

### Original Article

## Handgrip Strength and Socially Dominant Behavior in Male Adolescents

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**Abstract:** Handgrip strength (HGS) is highly heritable and a good overall measure of strength and muscle function. Indicative of blood testosterone levels and fat-free body mass, HGS is also highly sexually dimorphic. Recent psychological research shows that HGS is correlated with a number of social variables, but only in males. We conducted three studies to further investigate the relationship between HGS and measures of aggression and social competition among adolescents. Consistent with previous reports, correlations were almost exclusive to males, but this was only visible during late adolescence (i.e., high school). These findings support evolutionary hypotheses regarding grip strength in male-male competition and suggest that similar to measures of testosterone, HGS is a measure that is predictive of social behavior in older adolescent males.

**Keywords:** adolescence; aggression; dominance; handgrip strength; testosterone

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### Introduction

The morphology of the human hand is the product of a long evolutionary history of primate arboreal adaptation and subsequent biocultural evolution in the hominin lineage. The human hand possesses both primitive characteristics such as five independent rays that articulate with carpals with two long bones in the upper limb and derived characteristics such as the relatively long, opposable pollex (thumb) (Aiello and Dean, 1990). The origin of bipedal locomotion in African late Miocene/early Pliocene hominins (Richmond and Jungers, 2008; Lovejoy, Suwa, Spurlock, Asfaw, and White, 2009) released the hominin

upper limb from its primary ancestral role in arboreal locomotion and opened the opportunity for derived behaviors such as carrying and manipulating objects in the environment (Marzke, 1999). These new behaviors (tool usage, tool manufacture, and object transport) created selective pressures that acted to modify hominin hand morphology and enable a wider array of power and precision grips (Marzke and Marzke, 2000; Young, 2003). This flexible and powerful gripping ability continues to be an important element of modern human behavior.

Recent research has demonstrated an association between hand grip strength (HGS) and indicators of fitness in contemporary college-age males (Gallup, White, and Gallup, 2007; Shoup and Gallup, 2008), suggesting that HGS may be used as a measure of variance in male intrasexual competition during adolescence. The maintenance and elaboration of HGS in human males may have provided a selective advantage to stronger individuals competing for scarce resources (Gallup et al., 2007). Young (2003) hypothesized that the selection for improved handheld clubbing prowess for protection, hunting and intrasexual competition led to anatomical changes resulting in powerful HGS among males. While some of these selective pressures are less prevalent in modern society, it appears this history has resulted in HGS's association with other sexually selected traits in males, including facial attractiveness (Shoup and Gallup, 2008), mating opportunities, masculine-specific body morphology, and intrasexual adolescent aggression (Gallup et al., 2007).

Independent of the proposed relationship with male social behavior, HGS measured by a hand-held dynamometer is also an easily obtainable measure of physical health and muscle function. Within adult populations, HGS is also a good predictor of health parameters such as protein loss (Windsor and Hill, 1988), bone-mineral density (Kritz-Silverstein and Barrett-Connor, 1994; Foo, Zhang, Zhu, Ma, Greenfield, and Fraser, 2007; Sinaki, Wahner, and Offord, 1989), muscle mass (Kallman, Plato, and Tobin, 1990; Guimaraes, Carlsson, and Marie, 2007), physical functioning (Fredericksen et al., 2002; Stenholm, Rantanen, Heliovaara, and Koskinen, 2008; Arroyo, Lera, Sanchez, Bunout, Santos, and Albalá, 2007), and is negatively correlated with disability (Giampaoli et al., 1999), morbidity (Hughes, Gibbs, Dunlop, Edelman, Singer, and Chang, 1997), and mortality rates in adults (Laukkanen, Heikkinen, and Kauppinen, 1995; Rantanen et al., 2000; Sasaki, Kasagi, Yamada, and Fujita, 2007).

Although diet and exercise contribute to one's HGS, a twin study of 1,757 pairs showed it is highly heritable after adjusting for effects of sex, weight, height and age ( $h^2 = 0.50$ , see Frederiksen et al., 2002). Likewise, these authors report no evidence for a substantial effect of nonadditive genetic factors or shared environment. Other smaller twin studies vary in the degree of genetic influence. Arden and Spector (1997) show the heritability of HGS to be lower among females ( $h^2 = 0.36$  after controlling for age, height and weight), while Reed, Fabsitz, Selby, and Carmelli (1991) estimate the heritability of male HGS to be 0.65 after adjustments of weight, height, age, and various anthropometric measures such as fatness, muscle mass and frame size.

Despite the presence of these correlations for each sex, research has shown striking sex differences in HGS among adult populations, with males far outscoring females (Kamarul, Ahmad, and Loh, 2006; Mathiowetz, Kashman, Volland, Weber, Dowe, and Rogers, 1985). Additionally, senescence accounts for a larger percentage of the variation in HGS in men, with male HGS declining more quickly after age 30 (Vianna, Oliveira, and Araujo, 2007). Sex differences have also been observed in forebrain and cardiac

sympathetic nervous responses at the onset of handgrip exercise (Wong, Kimmerly, Masse, Menon, Cechetto, and Shoemaker, 2007), with smaller cardiovascular response (heart rate and mean arterial pressure) and weaker insular cortex activation observed in women. Interestingly, this may reflect both physiological and psychological sex differences when asked to provide a maximum squeeze of a dynamometer. While greater height, weight, and muscle mass in males has been submitted as an explanation for this effect (Kallman et al., 1990; Kamarul et al., 2006; Kuh, et al., 2006), the sexual dimorphism in androgenic hormones (i.e., testosterone) may be the responsible factor. For instance, men with reduced testosterone levels caused by androgen deprivation have been shown to have low grip strength (Soyupek, Soyupek, Perk, and Ozorak, 2008), and supplementary increases in testosterone enhance HGS as well as lean body mass in elderly men with low serum T (Page et al., 2005; Sih, Morley, Kaiser, Perry, Patrick, and Ross, 1997; Wang et al., 2000).

This hormonal relationship may, in turn, explain HGS's association with indicators of male-male competition. Meta-reviews have demonstrated a positive relationship between testosterone and aggression (Book, Stazyk, and Quinsey, 2001), with this link often being more clear among males than females (Archer, 1994). In particular, research on male adolescents (15-17 years) has shown a strong relationship between testosterone and levels of verbal and physical aggression (Olweus, Mattsson, Schalling, and Low, 1980). This same effect is absent in studies of boys before and at the beginning of puberty (10-14 years), when they have not yet experienced an influx of testosterone and reproductive behaviors are less salient (Susman, Inoff-Germain, Nottelmann, Loraiux, Dutler, and Chrousos, 1987; Inoff-Germain, Arnold, Nottelmann,, Susman, Cutler, and Chrousos, 1988). Dominance is also positively correlated with testosterone levels in adult males (Mazur and Booth, 1998), and the act of competing for dominant status can increase testosterone for the winner, while decreasing it for the loser. Although testosterone levels are not associated with levels of aggression in younger males (aged 10-14 years), they did predict perceived dominance in a population of 6-13 year old males (Schaal, Tremblay, Soussignan, and Susman, 1996). Following a connection with testosterone, studies investigating HGS and aggression show that the two positively correlate in late adolescent and adult males (Gallup et al., 2007; Archer and Thanzami, 2007). To our knowledge, however, HGS has not yet been used in studying peer aggression, dominance, and social competition among younger adolescents.

The current research presents three studies investigating whether individual differences in HGS account for any of the observed variance in measures of social competition (i.e., aggression, popularity, dominance) among males and females. In the first study, HGS was collected from ninth grade high school students who also self-reported their involvement in peer aggression and victimization during middle school. The second study used the same methodology as in Study 1, but examined the retrospective high school experiences of college-aged students. Both studies also investigated the relationship between HGS and perceived popularity. The third study investigated the relationship between the HGS of twelfth grade students and independent ratings of relative peer aggressiveness and social dominance as perceived by individuals observing their yearbook photos. Based on previous research indicating a relationship between HGS, health and attractiveness, independent ratings of physical attractiveness and health were also collected. Although this third study did not directly measure behavior of the students, it served as a unique test for whether the underlying physiological features responsible for HGS also

influence outside perceptions of aggression and dominance. We hypothesized that HGS would be positively correlated with peer aggression and negatively associated with peer victimization for males, while we did not expect to find a relationship for females. Likewise, we predicted HGS would correlate positively with independent ratings of aggressiveness and social dominance in males only. General discussion of these studies will address evolutionary interpretations regarding intrasexual competition and sexual selection.

## **Study 1: Handgrip strength and self-reported aggressive behavior and popularity during middle school**

### **Materials and Methods**

#### *Participants*

Participants included 68 male (ages 13-15,  $M = 14.21$ ,  $SD = .48$ ) and 70 female (ages 14-16,  $M = 14.21$ ,  $SD = .45$ ) ninth grade high school students from a mid-sized public high school in upstate New York. Participation in this research was completely voluntary, and responses were held anonymous. This research was approved by the district superintendent and the University Institutional Review Board.

#### *Survey*

Teachers administered a social experiences survey (slightly modified from Newman, Holden, and Delville, 2005) to their freshman students during homeroom class early in the fall semester. Questions included how often they were a victim or perpetrator of (a) physical aggression (hitting, kicking, physical intimidation) (b) demeaning, diminishing and embarrassing behavior, (c) isolation, and (d) exclusion during middle school (victimization:  $\alpha = .82$ ; aggression:  $\alpha = .82$ ). Responses were recorded on a 5-point Likert scale (1 = not at all, 2 = once or twice, 3 = occasionally, 4 = frequently, 5 = very often), and for each set of questions participants were asked to identify whether the aggressor or victim was more often a male or female. Composite scores were calculated for total aggression and victimization during middle school (min 4, max 20). They also rated their popularity with their peers during middle school (1 = not at all, 2 = a little popular, 3 = somewhat popular, 4 = fairly popular, 5 = very popular).

#### *Anthropometrics and Analysis*

Participants from grades 9-12 were shown how to use a handheld dynamometer (Lafayette Instruments model 78010) during a yearly health screening session; however, we were only able to obtain survey data from ninth graders. Each subject was instructed to squeeze the dynamometer as hard as possible with one hand and then the other. Measurements were recorded (in kilograms) on two separate squeezes from each hand, alternating between right and left. Each squeeze was rounded to the nearest kilogram, and the maximum HGS of the two trials was recorded. The subsequent analyses used the average of the maximum HGS for each hand. Due to past research indicating a positive relationship between HGS and age among adolescents (Mathiowetz, Wiemer, and Federman, 1986), we controlled for age using partial correlations to analyze HGS in relation to peer aggression/victimization and popularity. Likewise, based on further data

provided by nursing staff following the health screening session, we also controlled for effects of body mass index (BMI).

**Results**

Table 1 shows the descriptive statistics of HGS and peer social experiences for both males and females. Sex differences in HGS are in accord with results from previous studies, with males outscoring females ( $t(136) = 8.71, p < .001, \text{Cohen's } d = 1.48$ ). Survey results indicate that the majority of aggressive peer interactions were intrasexual, with 85.92% of males and 73.55% of females reporting victimization, and 94.34% of males and 75.59% of females reporting aggression described the interactions as predominantly with members of the same sex. Twenty-one males and 11 females reported not being aggressive or victimized on any level during middle school. These individuals were included in the subsequent analyses.

**Table 1.** Descriptive statistics ( $M \pm SD$ ) for HGS and composite Likert scores of social variables in males and females.

|              | Right HGS  | Left HGS   | Victimization | Aggression | Popularity |
|--------------|------------|------------|---------------|------------|------------|
| Males (68)   | 37.66±7.50 | 35.02±7.08 | 6.22±2.72     | 6.31±2.35  | 3.18±1.37  |
| Females (70) | 28.71±5.10 | 26.49±5.27 | 6.30±2.95     | 6.54±3.19  | 3.61±1.17  |

Note. Victimization and aggression composite scores range from 4 to 20, while popularity ranges from 1 to 5.

Table 2 shows the partial correlations between HGS and peer aggression/victimization while controlling for age and BMI. Self-reported peer aggression and victimization was not correlated with HGS in either sex.

**Table 2.** Correlations between HGS and self-reported social variables in ninth grade students.

|               | HGS   | Victimization | Aggression | Popularity |
|---------------|-------|---------------|------------|------------|
| HGS           | -     | -.064         | .100       | -.007      |
| Victimization | .088  | -             | .210       | -.410***   |
| Aggression    | .132  | .489***       | -          | .094       |
| Popularity    | .302* | -.084         | .343**     | -          |

Note. Males are represented above the diagonal (-) and females are represented below.

\* $p < .05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$

Perceived popularity was not correlated with HGS among males, but it was positively correlated with HGS in females ( $r = .302, p < .05$ ). Likewise, perceived popularity was positively correlated with self-reported peer aggression in females ( $r = .343, p < .01$ ), but not males. Pellegrini and Long (2003) witnessed a similar positive relationship among female middle school students in regards to aggression and dating popularity. On the other hand, perceived popularity was negatively correlated with peer victimization in males ( $r = -.410, p < .001$ ), but not females. Self-reported peer aggression and victimization were highly intercorrelated in females ( $r = .489, p < .001$ ), but this was

not true in males ( $r = .210, p = .091$ ).

## **Study 2: Handgrip strength and self-reported aggressive behavior and popularity during high school**

### **Materials and Methods**

#### *Participants*

This study included 65 male and 52 female undergraduates at a mid-sized public university in upstate New York. All participants were students in an introductory biology course and ranged in age from 17-25 (males:  $M = 19.35, SD = 1.09$ ; females:  $M = 19.43, SD = 1.30$ ). Participation was voluntary and all responses were held anonymous. The University Institutional Review Board approved this research and each individual gave consent for their participation in this study.

#### *Survey*

The same social experiences survey was given as in Study 1, but participants were asked to respond according to their experiences during high school (victimization:  $\alpha = .66$ ; aggression:  $\alpha = .74$ ). Responses were recorded on the same 5-point Likert scale (1 = not at all, 2 = once or twice, 3 = occasionally, 4 = frequently, 5 = very often), and for each set of questions participants identified whether the aggressor or victim was more often a male or female. As in Study 1, aggression and victimization composite scores were calculated as an index of overall aggression and victimization across high school (min 4, max 20). Similarly, a question was asked about how popular they were with their peers during high school (1 = not at all, 2 = a little popular, 3 = somewhat popular, 4 = fairly popular, 5 = very popular).

#### *Anthropometrics and Analysis*

Similar to Study 1, participants were shown how to use a hand-held dynamometer (Lafayette Instruments model 78010). Due to more available time, measurements were recorded on three separate squeezes from each hand, the maximum HGS of the three trials was recorded (in kilograms), and the subsequent analysis used the average of the maximum HGS for each hand. In addition, unlike the previous study, data was not collected on participant BMI. Therefore, analyses only controlled for effects of age using a partial correlation between HGS and peer aggression/victimization and popularity scores.

### **Results**

Table 3 shows the descriptive statistics of HGS and retrospective peer aggression and victimization among male and female college students. Consistent with both previous research and the first study, males had a stronger HGS than females ( $t(115) = 14.67, p < .001, Cohen's d = 2.80$ ). Responses to the social experiences survey indicate that 90.10% of males and 81.98% of females reporting victimization stated that it was predominantly intrasexual, which was also true for 95.83% of males 86.09% of females reporting aggressive behavior. Four males and nine females reported not being aggressive or victimized on any level during high school. These individuals were

included in the subsequent analyses.

**Table 3.** Descriptive statistics ( $M \pm SD$ ) for each variable of interest in males and females.

|              | Right HGS  | Left HGS   | Victimization | Aggression | Popularity |
|--------------|------------|------------|---------------|------------|------------|
| Males (65)   | 47.83±9.85 | 44.83±9.23 | 6.83±2.08     | 7.22±2.26  | 3.38±.98   |
| Females (52) | 25.33±6.04 | 24.11±6.04 | 5.71±1.86     | 6.12±1.91  | 3.51±.81   |

Note. Victimization and aggression composite scores range from 4 to 20, while popularity ranges from 1 to 5.

Pearson correlations between HGS and peer aggression/victimization and popularity are shown in Table 4. In males, individuals with higher HGS reported significantly lower levels of peer victimization during high school ( $r = -.430, p < .001$ ), and perceived themselves as more popular during high school ( $r = .327, p < .05$ ). There was no relationship between male HGS and peer aggression. In females, HGS was not correlated with peer victimization or popularity levels during high school. There was a positive trend between HGS and female aggression, but this was not statistically significant ( $r = .277, p = .052$ ). Popularity levels were negatively correlated with reported peer victimization in both sexes (males:  $r = -.337, p < .05$ ; females:  $r = -.346, p < .05$ ), and as in Study 1, self-reported peer aggression and victimization were positively correlated among females ( $r = .357, p < .05$ ), but not in males ( $r = .155, p = .249$ ).

**Table 4.** Correlations between HGS and retrospective social variables in college students.

|               | HGS  | Victimization | Aggression | Popularity |
|---------------|------|---------------|------------|------------|
| HGS           | -    | -.430***      | -.139      | .327*      |
| Victimization | .083 | -             | .155       | -.337*     |
| Aggression    | .277 | .357*         | -          | .068       |
| Popularity    | .038 | -.346*        | .079       | -          |

Note. Males are represented above the diagonal (-) and females are represented below.

\* $p < .05$ ; \*\*\*  $p < .001$

### Study 3: Handgrip strength and perceptions of high school seniors

#### Materials and Methods

##### Participants

Five male and four female independent raters (ages 18-28,  $M = 22.89, SD = 3.26$ ) were asked to rate yearbook photos of twelfth grade high school students. Participants included six undergraduate and three graduate students from three separate institutions in upstate New York. None of the raters had ever lived in the same county of the high school population, and no one reported recognizing any of the high school students. Participation was anonymous and completely voluntary. This research was approved by the University Institutional Review Board.

##### Questionnaire

A yearbook was obtained from the same high school as in Study 1. Individual

senior portraits (6.35cm x 4.45cm) included the face, neck and shoulders of each student. In all, 69 male (ages 16-18;  $M = 17.09$ ,  $SD = .41$ ) and 93 female (ages 16-19;  $M = 17.10$ ,  $SD = .45$ ) twelfth grade students were included in the analysis. Clothing was partially standardized as all males wore a collared shirt and a tie, and all females wore the same black, v-necked blouse; however, make-up and hair styles varied between individuals. Student names were removed and pages were scanned and presented as a packet. Individual photos were assigned an arbitrary number and the order of yearbook photo presentation was randomized across raters using Microsoft Excel. Raters were asked to respond on a 7-point Likert scale to the following questions about each student: (1) how aggressive do you think this person is among their peers? ( $\alpha = .75$ ), (2) how dominant do you think this person is among their peers? ( $\alpha = .77$ ), (3) how physically attractive do you find this person? ( $\alpha = .88$ ), and (4) how healthy do you think this person is? ( $\alpha = .79$ ). For each measure, all ratings of an individual were then summed (min 9, max 63).

*Anthropometrics and Analysis*

Grip strength was recorded during the same health screening session as in Study 1. Similar to the Study 1, analyses between HGS and ratings of aggressiveness, dominance, attractiveness and health were conducted using partial correlations controlling for age and BMI.

**Results**

Table 5 shows the descriptive statistics for HGS and ratings of aggression and dominance among male and female 12<sup>th</sup> grade high school students. As with the previous two studies, there was a large sex difference in HGS ( $t(160) = 17.32$ ,  $p < .001$ , Cohen’s  $d = 2.70$ ). Table 6 shows the partial correlations controlling for age and BMI between yearbook photo ratings and HGS in males and females. Males with higher HGS were rated as more aggressive ( $r = .302$ ,  $p < .05$ ), more dominant ( $r = .301$ ,  $p < .05$ ), and healthier than their peers ( $r = .281$ ,  $p < .05$ ). There was a positive trend between HGS and ratings of male attractiveness, but it was not statistically significant ( $r = .205$ ,  $p = .099$ ).

**Table 5.** Descriptive statistics ( $M \pm SD$ ) for HGS among males ( $N = 69$ ) and females ( $N = 93$ ).

|         | Right HGS  | Left HGS   | Aggressive | Dominant | Attractive | Healthy  |
|---------|------------|------------|------------|----------|------------|----------|
| Males   | 47.83±6.54 | 45.02±7.02 | 3.72±.75   | 3.68±.85 | 3.35±.73   | 4.84±.60 |
| Females | 30.87±6.19 | 28.63±5.75 | 3.14±.69   | 3.49±.77 | 4.18±1.03  | 5.00±.62 |

*Note.* Outside ratings of aggression, dominance, attractiveness, and health range from 1 to 7.

In marked contrast, ratings of female photos were unrelated to HGS on all measures. It is important to note that ratings of aggressiveness and social dominance were highly intercorrelated across both sexes ( $r > .75$ ,  $p < .001$  for both), suggesting that ratings on these traits were actually part of a single aspect of personality perception. Similarly, in both sexes ratings of health and attractiveness were strongly intercorrelated ( $r > .75$ ,  $p < .001$ ). Each was also associated with perceptions of dominance in both sexes ( $p < .001$ ), but the relationship was considerably stronger in males. Ratings of aggression and health

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were correlated in males ( $r = .332, p < 0.01$ ) but not females, and attractiveness and aggression were not correlated in either sex. If we condensed these four measures into two factors (aggression-dominance and health-attractiveness), both were positively correlated with HGS among males (aggression-dominance:  $r = .318, p < .01$ ; health-attractiveness:  $r = .244, p < .05$ ), while there remains no relationship with HGS among females (aggression-dominance:  $r = .092, p = .384$ ; health-attractiveness:  $r = .155, p = .143$ ).

**Table 6.** Correlations between HGS and perceived ratings of twelfth grade student portraits.

|            | HGS  | Aggressive | Dominant | Attractive | Healthy |
|------------|------|------------|----------|------------|---------|
| HGS        | -    | .302*      | .301*    | .205       | .281*   |
| Aggressive | .061 | -          | .800***  | .218       | .332**  |
| Dominant   | .110 | .777***    | -        | .604***    | .664*** |
| Attractive | .150 | .012       | .388***  | -          | .891*** |
| Healthy    | .142 | .020       | .440***  | .779***    | -       |

*Note.* Males are represented above the diagonal (-) and females are represented below.

\* $p < .05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$

## Discussion

The findings from these three studies are consistent with recent evolutionary hypotheses predicting that characteristics either connected with or developmentally linked to HGS are important in male-male social competition and sexual selection (Gallup et al., 2007; Young, 2003). This research indicates that HGS, a simple and easily obtainable measure of overall strength and muscle function, is in fact an informative variable related to adolescent social behavior, and thus remains valuable in studying human behavior from an evolutionary perspective.

Measures of socially dominant behavior and appearance were significantly correlated with HGS in males, but this was only true during late adolescence (i.e., high school). In the first study, HGS was unrelated to measures of aggression and victimization during middle school in both male and female ninth graders. In the second study, male college students with higher HGS reported fewer instances of intrasexual peer victimization during high school, and perceived themselves as more popular. In the third study, raters observing only yearbook photos perceived twelfth grade males with higher HGS as being more aggressive, more dominant and healthier. For females, the only significant correlation with HGS was in Study 1, revealing a positive correlation between HGS and perceived popularity. It remains unclear why this association was present for females and not males, but future research should examine variables contributing to middle school popularity that may also be associated with HGS (see Eder and Kinney, 1995). Overall, these findings are consistent with previous research indicating that HGS is related to socially dominant behaviors and appearance nearly exclusively in males. These sex differences are likely related to the sexually dimorphic expression of aggression among adolescents (Archer, 2004), with males typically using direct, physical forms of aggression compared to females, and therefore physical strength should contribute to this effect.

Interestingly, Study 1 revealed no relationship between male HGS and the observed

social variables during middle school. These results match up with those showing a lack of a relationship between testosterone and aggression among younger adolescent males aged 10-14 years (Susman et al., 1987; Inoff-Germain et al., 1988). Although physical aggression is known to decrease during adolescent development (Brame, Nagin, and Tremblay, 2001), our data suggests that the importance of physical strength may increase in competitive social contexts during high school when reproductive activities are more salient. In other words, a male's overall strength or androgenic development (i.e., masculine-specific body configuration) may be more central to social competition during high school, as these features become more pronounced with advanced pubertal development and the disparity among physical size and stature decreases. It is possible that the variation in physical maturation among early adolescent boys makes HGS an unreliable measure of social competition during middle school. In other words, the implicit awareness that some boys have not yet had their growth spurt may play a more pronounced role in male-male physical competition.

We suggest the relevance of HGS to late adolescent social experiences almost certainly lies in relation to physiological, developmental, and genetic underpinnings. In turn, we propose that blood testosterone levels may be the foremost contributing factor to the observed variation in HGS among adult males. Consistent with this view, testosterone levels have been positively linked to both male aggression (Book et al., 2001) and dominance (Mazur and Booth, 1998). Likewise, testosterone levels have been shown to increase dramatically with initial pubertal development in males (115 ng/dl at age 13 to 364 ng/dl at age 15, see Rowe, Maughan, Worthman, Costello, and Angold, 2004), and in our sample there was a strong positive correlation between male HGS and age among ninth graders (ages 13-15;  $r = .473$ ), but not twelfth graders (ages 16-18;  $r = .031$ ). In accord with the findings from Study 3, previous research has revealed that the faces of males with high testosterone are also perceived as more dominant (Swaddle and Reiersen, 2002). Likewise, the overall results find HGS to predict similar socially dominant behaviors with reported links to testosterone levels in post-pubescent males only (Inoff-Germain et al., 1988; Olweus et al., 1980; Susman et al., 1987). The fact that perceived aggressiveness and social dominance actually predicted a male's HGS signifies that not only is one's initial perceived personality correlated to underlying physiological features, but this may be what ultimately provides the observer with the information necessary to make adaptive social decisions. It remains unknown whether raters based their decisions on specific facial features or if other aspects of body morphology present within the photos (e.g., shoulder breadth) contributed to their perceptions. These issues notwithstanding, past research shows that a male's HGS is predictive of facial characteristics (Shoup and Gallup, 2008) and shoulder breadth and circumference (Gallup et al., 2007). Therefore, it is not necessarily important that the exact features used for rating are identified, and instead, it is likely that raters used a combination of visual cues.

Previous research has indicated that features associated with or directly linked to HGS may be under sexual selection, as HGS correlates with earlier sexual activity and more sexual partners in males (Gallup et al., 2007). The current research suggests that these reproductive advantages may be gained at least partially through social dominance, a trait that is cross-culturally preferred by females seeking mates (Shackelford, Schmitt, and Buss, 2003). Older males with higher HGS reported lower intrasexual peer victimization, higher popularity levels, and were rated as more aggressive and dominant compared to their

peers. Taken together, these variables may serve as a proxy for social dominance during adolescence. Consistent with this interpretation, past research reveals perceived dominance to be a strong predictor of sexual activity in adolescent males (Mazur, Halpern, and Urdy, 1994).

Some limitations to this research include the fact that these social variables were not directly observed, and instead were either self-reported in a survey or perceived through outside raters. As a result this may not reflect actual aggressive or dominant behaviors of the adolescents. We also did not investigate motives behind peer aggression or to what degree physical strength and prowess was involved in aggressive or dominant interactions. However, the current research does offer insight into sex differences in physical strength and socially dominant behaviors during distinct periods of adolescent development, and further supports previous research showing strong sex differences in the relationship between HGS and social variables. In addition, the results provide evidence that changes in HGS may accurately reflect changes in testosterone levels, due to consistency in how these variables reliably predict aggression and dominance among older, but not younger adolescent males. In order to more directly test these hypotheses, future research should measure aggressive behavior through a combination of survey use and ethnographic methodology, and directly investigate the correlation between HGS and testosterone across age ranges. Previous research already supports this connection, revealing a positive relationship between serum testosterone and the development of strength parameters (including HGS) in adolescent males aged 10-12 years (Hansen, Bangsbo, Twisk and Klausen, 1999).

Although HGS was the only morphological measurement taken in these studies, it is important to note that features such as overall larger body size and masculine specific body morphology (which are also associated with higher testosterone levels) may be contributing factors, and therefore could also be collected in future research. However, we argue that when considering HGS in terms of male-male competition and dominance, that it can be done independent of body configuration because unlike HGS, large body size is unrelated to health and vitality. In addition, it is not simply size and appearance that facilitate social competition and dominance in males, but a combination of physical prowess, vitality, and social ability; and current and past findings imply that HGS is strongly connected to all of these measures (Arroyo et al., 2007; Fredericksen et al., 2002; Gallup et al., 2007; Giampaoli et al., 1999; Hughes et al., 1997; Laukkanen et al., 1995; Rantanen et al., 2000; Sasaki et al., 2007; Stenholm et al., 2008).

Overall, the present research reveals that individual differences in HGS account for a significant portion of variance among measures of social competition in older adolescent males. This research provides support for the evolutionary view that features linked with higher HGS (i.e., testosterone) have been selected for in males due to various competitive advantages. In summary, HGS is an easily obtainable and highly informative measure related to adolescent male behavior that should be considered in future research investigating social-sexual competition. Due to the limitations of high potential costs, as well as low reliabilities associated with testosterone measures owing to differences in the time of collection, HGS may be an appropriate alternative for assessing student populations.

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