. Although the study of associations with HGS in this context is relatively new, quite some estimates have been published. It is therefore timely to review these results and combine them with the newly presented data here to come to more robust conclusions and suggestions for further research. We therefore also present a meta-analysis of all available data.

| Hypothesis tested | gender | N | Reference |
|---|---|---|---|
| HGS related significantly to 2D:4D in two samples | m | 88+52 | Fink et al 2006 |
| HGS related positively to rated masculinity, dominance and attractiveness | m | 32 | Fink et al 2007 |
| HGS related to SHR, aggressive behavior, age at first sexual intercourse and promiscuity | m | 82 | Gallup et al 2007 |
| HGS did not relate to 2D:4D | m | 82 | |
| HGS did not relate to any of the above | f | 61 | |
| HGS related to facial attractiveness and SHR, but not to number of partners and age at first sexual intercourse | m | 38 | Shoup & Gallup, 2008 |
| HGS related to perception of dance ability | m | 40 | Hugill et al. 2009 |
| HGS related to victimization, popularity but not aggression | m/f | 255 | Gallup et al., 2010 |
| HGS related to perceived aggressiveness, dominance and health, but not with attractiveness | m | 69 | |
| HGS did not relate to perceived aggressiveness, attractiveness, dominance and health | f | 93 | |

Table 1. Overview of results of relationships between hand-grip strength (HGS) and measures of masculinity and sexual behavior in previous studies.

## 2. Materials and methods

### 2.1 Study design

We measured bilateral asymmetry and masculinity/femininity from scans (HP scanjet G4050, 4800*9600 DPI) of hands and photographs (Nikon D70, 6 megapixel) of faces of 52 men and 48 women with an average age of 22.6 (SD = 2.66) and 22.3 (SD = 1.87) years respectively. The degree of handedness was also self-evaluated on a scale of 0 (extreme left-handed) to 10 (extreme right-handed). Hand-grip strength (HGS) was determined using a Biometrics precision dynamometer. For each participant, the strength was determined twice on each side and the maximum value was obtained as HGS. All participants also completed a questionnaire asking for their age of first sexual contact and their total lifetime number of sexual partners. Each photograph was rated for its attractiveness by 10 to 30 opposite sex raters. As the repeatability of these ratings was about 30%, reliable estimates of attractiveness were obtained.

For each participant the length of the left and right 2nd (D2), 3rd (D3), 4th (D4) and 5th digit (D5) as well as the width of the palm of the hand (P) were independently measured 3 times and averaged (Fig.1). On each photograph, initially 7 landmarks were placed on each side of the face to obtain measures of facial asymmetry: i.e.; the width of the eye (EW), the distance between the pupil of the eye and the widest point at the side of the nostrils (EN), and the distance between the cheek bone and the corner of the mouth (CM) (Fig.1). Landmarks were placed in 3 independent sessions (i.e., on three separate days) and distances were averaged across sessions to reduce measurement error. In addition, since traits within hands and face showed correlations in the signed FA, traits were averaged within hands and faces to obtain two composite estimates (handFA and faceFA1, see Van Dongen et al., 2009 for details). The relative lengths of the second to fourth digit (2D:4D ratio) was also calculated (see also Van Dongen, 2009).

In addition, 19 landmarks were placed (Fig. 1) and based on these landmarks, a procrustes analysis was performed in MorphoJ (available at: http://www.flywings.org.uk/MorphoJ_page.htm; Klingenberg, 2011) to extract an overall measure of facial FA (faceFA2). In addition, facial masculinity was obtained as outlined in Little et al. (2008) and the EME angle was also calculated (Daniel & Pawlowski, 2007). Masculinity was also obtained from the procrustes analysis in MorphoJ by performing a canonical variate analysis for sexual dimorphism. This will allow to visualize the sexual dimorphism and to correlate the canonical variate with the measure obtained following Little et al (2008) and as outlined in Fig.1. An average measure of facial masculinity was obtained from the four individual measures after standardisation. All measurements were performed in ImageJ, freely available at http://rsb.info.nih.gov/ij/. First we tested if measures of masculinity differed between males and females using t-tests. The correlations among the masculinity measures (facial, EME angle, HGS, 2D:4D) were also graphically explored using a biplot from a principal component analysis. Next, correlations with FA, sexual behaviour and attractiveness were also investigated.

### 2.2 Literature search and meta-analysis

Studies investigating associations between HGS, attractiveness, FA, other forms of masculinity/femininity, sexual behaviour and dominance were obtained from Web of Science and PubMed. Six papers were found of which results are summarized in Table 1. Effect sizes (Pearson's correlations) from these studies as well as the results presented here were grouped in 5 different categories: masculinity measures (objective measurements on body or face); digit ratios; ratings (of masculinity, dominance, popularity); sexual behaviour (age of first contact, promiscuity) and attractiveness. Effect sizes in these categories and for males and females were presented in a funnel plot (i.e., in relation with sample size) to explore problems of publication bias. Effect sizes were then compared among the 5 categories and between males and females by a mixed model ANOVA with reference as random effect.

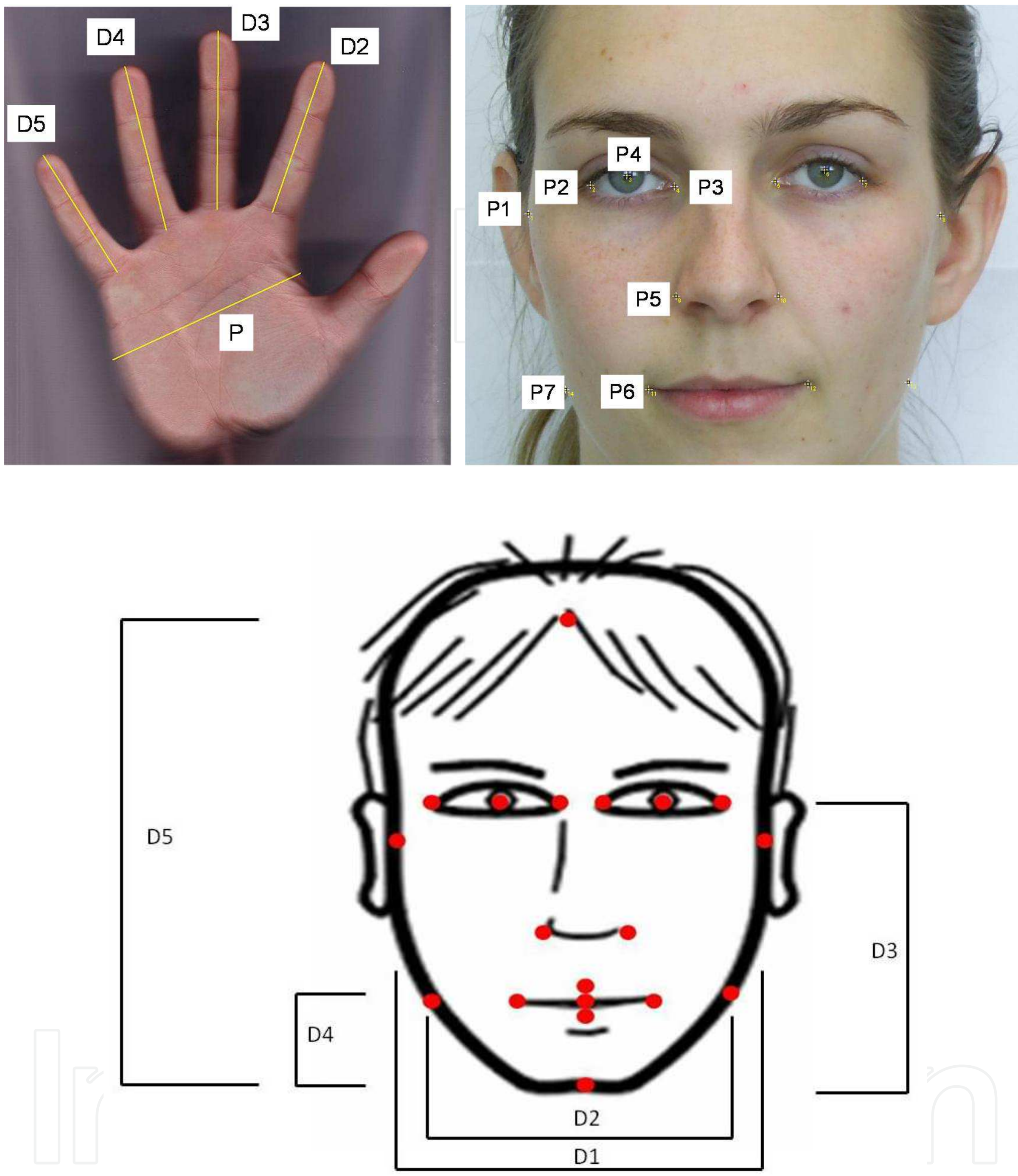


Fig. 1. Top: Scan of right hand with indication of four digit lengths (D2 to D5) and width of hand palm (P) (left) and Landmarks located at both sides of facial photographs, and linear distances derived: eye width (EW: P2-P3), distance from cheekbone to corner of mouth (CM: P1- P6), distance between pupil and most lateral side of nostril (PN: P4-P5) (right). Bottom: Position of landmarks placed on pictures of all faces (see also Little et al., 2008). Sexual dimorphism was calculated by four measures: Cheekbone prominence (D1/D2); Face width/lower face height (D1/D3); Jaw height / lower face height (D4/D3) and Lower face height / Face height (D3/D5).

## 3. Results

### 3.1 Measures of masculinity/femininity and sexual dimorphism

Each of the four measures of masculinity (based on the landmarks in Fig. 1) showed a statistically significant sexual dimorphism (Table 2). Therefore, an average measure was obtained after standardisation (further called facial masculinity or masc_face).

| | males | females | t-statistic | p-value |
|---|---|---|---|---|
| Cheekbone prominence | 1.13 | 1.17 | $t_{97}=4.25$ | <0.0001 |
| Face width / lower face height | 1.17 | 1.23 | $t_{97}=4.50$ | <0.0001 |
| Jaw height / lower face height | 0.42 | 0.41 | $t_{97}=-2.72$ | 0.008 |
| Lower face height / face height | 0.59 | 0.57 | $t_{97}=-3.14$ | 0.002 |

Table 2. Tests of facial sexual dimorphism in the four individual measures (Fig. 1).

Facial shape also differed significantly between males and females based on the geometric morphometrics approach ($p<0.0001$). The shape differences are given in Figure 2.

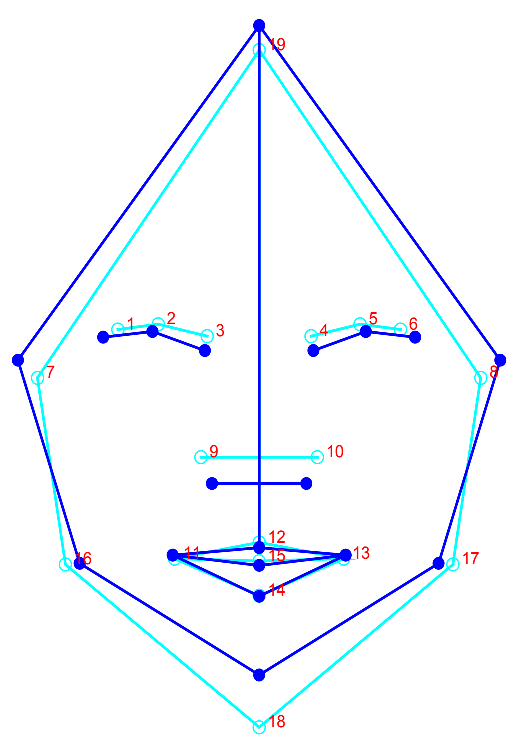


Fig. 2. Shape differences between males (light blue) and females (dark blue) from the canonical covariate analysis on the procrustes coordinates.

The canonical variate of the shape difference between males and females correlated strongly with facial masculinity as calculated above (see Table 2 for details). Thus, facial masculinity as measured by the relative proportions of different distances in the face (Table 2; Little et al., 2008) closely reflects the sexual dimorphism present in the landmarks used. We, therefore, used facial masculinity based on the relative proportions of the distances in Figure 1 for comparability with other studies.

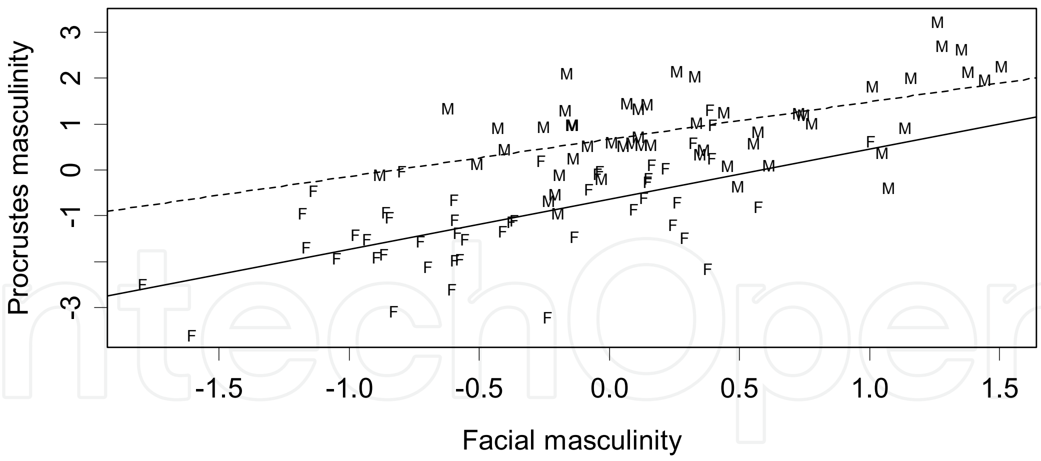


Fig. 3. Association between facial masculinity as obtained following Little et al. (2008) (facial masculinity) and the canonical variate obtained from the geometrics morphometrics approach (procrustes masculinity).

| Across males and females: | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | FAhand | FAface1 | FAface2 | 2D:4D | masc_face | HGS | angle | #partners | AFC | attract |
| FAhand | | | | | - | - | - | - | - | - |
| FAface1 | 0.05 | - | - | - | - | - | - | - | - | - |
| FAface2 | 0.08 | **0.42*** ** | - | - | - | - | - | - | - | - |
| 2D:4D | -0.08 | 0.14 | 0.13 | - | - | - | - | - | - | - |
| masc_face | -0.06 | 0.13 | 0.08 | 0.07 | - | - | - | - | - | - |
| HGS | 0.05 | -0.01 | -0.16 | -0.05 | **0.42*** ** | - | - | - | - | - |
| angle | -0.12 | -0.15 | **-0.22*** | 0.02 | -0.16 | -0.06 | - | - | - | - |
| #partners | **-0.28**** | **-0.22*** | -0.01 | -0.06 | -0.07 | -0.05 | 0.12 | - | - | - |
| AFC | 0.17 | **0.31**** | **0.20** | 0.02 | -0.02 | 0.08 | -0.04 | -0.64*** | - | - |
| attract. | -0.04 | **0.21*** | 0.02 | 0.03 | -0.08 | **-0.25*** | 0.06 | 0.06 | -0.14 | - |
| By sex (males above diagonal/females below diagonal) | | | | | | | | | | |
| | FAhand | FAface1 | FAface2 | 2D:4D | masc_face | HGS | angle | #partners | AFC | attract |
| FAhand | - | -0.13 | -0.10 | -0.10 | -0.20 | 0.07 | -0.04 | -0.21 | **0.29*** | 0.01 |
| FAface1 | 0.26 | - | **0.40**** | 0.08 | 0.21 | -0.03 | 0.12 | -0.23 | **0.33*** | -0.13 |
| FAface2 | **0.35** | **0.46**** | - | 0.19 | 0.27 | -0.11 | -0.08 | **-0.32*** | 0.20 | 0.08 |
| 2D:4D | -0.01 | 0.24 | 0.00 | - | 0.27 | 0.04 | 0.10 | -0.14 | 0.02 | 0.09 |
| masc_face | 0.04 | 0.04 | 0.01 | 0.06 | - | 0.12 | 0.09 | 0.04 | -0.17 | 0.26 |
| HGS | -0.08 | -0.13 | -0.24 | 0.17 | 0.25 | - | -0.03 | 0.09 | -0.04 | 0.04 |
| angle | -0.27 | **-0.33*** | **-0.40**** | -0.11 | **-0.34*** | 0.11 | - | 0.17 | 0.01 | 0.06 |
| #partners | **-0.36*** | -0.21 | 0.03 | 0.00 | -0.02 | 0.05 | 0.04 | - | **-0.65*** ** | -0.04 |
| AFC | -0.04 | **0.29** | **0.24*** | -0.10 | -0.05 | -0.09 | -0.08 | **-0.62*** ** | - | -0.07 |
| attract | -0.07 | -0.26 | -0.07 | --0.11 | -0.04 | -0.18 | 0.01 | 0.04 | -0.16 | - |

Table 3. Correlation coefficients and statistical significance (*: p<0.05; **: p<0.01; ***: p<0.001, indicated in bold) of associations among fluctuating asymmetry (FA) values (hand and face), measures of masculinity (face, hand grip strength (HGS), eye-mouth-eye angle and digit ratio (2D:4D)), sexual behavior (number of partners and age of first sexual contact (AFC)) and attractiveness. Correlations are given across both sexes (top table) and for males and females separately (bottom table).

Next to the facial masculinity studied here (which was significantly dimorphic: $t_{97}$=5.69, p<0.0001), only one other measure of masculinity/femininity also showed a significant sexual dimorphism in our sample. Males showed significantly higher HGS ($t_{97}$=10.1, p<0.0001), but no differences were observed for 2D:4D ($t_{94}$=1.54, p=0.12) and the EME angle ($t_{97}$=0.92, p=0.36) (see also Fig. 4). Across males and females, only HGS and facial masculinity showed a significant positive correlation (Table 3), a pattern that appeared consistent among both sexes (Fig.5), albeit not significantly so within sexes (Table 3). In woman, the EME angle and facial masculinity were negatively correlated, yet, unexpectedly, slightly positively in males (Table 3, Fig. 5). A principal component analysis of the

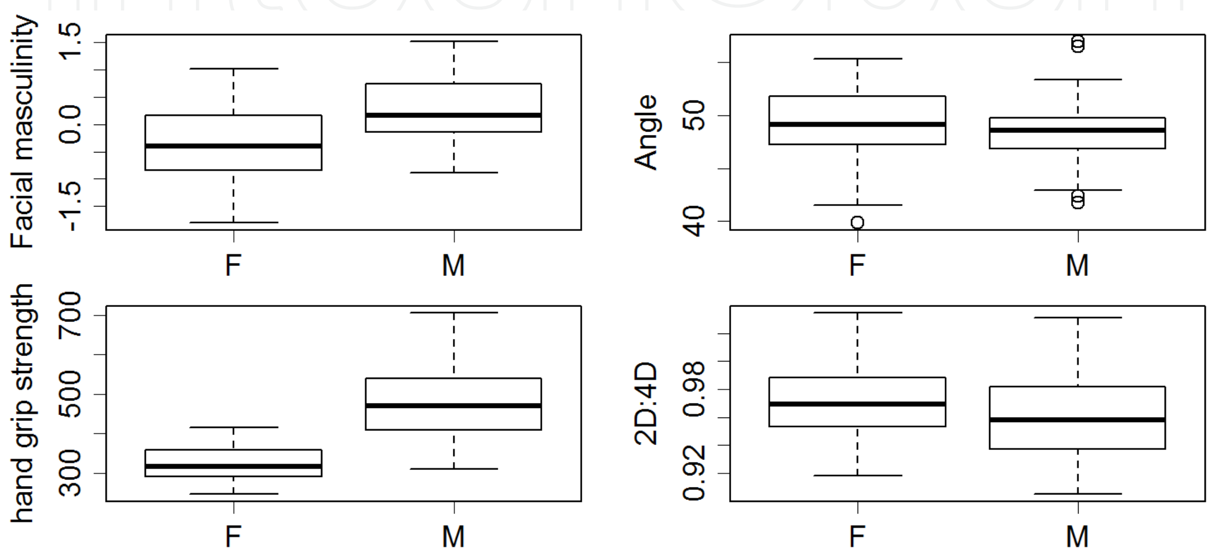


Fig. 4. Boxplots of the differences in measures of potentially sexually dimorphic traits: from top left to bottom right: facial masculinity based on the 19 landmarks, eye-mouth-eye angle, handgrip strength and digit ratio)

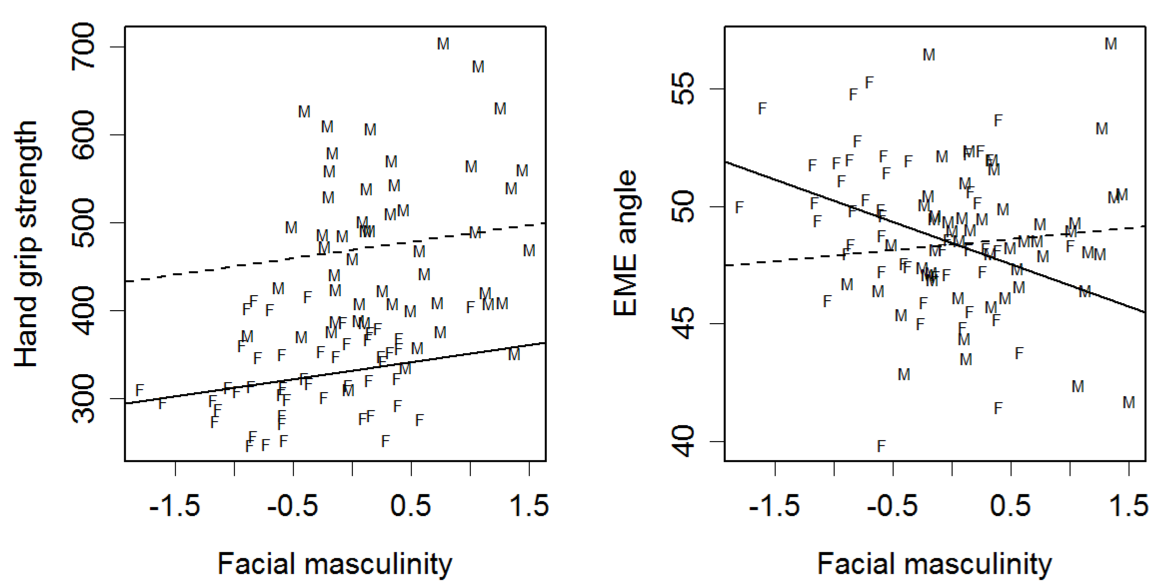


Fig. 5. Associations between measures of masculinity that were statistically significant (Table 3).

masculinity traits confirmed the lack of strong correlations. The first principal component explained 37% of the total variation and was determined by HGS and facial masculinity. The second and third each explained about 25% of the total variation and each reflected one other variable, 2D:4D and EME angle respectively (Fig.6). Thus, in order to capture a large amount of the variation, three components were required, one of which only combined variation across two variables.

### 3.2 Asymmetry measurements

The degree of measurement error (ME) of FA (i.e., the percentage of variance due to ME relative to the total variance (FA+ME)) due to scanning and placing landmarks, were the following: D2: 16%; D3: 20%; D4: 18%; D5: 13%. None of the hand measurements showed significant directional asymmetry (all $p > 0.05$). After standardization, asymmetries of hand-traits were averaged into a single measure of asymmetry per individual (FAhand). Both handedness and asymmetry in power between right and left hand were significantly correlated with the signed asymmetry of the hand (handedness: $r = 0.33$, $p = 0.001$; power: $r = 0.30$, $p = 0.001$) (see also Van Dongen et al., 2009). For the three facial characteristics measurements were less accurate (EW: 57%; EN: 14%; CM: 73%). Facial FA showed significant directional asymmetry (all $p > 0.05$), two facial traits (EW: $t_{99} = 3.2$, $p = 0.002$ and PN: $t_{99} = 1.98$, $p = 0.05$) showed larger values on the right side, on average.

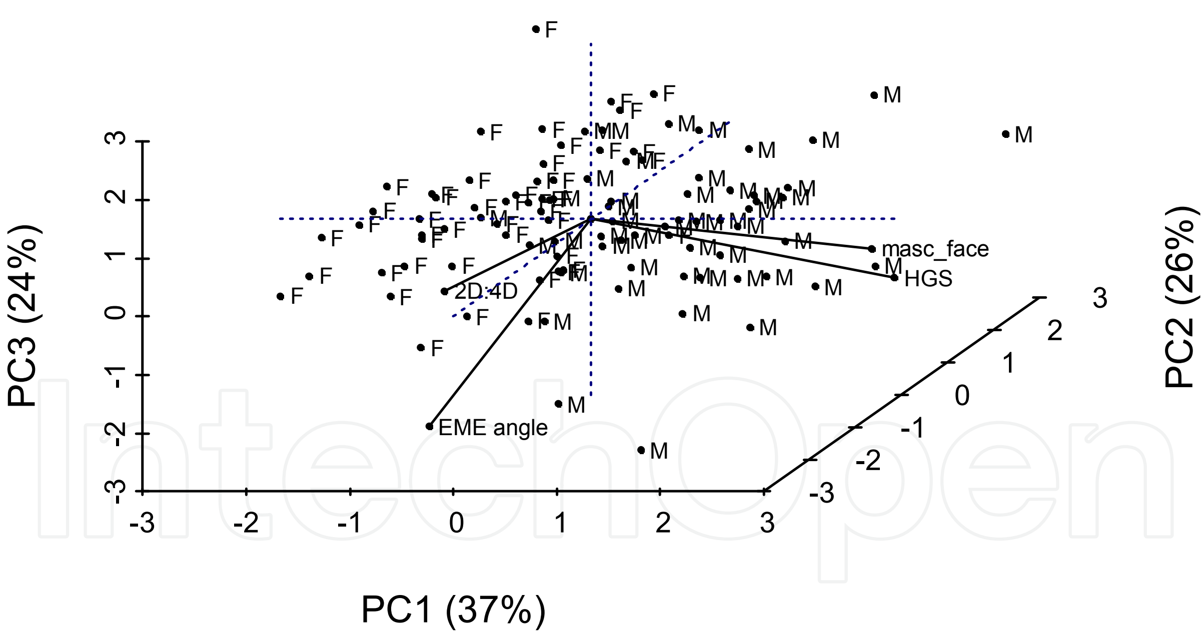


Fig. 6. 3D biplot of associations among the 4 measures of masculinity/Femininity (see text for details).

Because the three measurements of facial FA did not show high accuracy (though did show associations with sexual behavior, see Van Dongen et al., 2009 and below) we decided to take additional measurement on the face in the form of 19 landmarks. Procrustes ANOVA showed significant directional asymmetry ($F_{31,1798}=2.42$, $p<0.0001$) and significant FA ($F_{1798,1426}=2.28$, $p<0.0001$).

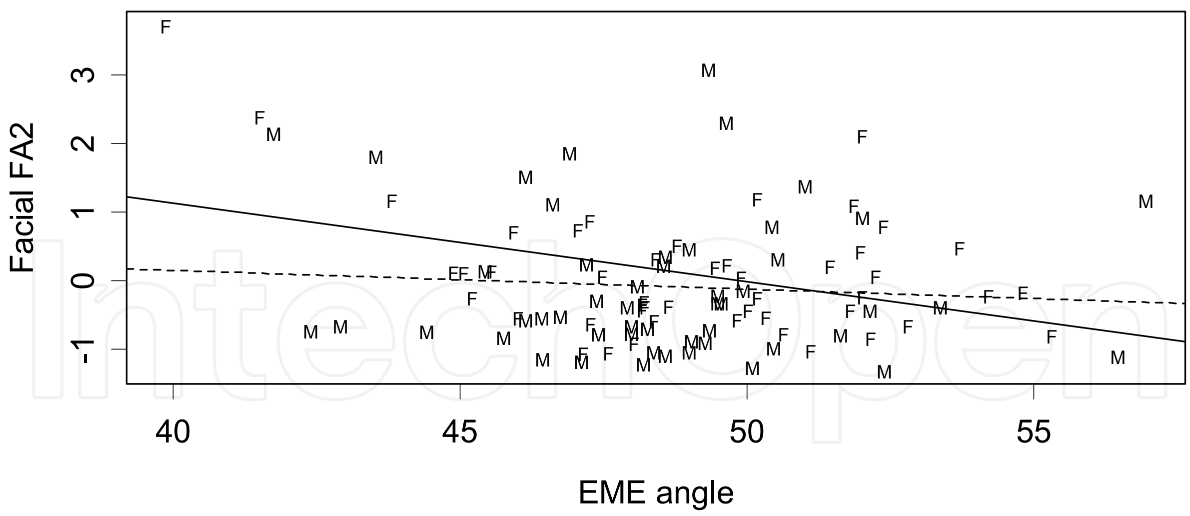


Fig. 7. Associations between eye-mouth-eye angle and facial asymmetry in males (dashed line) and females (solid line).

### 3.3 Correlations among FA, masculinity and sexual behaviour

All correlations, across both sexes and for males and females separately, are provided in Table 3. It is important to realize that many tests are being performed and some of them are significant at the 5% level just by chance. It is, therefore, only relevant to interpret correlations significant at the 5%/135=0.04% level (after Bonferonni correction). The only correlations which are significant at this level are situated between FA and sexual behaviour, between the number of partners and age of first sexual contact, between the two measures of facial FA, and between facial masculinity and HGS (Table 3). One correlation that is worth mentioning (albeit not significant after Bonferonni correction) is the negative association between EME angle and facial FA in woman (Table 3) indicating a wider (more feminine) EME angle to be associated with higher facial FA (Fig.7).

### 3.4 Meta-analysis

A funnel graph of all available effect sizes is provided in figure 8. There does not appear to be a problem of publication bias (correlation between sample size and effect size = -0.11, d.f.=81, p=0.29). 16 out of 83 estimates were statistically significant (20%) and 64 out of 83 estimates were in the expected direction (i.e., a positive effect size) (77%), a proportion that is significantly higher than 50% ($p<0.0001$). The average weighted effect size across all estimates equalled 0.19 (0.05), which was significantly different from zero ($t_7=4.00$, $p=0.007$). Thus, on average there appears to be a robust correlation. However, average effect sizes were only half as high in females (difference=-0.10 (0.03), $F_{1,74}=11.3$, $p=0.001$), and differed significantly among the broad categories of masculinity and sexual behaviour ($F_{1,66}=3.06$, $p=0.015$). Although most two-by-two comparisons were not statistically significant, averaged across males and females, the highest effect sizes that were significant at the 0.01 level were found for objective measurements of bodily and facial masculinity (average effect size: 0.24 (0.05)) and ratings of dominance and attractiveness of opposite sex raters (average effect size: 0.22 (0.05)). Lower effect sizes, albeit still significant at the 0.05 level, were observed for 2D:4D (average effect size: 0.13 (0.05)) and measures of sexual behaviour (average effect size: 0.14 (0.05)). The remaining two were even somewhat lower, no longer statistically significant but still in the expected direction: attractiveness (average effect size:

0.12 (0.08)) and self rated dominance, aggression and popularity (average effect size: 0.09 (0.05)). These differences appeared comparable between males and females as there was no significant interaction ($F_{5,68}$=2.00, p=0.09), but the power to detect an interaction was probably small. Therefore, we also present average effect sizes by sex (Table 4).

| Category | sex | effect size (SE) | p-value |
|---|---|---|---|
| 2D:4D | males | **0.15 (0.06)** | 0.02 |
| | females | **0.11 (0.06)** | 0.10 |
| Attractiveness* | males | **0.24 (0.09)** | 0.01 |
| | females | -0.07 (0.12) | 0.57 |
| Masculinity | males | **0.24 (0.06)** | <0.001 |
| | females | **0.24 (0.06)** | <0.001 |
| Ratings* | males | **0.29 (0.05)** | <0.001 |
| | females | 0.10 (0.08) | 0.24 |
| self ratings | males | **0.12 (0.05)** | 0.04 |
| | females | 0.06 (0.05) | 0.30 |
| sexual behavior* | males | **0.24 (0.06)** | <0.001 |
| | females | 0.04 (0.06) | 0.52 |

Table 4. Average weighted effect sizes of the associations between hand grip strength and other measures of masculinity (masculinity: objective measurements; ratings: ratings of masculinity and dominance by opposite sex raters; self ratings: own evaluations of masculinity, dominance, popularity; digit ratios (2D:4D), attractiveness and sexual behavior) for males and females. Categories where males have a significantly higher effect size are indicated by a * (although the interaction was not statistically significant, see text for details).

## 4. Discussion

### 4.1 Associations between masculinity, attractiveness, fluctuating asymmetry and sexual behaviour

This study, albeit small in terms of new data added to the existing literature, did not provide strong evidence that measures of masculinity would be related to sexual behaviour, attractiveness or fluctuating asymmetry. Clearly, sample sizes were relatively small, yet, it did allow to detect robust associations between FA and measures of sexual behaviour (see Van Dongen et al., 2009 for further discussion), but not attractiveness (this study). Thus, this suggests that sample sizes were sufficiently large for some aspects (i.e., associations with FA), and that asymmetry may be more closely related to sexual behaviour and promiscuity that masculinity. Nevertheless, many others have shown associations between masculinity and both attractiveness and sexual behaviour, such that this small study clearly cannot cast any doubt on the relevance of masculinity and hormone levels in human sexual behaviour and attractiveness. However, there is some doubt about the associations among different measures of masculinity and their association with sex-hormone levels (e.g., Koehler et al., 2004; Campbell et al., 2010). In this study, associations among the four objective measures were weak, with the exception of the association between facial masculinity and hand grip strength. HGS also showed a clear sexual dimorphism, as did facial masculinity. However, eye-mouth-eye angle and 2D:4D did not show correlations with facial masculinity or HGS and were not sexually dimorphic. Results for 2D:4D are discussed elsewhere (Van Dongen 2009). For EME angle, one study of similar size as this one did show a sexual dimorphism and associations with attractiveness (Danel & Pawlowski, 2007). The results presented here thus question the generality of the usefulness of EME angle as a measure of masculinity and calls for further research. In spite of the fact that EME angle did not show a sexual dimorphism in this study and did not relate to masculinity (except perhaps weakly in woman), sexual behaviour or attractiveness, there was some suggestion that it correlated with facial FA. This certainly warrants further study since associations between FA and measures of masculinity are at best very weak and results vary among studies (Van Dongen submitted manuscript).

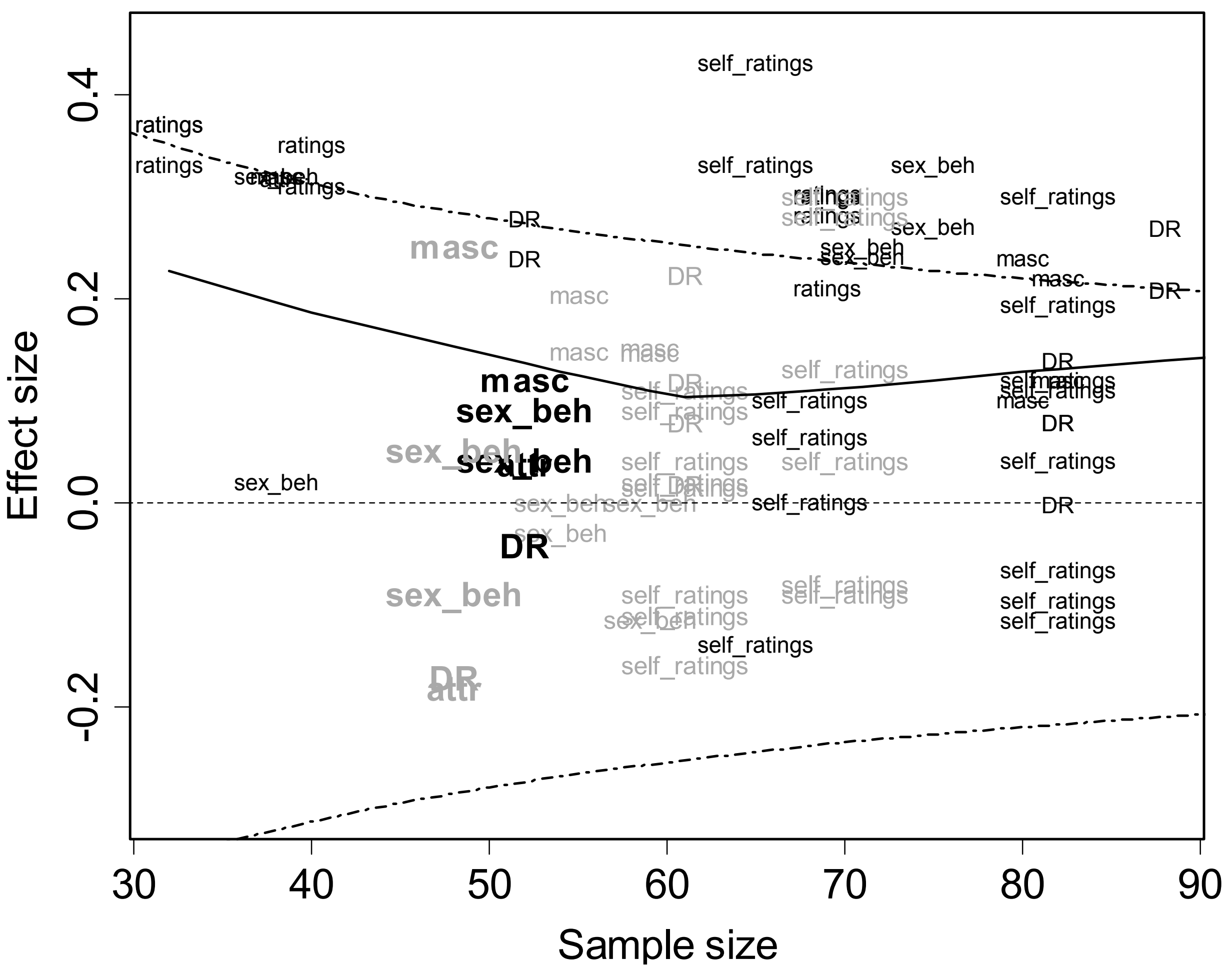


Fig. 8. Funnel graph (effect sizes vs. sample size) of the associations between hand grip strength and other measures of masculinity (masc: objective measurements; ratings: ratings of masculinity and dominance by opposite sex raters), self ratings (own evaluations of masculinity, dominance, popularity, …), digit ratios (DR: 2D:4D), attractiveness (attr) and sexual behavior (sex_beh). Dash-dotted lines represent critical values for the effect sizes, where more extreme values are statistically significant at the 0.05 level. The solid line the lowess curve of the association (or rather the lack of it in this case). effect sizes for males are given in black, those of females in grey, and estimates from this study are provided in a larger bold font.

### 4.2 Handgrip strength as a measure of masculinity

Our results show that HGS relates to facial masculinity (but not 2D:4D) in both males and females. HGS has only recently been put forward as a useful measure of masculinity (Table 1), and we here present an overview of the current literature. There appears to be a highly significant and robust average weighted effect size of about 0.2, of correlations between HGS and different correlates of masculinity/femininity. There also appears to be some variation in the effect sizes. On the average, effect sizes were smaller in females and lowest for sexual behaviour and self rated dominance, aggression and popularity. Although there was no significant interaction between sex and type of masculinity measure, the p value was only 0.09, suggesting that the difference between may not have been similar for the different categories. Although we should interpret these test with caution (and await further study), the differences in effect sizes between males and females were strongest for attractiveness, sexual behaviour and rated masculinity. In each of these, relatively strong average effect sizes were observed for males, and nearly zero for females (Table 4). Thus, HGS appears to be related to objectively measured masculinity in both males and females (Table 4 and data from this study), and to a lesser extent with 2D:4D (Table 4). For all other categories, no significant associations were found for females (Table 4). Although it may be to preliminary at this point to make any firm conclusions, our results and the combined analysis of the data from the literature suggests that HGS relates to morphological measures of masculinity alone in females, but also to attractiveness, rated and self-rated masculinity and dominance and sexual behaviour in males.

## 5. Conclusion

In this paper we study associations between objective morphological measures of masculinity/femininity and physical strength (handgrip strength) in relation to developmental instability (as measured by fluctuating asymmetry, FA), attractiveness and sexual behaviour. In spite of the relatively small sample sizes, we were able to detect associations between FA and sexual behaviour (further discussed in Van Dongen et al., 2009), yet not with our measures of masculinity. We next focussed on a relatively recently studied measure of masculinity/femininity, namely physical strength expressed as handgrip strength (HGS). We reviewed results from the recent literature and demonstrated a robust association between HGS and other measures of masculinity/femininity. In addition, we were able to detect some sources of variation. On the one hand, HGS related to morphological features of bodily masculinity (and to a lesser extent but still significantly so to 2D:4D ratios) equally strong in both males and females. However, associations between HGS and either attractiveness, (self-)ratings of dominance, masculinity and popularity and sexual behaviour were weaker or absent in females compared to males. Thus, based on the available literature we conclude that physical strength is determined by circulating hormones affecting morphologically dimorphic structures, yet affects behaviour and the physical expression of it in males only. Physical strength and masculinity is thus likely to play a role in male-male competition and as a signal of mate value in sexual selection.

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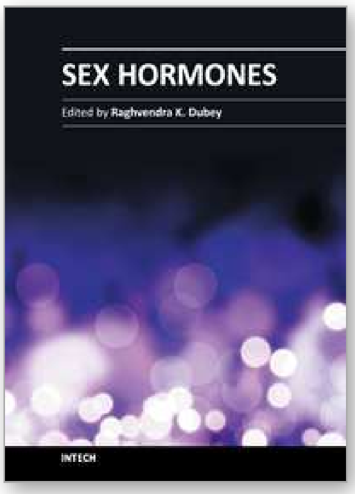


**Sex Hormones**

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Sex Hormones not only regulate reproductive function, but they also play a prominent role in the biology and physiology of several organs/tissues and in the pathophysiology of several diseases. During the last two decades, the information on the mechanisms of action of sex hormones, such as estrogens and androgens, has rapidly evolved from the conventional nuclear receptor dependent mechanisms to include additional non-nuclear, non-genomic and receptor-independent mechanisms. This highlights the need to update the current knowledge on sex hormones and their mode of action. Increasing evidence that exogenous/epigenetic factors can influence sex hormone production and action highlights the need to update our knowledge on the mechanisms involved. This book provides a systematic and updated overview of the male/female sex-hormones and their impact in the biology and physiology of various organs. Additionally, the book discusses their positive and negative association with the pathophysiology of various diseases (e.g. osteoporosis, cardiovascular-disease, hypogonadism, reproduction, cancer) and their therapeutic potential.



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