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Testosterone and Social Behavior

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Abstract
Popular perceptions of the effect of testosterone on "manly" behavior are inaccurate. We need to move away from such simplistic notions by treating testosterone as one component along with other physiological, psychological and sociological variables in interactive and reciprocal models of behavior. Several hormones can now be measured in saliva, removing the need for blood samples. Conceptual shifts have moved research from biological determinism to biosocial models in which the social environment plays a key role in understanding behavior-hormones associations. As a result, more social scientists are incorporating testosterone in their studies. Following a primer on testosterone, we describe testosterone's link to (a) gaining, maintaining and losing social status, (b) aggression and antisocial behavior, (c) peer and family relationships, and (d) gender similarities and differences. Research needed to take us to the next level of understanding is outlined.

"Testosterone poisoning," now part of the language, is a popular explanation for excessive "manly" behaviors such as boasting, violence and pugnaciousness. Middle-aged and older men think sagging libido and fatigue stem from their declining testosterone.

In fact, there is little empirical support for these popular assertions. We cannot say that they are all false because research literature is not conclusive. But it is already clear that there is no simple one-to-one relationship between testosterone and machoism or aggressiveness or sexuality (Mazur and Booth 1998). It seems wiser to view testosterone as one component in a confluence of interacting physiological, psychological and social influences that affect behavior.

The focus of this research is variables of interest to sociologists. Gaining, maintaining and losing status is a theme found in a great deal of sociological research. Many testosterone studies have focused on status change under the rubric of competition. Sociologists who focus on deviance and social integration will be interested in testosterone studies that focus on problem behavior, and the nature and quality of peer and family relations. Those who work in the area of health and social behavior will find studies of testosterone's link to depression. Those who study gendered behavior will be interested in the differences and symmetries in the links between testosterone and social behavior for males and females. Finally, sociologists will be interested to learn that the social environment has a key role in defining testosterone-behavioral links.

This article is dedicated to the memory of James M. Dabbs, a pioneer in the field of testosterone research who greatly enriched our knowledge methodologically and substantively. *Direct correspondence to Alan Booth, Department of Sociology, 211 Oswald Tower, Pennsylvania State University, University Park, PA 16801, 814-863-1141. E-mail: AXB24@psu.edu.*

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Following a primer on testosterone, we review the reciprocal linkage between testosterone and competition, deviant or norm-breaking behavior, and depression. We then take up the hormone's role in peer and family relationships and gendered behavior. Throughout, we stress the need for reciprocal biosocial models that take account of psychological variables and social influences. Finally, we suggest promising avenues for future research.

Primer on Testosterone

Hormones are chemical messengers that regulate, integrate and control bodily functions. The endocrine system produces several hundred hormones in response to nerve and chemical signals and to perceptual cues, which interact with each other and with the nervous system. Hormones regulate short-term processes, such as the nearly immediate responses to an external threat, and longer-term processes, such as sex differentiation, maturation and reproduction. Males produce testosterone mainly in the Leydig cells of the testes. Women also produce testosterone, but in smaller amounts, by converting dehydroepiandrosterone (DHEA) produced in the adrenal glands. Testosterone is one of several *androgenic* hormones, so called because they produce male characteristics. Baseline testosterone has fairly high heritability. The majority of estimates are between 50 percent and 70 percent with a mean of 60 percent (e.g., Gagnon et al. 2001; Harris and Vernon et al. 1998).

The human fetus, whether genetically male (XY) or female (XX), is otherwise sexually undifferentiated in the first weeks of life. Testosterone secreted by newly forming testes of an XY fetus causes its body and brain to become masculinized. Lacking testosterone, a fetus develops as a female and when born looks like a female infant. XY fetuses that abnormally fail to produce testosterone may be mistaken for girls at birth. Research on non-humans convincingly shows that genetic females exhibit male features if exposed to high testosterone in utero and genetic males show female features if deprived of the hormone (Breedlove 1992).

During the preschool and early elementary school years testosterone levels are low in boys and girls. During adolescence testosterone production surges, on average 10-fold in males and two- or three-fold in females (see Figure 1). These changes are implicated in the emergence of secondary sexual characteristics that include ripening sexual apparatus, male musculature, body hair and deepening voice. Fully adequate male sexual behavior requires a minimal amount of testosterone, but beyond that, variations in hormone level are not reliably related to sexuality (or to homosexuality).

Testosterone levels reach a peak in young adult males. Men who maintain a constant body weight also maintain their testosterone levels as they age. More typically in American society, men add weight and lose testosterone as they grow older. Older men often maintain age-appropriate sexual behavior (assuming good health and partner availability) even at very low testosterone levels. If male testosterone is exceedingly low, therapeutic testosterone supplementation can improve sexuality, increase muscle mass and reduce body fat.

Figure 1. Testosterone by Age and Sex

From: Booth, Alan, David R. Johnson, Douglas A. Granger, Ann C. Crouter and Susan McHale 2003. "Testosterone and Child and Adolescent Adjustment: The Moderating Role of Parent-Child Relationships." Developmental Psychology 39:85-98.

Much of our knowledge is based on studies of men and boys because males produce far more testosterone than females, so the hormone is easier to measure. Also, the hormone's effects are clearer in males than females. We will review the gender consistencies and inconsistencies in behavior-testosterone research in a subsequent section.

After childhood, testosterone is diurnal, being highest in the morning and declining across the afternoon and evening. Possibly diurnal variation is related to patterns of problem or psychopathological behavior (Granger, Shirtcliff, Zahn-Waxler, Usher, Klimes-Dougan and Hastings 2003). Controlling for diurnal variation, testosterone levels are highly correlated within individuals across hours, days and years (Granger, Shirtcliff, Booth, Kivlighan and Schwartz 2004). This fact has led many investigators to assume that testosterone level is a trait that explains differences between individuals with respect to aggression and violence. However, there is little empirical support for this position.

During the past two decades, the improving ability to measure testosterone in saliva (rather than requiring blood samples) has created opportunities to test biosocial models in naturalistic settings (Dabbs 1993; Granger, Schwartz, Booth, Curran and Zakaria, 1999; but see Granger et al. 2004).

A series of conceptual shifts has placed new emphasis on the contributions of both nature *and* nurture to individual development (Magnusson and Cairns 1996; Plomin and Rutter 1998; Rutter et al. 1997). Leading this paradigm shift are social scientists who are testing "biosocial" alternatives to traditional models of individual differences and intra-individual change in behavior (e.g., Booth, Johnson, Granger, Crouter and McHale, 2003; Foshee et al., forthcoming; Udry

1988). Individual differences in behavior are considered to be interactive products of genetic, environmental and physiological processes over time (Cicchetti and Dawson 2002).

The nature of the link between testosterone and behavior is not simply a biological "cause-and-effect" mechanism. It is better described as a bi-directional relationship that is highly dependent on intrinsic individual differences in social perception, previous experience and propensity for specific behavior, as well as the demand or "press" of the social context for particular behaviors (Sapolsky 1997). We do not assume that testosterone is a mechanism in and of itself that causes or creates behavior. Instead, we assume that testosterone increases the likelihood that certain behaviors will be expressed, if the propensity for that behavior already exists, and the expression of that behavior is consistent with social contextual demands. Characteristics of the social landscape permit, stimulate, suppress or set the stage for the expression of specific testosterone-behavior relationships.

One important aspect of the social landscape that affects testosterone production is stress. A number of studies have shown that extended periods of stress suppress testosterone production. For example, testosterone levels were low during the early (and degrading) weeks in Officer Candidate School, but returned to normal just before graduation, a time when achievements are recognized (Kreuz, Rose and Jennings 1972). Testosterone also drops right after incarceration (Thompson, Dabbs and Frady 1990). Soon after the Americans who had been held hostage at the American Embassy in Iran were freed, testosterone increased as a result of their newly gained status as free individuals (Rahe, Karson, Howard, Fubin and Poland 1990). Research indicates that elevations in cortisol (a stress hormone) lower testosterone, and declines in cortisol are followed by a rise in testosterone. Research focused on behavior-testosterone associations should incorporate environmental sources of stress as a potentially important player in such studies.

Testosterone, Dominance, Aggression and Related Behaviors

The word most often associated with testosterone in everyday parlance is aggression. Although in some species (e.g., rats) higher testosterone is associated with aggression in everyday encounters (Monaghan and Glickman 1992), in humans (and other primates) higher testosterone is association with the type of dominance that sometimes entails aggression. In our view, aggression is behavior intended to inflict physical injury on another individual. Dominance is behavior intended to gain or maintain status. Status confers influence, power or valued resources (Mazur and Booth 1998). The vast majority of dominance episodes do not involve the intent to physically harm others. Furthermore, testosterone levels associated with dominance behavior that entails the intent to injure others appear to be no higher than testosterone levels associated with dominance behavior that does not entail physical harm. For example, there is no significant difference in the testosterone levels of socially dominant but non-aggressive prisoners and of aggressive prisoners (Ehrenkranz, Bliss and Sheard 1974).

Studies used as evidence that higher testosterone associated with pubertal development is linked to aggression in youth are not clear cut. Two studies by Olweus and his colleagues (1980, 1988) and another by Mattsson, Schalling, Olweus, Low and Svensson (1980) are often interpreted as evidence of a testosterone-aggression link. But their data do not support such a conclusion. A comparison of samples of institutionalized delinquent boys and non-delinquent high school students revealed that testosterone was slightly higher in the delinquent sample, but the difference was not statistically significant. The delinquent sample of youth who were incarcerated for violent crimes had slightly higher testosterone levels than those institutionalized for non-violent offenses, but again the difference was not statistically significant. Staff and professional evaluations of aggressiveness were also unrelated to testosterone levels.

Testosterone-related differences in aggression in the non-delinquent sample were studied as well. None were statistically significant. The only difference manifested was that adolescents with higher testosterone were more likely to respond more vigorously in response to challenges from teachers and peers. The vigorous response finding is consistent with our assertion that testosterone is linked with aggression only when it is part of dominance behavior.

Another study pertinent to the link among testosterone, dominance and aggression is a longitudinal study of boys investigated when they entered kindergarten and thereafter until 13 years of age (Tremblay, Schaal, Boulerice, Arseneauth, Sousssignan and Perusse 1998; Tremblay, Schaal, Boulerice, Arseneault, Soussignan, Paquette and Laurent 1998; Tremblay 2000). Using measures that incorporated self, peer and teacher ratings, Tremblay and his colleagues discovered that testosterone levels at the start of puberty were linked to social dominance a year later but not to physical aggression. Dominance was not related to current aggression or aggression over the previous three years. On the other hand, body mass was a predictor of physical aggression. The extant research suggests that the rise in testosterone associated with pubertal development does not lead directly to aggressive behavior.

Another term often associated with testosterone is *antisocial* behavior. We view this as another form of dominance behavior that occurs in settings where authority figures require behavior to conform closely to rigid standards such as in schools, prisons, the military and sometimes families. Individuals who are predisposed to dominate behavior but hold subordinate positions in such organizations are likely to break the rules in order to prevail over the constraining environment. Udry and colleagues observed an association between norm-violating behavior and testosterone (Udry 1988, 1990). Much of such behavior is expressed through vandalism and status violations rather than aggression (Rutter, Giller and Hagell 1998). Such rebellious behavior is termed antisocial behavior by those in authority and those who study such behavior.

In addition to aggression and antisocial acts, two other types of behavior are often associated with testosterone. One is risky behavior, and the other is initiative. Both are important in achieving and maintaining status. Risk-taking behavior refers to acts that at the same time increase the chances of success *and* the odds of failure in maintaining or increasing status. Daltzman and Zuckerman

(1980) were among the first to observe a link between sensation seeking and testosterone. Recent studies have linked testosterone-related risk behavior to health deficits (Booth et al. 1999a).

Initiative is less often associated with the testosterone-dominance link, but is an important factor in understanding testosterone-dominance links. A dominate act requires initiative to challenge someone else's status or to protect one's own status. As the same time a testosterone-related initiative is necessary to build friendship networks, marriages and other close relationships where dominance behavior occurs less often, but is still crucial to the operation of the group.

Although research provides considerable evidence that testosterone is associated with dominant behavior, correlation does not prove causation. If the administration of testosterone was followed by an increase in dominant behavior, we would have a stronger case for asserting a causal relationship. Two experiments support the idea that the link is causal. In one study with a double-blind, randomized, crossover design, young men were given doses of testosterone or a placebo. Subjects were paired with a fictitious subject and told that each member of the pair could, by pushing a button, reduce the cash flowing to the other member. The subject was told that the other individual was reducing the cash that was flowing to the subject. Subjects receiving testosterone rather than the placebo pushed the button significantly more times (Kouri, Lukas, Pope and Oliva 1995). A second study with the same design was conducted with men aged 20 to 50 years (Pope, Kouri and Hudson 2000). This time testosterone was administered over a six-week period. Subjects participated in the same experiment. Results indicated that those who had had the treatment pushed the button many more times. These studies put us in a much stronger position to claim that testosterone stimulates dominant behavior.

Testosterone and Status Hierarchies: What We Learn from Competition Studies?

Dominance hierarchies occur only in face-to-face groups where members interact with one another. (See Mazur 2005 for a detailed development of the dominance hierarchies concept.) They may be as small as a dyad or consist of 100 or so members. They persist over time and are characterized by the unequal ranking of members in terms of power, influence and access to valued resources and prerogatives. High ranking members influence others in the group and subordinate individuals have little influence and limited resources and are constrained in their choices. Members know where they fit into the hierarchy and regard it as legitimate. Rankings change as youth mature and those in power pass their prime, membership changes, or environmental challenges alter the needs of the group.

Virtually everyone lives and works in groups that have dominance hierarchies whether they are families, peer groups, work groups, civic organizations, religious groups or play groups. Large organizations such as corporations and governments are overlain with many face-to-face groups, each operating somewhat autonomously. Within every hierarchy there are shifts in the status ranking over time. Status changes are preceded by competition.

Face-to-face status competition often occurs during polite conversation, though it may additionally include assertive eye contact or posturing, or the display of culturally elaborated status symbols, or rarely, argumentative and physical tussling. When these competitions occur, each adversary attempts to out-stress his opponent. This is often done without violence or overt aggressiveness, and indeed may occur so gently that the participants and other observers are barely aware of the competition. Generally, after one or a series of such encounters, one adversary concedes higher rank to the other, thus relieving the tension of the contest and establishing relative rankings in the group. Based on studies of change in status in competitive events, testosterone would appear to play a fundamental role in the face-to-face competition at least in males (Mazur 1985).

Sporting events are excellent venues for studying the hormonal correlates of face-to-face dominance episodes because they are highly organized and monitored, the rules are clear, and measures of performance, such as winning and losing, are well defined. Research has focused on three phases of competition: pre-event, event and post-event. In general, men's testosterone levels increase prior to competition and rise during the contest itself. Afterward, testosterone levels of winners often remain higher than the testosterone of losers.

These results come mostly from studies of male athletes (e.g., Mazur and Booth 1998). There are only three studies of women, each suggesting a different profile than is found in men (Bateup, Booth, Shirtcliff and Granger 2002; Kivilighan, Granger and Booth 2005; Mazur, Susman and Edelbrock 1997). Another caveat is that the vast majority of studies have focused on experienced competitors (e.g., Bateup et al. 2002; Booth et al. 1989; Elias 1981; Mazur, Booth and Dabbs 1992; Salvador et al. 1999). In the only study comparing varsity with novice competitors, testosterone behavior patterns were different for novices than for experienced players (Kivlighan et al. 2005).

The *pre-event* rise in testosterone possibly improves psychomotor function and coordination (Herrmann and Beach 1976), and mental activity (Herrmann, McDonald and Bozak 1976; Klaiber et al. 1971), and makes people more willing to use risky strategies (Daltzman and Zuckerman 1980), although none of these effects are conclusively demonstrated. Men appear to adjust their pre-competition rise in testosterone to the perceived strength of the opponent and the importance of the event. The greater the challenge, the greater the hormone increase (Booth et al. 1989; Gonzalez-Bono et al. 1999; Mazur, Booth and Dabbs 1992; Mazur and Lamb 1980; Salvador et al. 1987; Neave and Wolfson 2003).

The link between testosterone and performance during an *event* has received very little attention because of the difficulty in collecting saliva samples and other measures during the event itself. Studies have been limited to studying the associations between the change in testosterone (typically a rise) during the event and performance as measured after the event. One study of male rowers suggests that elevation in testosterone during the event is associated with superior performance, as indicated by the amount of time it takes to row 2000 meters (Kivlighan et al. 2005).

Post-event research indicates that winners have higher testosterone than losers. Not all studies show this effect (e.g., Suay et al. 1999), but it has been

replicated several times, not only in physically vigorous competitions but in chess competitions (Mazur, Booth and Dabbs 1992). The extent of post-match rise in the hormone seems to depend on the importance of the win and the participants' evaluations of their own performances (e.g., Booth et al. 1989; Elias 1981; Mazur and Lamb 1980). When male competitors believe they have won by luck rather than personal effort, there is little if any post-win rise in testosterone (McCaul, Gladue and Joppa 1992).

As indicated at the outset, we propose that bio-social models are reciprocal where testosterone affects dominance, and also that changes in dominance change behavior (or social status), which changes testosterone levels as demonstrated in studies of primates (Rose, Bernstein and Gordon 1975). It is theoretically tempting to presume bi-directional effects in humans: testosterone increases competitiveness, and competitiveness increases testosterone. The studies noted above indicate that winning a competition increases one's testosterone, which increases the likelihood of engaging in and winning more competitions, which increases or maintains high testosterone, and so on. Losing a competition would depress testosterone, which would encourage avoidance of further competition. This would neatly account for the self-reinforcing effects of winning and losing streaks. However, the evidence is weak and additional research is needed to reach a firm conclusion about reciprocity.

How are the testosterone changes noted in formal competition related to changes in other face-to-face groups? We expect that any face-to-face negotiation that potentially entails an important change in ranking would involve changes in testosterone. If there was sufficient time (20 minutes or more prior to negotiation), an anticipatory rise in testosterone would occur. During negotiations testosterone increases in those who think they have a chance of gaining or maintaining status, and it decreases among those who think they are about to lose. At the conclusion of the negotiation the winner would experience a rise in testosterone, whereas the loser would experience a decline that could affect performance at subsequent dominance episodes.

For future research, perhaps the most important question is the extent to which the competition findings apply to dominance episodes occurring outside short term sporting events such as negotiating a commercial contract, engaging in a political campaign, and being a party to litigation, as well as to family and peer interaction. If so, we need to continue to explore gender differences and the links between testosterone and the amount of experience and skill that participants bring to a dominance episode. Skill may lead to confidence that may signal a rise in testosterone (Mazur and Booth 1998). We suggest future research should also include culture and individual development (when studies focus on youth). When dominance episodes entail groups of individuals the rank of the individual members within the group and extent of bonding between members are also important considerations. Individual feelings of efficaciousness and social skills may also advance or impede the testosterone production.

For dominance episodes that last for hours, days or weeks, we need to understand more about how the ebb and flow of successful performance is linked to testosterone production. To date, research has focused on one competitor in a

dominance episode but not the opponent. It would be useful to have information about the opponent's testosterone throughout the event, the opponents' self evaluation, and his/her evaluation of the opponent. Given the intensity of the competitor-opponent relationship, information on the opponent is bound to increase our understanding of the dynamics of dominance episodes.

Problem Behavior and Psychopathology

Unlike the research on competition, which centers on testosterone changes taking place over a few minutes or hours, much of the research on problem behavior (as well as on peer and family relationships) is cross-sectional and sometimes involves reports that cover much longer periods of time (weeks, months and years). We also switch to considering baseline testosterone, the characteristics level of the hormone that we have upon arising each morning. Research on the link between testosterone and problem behavior includes adult crime and depression as well as children's internalizing (depression) and externalizing (risky behavior). In keeping with contemporary thinking about hormones and the interests of sociologists, we rely heavily on research using the bio-social model, studies that examine the role of the social environment as moderating or mediating the link between testosterone and behavior.

Crime

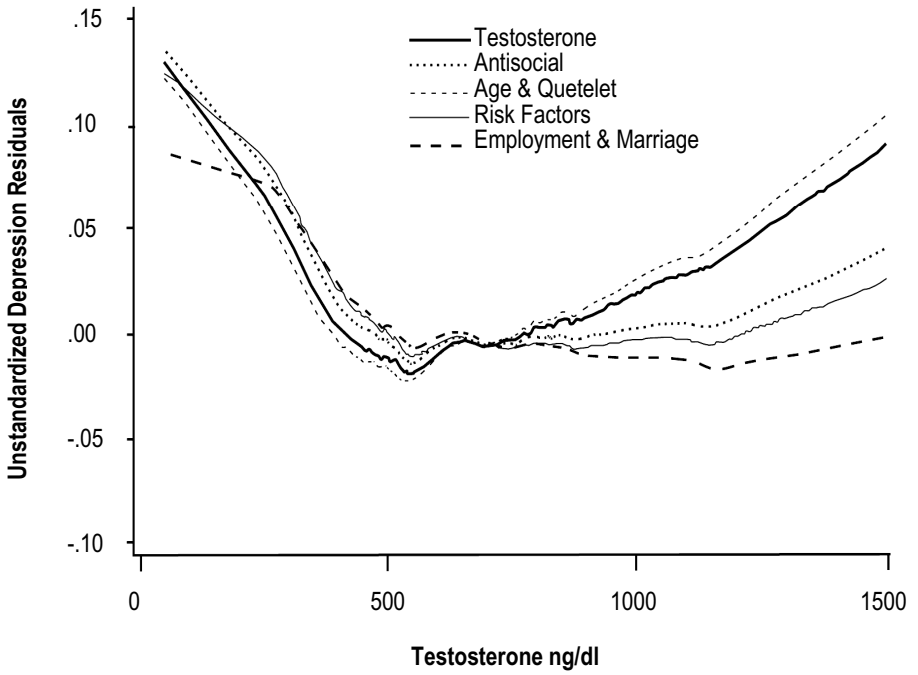
Men with higher levels of testosterone are more likely to be arrested for offenses other than traffic violations, to buy and sell stolen property, incur bad debts and use a weapon in fights (Booth and Osgood 1993). Individuals with testosterone more than one standard deviation above the mean were 28 percent more likely to engage in criminal behavior than those one standard deviation below the mean. There is no evidence of a threshold of testosterone where the propensity to commit crime increases at a higher rate. The association between testosterone and crime is explained in part by a record of juvenile delinquency. The remainder of the testosterone-crime association is accounted for by participation in conventional social roles. Conventional social roles include holding a steady job, being married and belonging to community organizations. The greater the testosterone, the more important social roles were to preventing criminal activities.

Depression

The largest study of the link between testosterone and depression revealed an unusual finding. The study, which involved more than 4,000 men ages 32 to 48, found that a parabolic model best fits the data (see Figure 2). Men with above- and below-average testosterone levels reported more symptoms of depression (Booth et al. 1999b). The link between high testosterone men and depression is the inverse for men with below-average testosterone. The relationship disappears for those with above average testosterone when controls for antisocial and risk behaviors and the absence of protective factors such as marriage and steady employment are in the equation. Anti-social and risky behavior brings people into

contact with the criminal justice system and puts individuals at odds with relatives and friends. Incarceration, being sued or paying fines, and social isolation increase the risk of depression. The association is unchanged by these factors for those with below-average testosterone. It is possible that low testosterone is linked to neurotransmitters that are associated with depression (Zhang, Ma, Barker and Rubinow 1999). Further analysis revealed that testosterone was not linked to other forms of psychopathology (bipolar disorder, paranoid schizophrenia, panic attacks, post traumatic stress disorder and several phobias). When exploring the links between testosterone and behavior it is important to keep in mind that the relationship may not be linear.

Figure 2. Lowess Curves of Testosterone and Depression



Source: Booth, Alan, David R. Johnson and Douglas A. Granger. "Testosterone and Men's Depression: The Role of Social Behavior." Journal of Health and Social Behavior (Testosterone and Men's Depression: The Role of Social Behavior) 40:130-40.

Military Combat

An analysis of factors that predict exposure to military combat reveals that high testosterone increases the likelihood of exposure (Gimble and Booth 1996). It is unclear whether individual or environmental variables influenced participation in combat. Soldiers with high testosterone may have taken an active role in seeking out combat. Or those in command may have recognized qualities that will make the individual a better combatant and assign him accordingly. It is also

possible that high testosterone individuals are antisocial enough to get combat assignments as punishment. In any case, the model shows impressive predictive ability despite the fact that we cannot determine the causal direction.

Risk Behavior and Depressive Symptoms in Youth

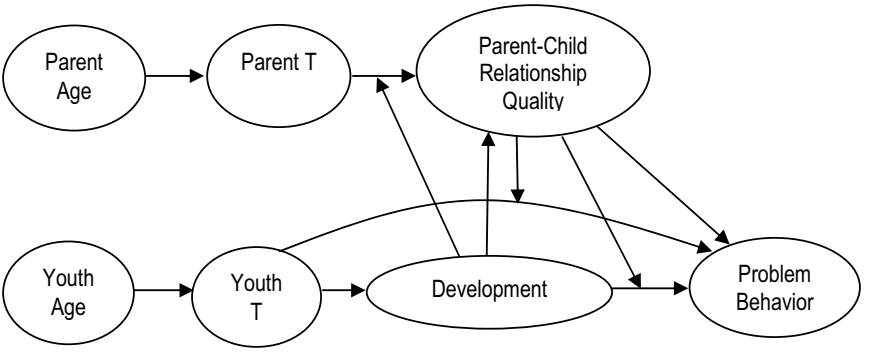
In a study of 654 normally developing youth (ages 7-17, M = 13.5), there was no evidence of direct testosterone-behavior effects (Booth et al. 2003). Rather, the expression of testosterone-related behavior was dependent on the quality of parent-child relations. That is, when parent-child relations were poor, high-testosterone sons (compared to low-testosterone sons) were more likely to engage in antisocial behavior, and low-testosterone sons (compared to high-testosterone sons) were more likely to report symptoms of depression. In daughters a different picture emerged. When daughter-mother relations were poor, low-testosterone daughters (compared to high-testosterone daughters) were more likely to express risky and antisocial behavior. When father-daughter relations were poor, low-testosterone daughters (compared to high-testosterone daughters) were more likely to be depressed. In short, testosterone's relationship with risk behavior and depressive symptoms was conditional on the quality of parent-child relations. As parent-child relationship quality increases, testosterone-related adjustment problems are less evident. Interestingly, unlike sons' testosterone, daughter's testosterone is negatively related to risk behavior.

It is clear from these studies that the biosocial model is a promising one for exploring problem behavior. Exploring the social environment as a source of variables that have the potential to moderate the hormone-behavior association will greatly expand our knowledge. The social environment also has potential for affecting hormones as well as behavior. When studying youth, the potential confounding influences of cognitive maturation and pubertal development add another layer of factors to take into account in developing research questions. As suggested by Mazur and Booth (1998), around puberty, the effect of testosterone on behavior may work through increased size, muscle mass and appearance of secondary sexual characteristics. These changes produce dramatic change in the way individuals are treated by peers, parents, siblings and authorities.

Also, future biosocial models should incorporate a wider range of variables in the analysis. For example, Figure 3 suggests that the parent-child relationship quality not only moderates the link between testosterone and problem behavior, but may also moderate the link between developmental phase and problem behavior and have a direct effect on problem behavior. The model also suggests that parents' testosterone may influence the quality of parent-child relationships. The phase of child development, especially the early adolescent tendency to engage in more conflict with parents and the late adolescence tendency to decrease the amount of time spent with parents in favor of peers, may also affect the testosterone-problem behavior association (Silk and Steinberg 2003).

A series of studies alerts us to the importance of the timing of measuring hormones and behavior in future studies of both youth and adults. A series of studies by Udry and his colleagues (1988, 1990) are particularly interesting with respect to timing issues. In a cross-sectional analysis of 12- to 13-year old boys,

Figure 3. Testosterone and Youth Behavior Problems



correlations were observed between testosterone and norm-violating behavior. In a prospective analysis of these boys over a three-year period, no associations between testosterone and behavior were observed (Drigotas and Udry 1993; Halpern, Udry and Suchindran 1997, 1998). Many interpreted this to mean that testosterone is largely organizational and not activational during adolescence (e.g., Mazur and Booth 1998). When the investigators conducted a third study in which the interval between data collection points was substantially shorter, they found that increases in testosterone were linked to first intercourse at a much earlier age in both boys and girls (Halpern, Udry and Suchindran 1997, 1998). Investigation showed that recall of sexual intercourse initiation over longer intervals was inaccurate and masked the relation between testosterone and problem behavior. Measurement timing deserves serious attention subsequent studies.

Peer and Family Relationships

While the vast majority of studies have focused on associations between testosterone and negative behavior, a handful of small studies suggest that higher levels of testosterone have positive links with interpersonal associations in some circumstances. In a study of college students, males and females with higher testosterone had a more forward and confident interaction style than those with low testosterone (Dabbs et al. 2001). Above average levels of testosterone have been linked to college students being helpful, engaging and outgoing (Dabbs and Ruback 1988). In adult women, above-average testosterone is related to being confident (Baucom, Besch and Callaan 1985).

Peer Relationships

A study of adolescent peers using the biosocial model indicates that testosterone may be linked to positive as well as negative behavior depending on the nature of the social moderator. Rowe, Maughan, Worthman, Costello and Angold (2004)

documented the association between testosterone and behavior in boys and showed that it was highly dependent on the nature of the immediate peer context. When peers were judged as positive social influences, high testosterone levels in boys were associated with assertive and dominant behaviors characteristic of leadership. When peers were engaged in deviant behavior (rule violation, substance use), high testosterone levels in boys predicted non-aggressive symptoms of conduct disorder.

Another study of peers reveals that the quality of the relationship adolescent boys have with their mothers or older sisters is important for understanding testosterone's links to peer relationships (Updegraff, Booth and Bahr 2006). Above average levels of testosterone are positively related to boys' perceptions of their best friends as popular, to their own perceived competence in peer and romantic relationships, and to the time they spend alone with a female. But this occurs only if a boy has a positive relationship with his mother or an older sister. It appears that female members of the family play an important role in socializing adolescent boys with respect to developing and maintaining meaningful relationships with peers.

In a classic study, Udry (1988) found that testosterone is linked to interest in sexual behavior, but that the interest is expressed behaviorally only in cases of father absence and low participation in team sports in the case of females. In males, however, the behavioral expression of testosterone's link to interest in sex is not moderated by any of the variables studied.

Marital Relationship Quality

Research on marital quality suggests that high levels of testosterone may result in either high or low marital quality depending on perceptions of the social environment. In a sample of established working- and middle-class families with school-age children, neither husbands' nor wives' testosterone showed a direct connection with marital quality (Booth, Johnson and Granger 2005). In contrast, the association between husbands' testosterone and positive and negative marital quality (as evaluated by both spouses) was conditional on husbands' perception of role overload. When perceptions of men's role overload were elevated, higher testosterone levels were associated with lower levels of marital quality. When role overload was low, higher testosterone levels were linked to higher levels of marital quality. The study offers additional support to the notion that depending on perceptions of the social context, testosterone enables positive behavior in some situations and negative behavior in others. What is the mechanism by which men's perceptions of the demands of the environment moderate the association between testosterone and marital quality? While we know of no research bearing on this question, we suggest that when stress is low, higher testosterone men may devote more attention to their spouses, take the initiative in expressing positive interaction, and make a greater overall investment in the relationship. When high testosterone men are under considerable stress they are more likely to disagree, be less responsive to affective cues, and take risks (e.g., infidelity, drug or alcohol use) that may threaten marital relationships.

An earlier study of men who were veterans indicated testosterone had direct negative effects on marital quality (Booth and Dabbs 1993). The men in the two samples were approximately the same age. What may account for the difference is that only some of the servicemen were in stable long-term marriages that involved children whereas the entire sample of men in the study reported above were in such unions. Maintenance of such long-term unions may mean that very few men in the recent study were predisposed to express low levels of affect and high levels of conflict whereas a much higher proportion of the men from a more diverse population are likely to manifest such behavior. These studies indicate the importance of taking into account early experiences and other background factors in studies linking testosterone and behavior.

Women's Orientation toward Family Relationships

Again we note the limited number of studies linking testosterone to female peer and marital relationships. One study that poses a challenge for future research explored gendered behavior in 250 women aged 27-30. Udry, Morris and Kovenock (1995) found that women with higher levels of testosterone were less likely to marry and assigned a lower priority to marrying. They also found that such women were less interested in children and had fewer children. Cashdan (1995) found that women with higher testosterone-associated dominance behavior felt less need for a partner. Whether testosterone-linked low interest in marriage and children is translated into poorer marital quality and lower parent-parent child relationship quality is unknown and is an important question for future research.

Men's Orientation to Family Relationships

Usually research focuses on the impact of higher levels of testosterone on behavior. Much less attention has been devoted to declines in testosterone and the role of the social milieu in that decline. For example, testosterone declines when men marry (Grey et al. 2002, Mazur and Michalek 1998) and declines further when they become fathers (Story et al. 2000), but climbs when they divorce (Mazur and Michalek 1998). Additionally, fathers with lower testosterone are more attuned to their infant's cries (Fleming et al. 2002). The origin and duration of these changes and the consequences they have for behavior is unknown. The decline may derive from attempts to meet the expectations associated with new roles and expectations, or it may have biological roots in pheromones or other stimuli. The mechanisms that explain these testosterone changes are ripe for study.

Examples of questions to be studied include: What behaviors change as a result of the declines in testosterone associated with marriage or becoming a parent? Whose behavior precedes the change in testosterone? Does the behavior following the decline in testosterone then lead to further changes in the hormone? Does the process of assuming more and more of the parenting responsibilities lead to further declines in testosterone or does it eventually contribute to an increase in testosterone that leads to the father becoming more involved with offspring?

Answering such questions requires knowledge of risk and resilience factors that may influence context (Luthar et al. 2000, Masten et al. 1990). For example,

the well-known buffer, parent-child relationship quality, may depend on such things as whether the parent was raised in a supportive family, the current family is disadvantaged economically, and whether the quality of the parents' marriage is high or low.

Gender Differences

Testosterone's link to behavior in females has some parallels with males and some differences. In both female and male children, low levels of testosterone are related to depression (Booth et al. 2003). In the same study testosterone is negatively related to externalizing behavior in females and positively related to such behavior in males. There is too little research on testosterone-behavior associations among females to even tentatively account for the gender differences, making this an important question to address in future research.

As noted above, the link between testosterone and sexual behavior among youth was found to vary by gender (Udry 1988). Although testosterone was positively related to interest in sex, having a father in the household and participating in sports inhibited the interest from being expressed in sexual intercourse in females but not in males.

We know that high levels of testosterone are related to peer competence and the amount of time spent with peers by males, but not by females (Updegraff et al. forthcoming). A similar picture has been observed among adults. In a study of marital quality wives' testosterone was unrelated to marital quality whereas husbands' testosterone was related both positively and negatively related to marital quality depending on the males' role overload at the time marital quality was measured (Booth et al. 2005).

On the other hand, testosterone's link to parenting behavior is similar for males and females. Higher testosterone is associated with lower levels of interest in marriage and parenting (Cashdan 1995, Udry et al. 1985) among females. In men, studies suggest that low levels of testosterone are associated with the anticipation of becoming a parent (Story et al. 2000) and being more attuned to caring for offspring (Fleming et al. 2002). Low testosterone has a positive role in marriage and parenting among both males and females.

Whether testosterone has links to status, dominance behavior, aggression, risk behavior and initiative that is similar in males and females is unclear. Grant and France (2001) indicated that high testosterone women are more likely to report dominating behavior. Studies of women in prisons report both positive and null associations between testosterone and dominance or aggression (Banks and Dabbs 1996; Dabbs and Hargrove 1997; Dabbs, Ruback, Frady, Hooper and Sgoutas 1988). Some studies report testosterone to be negatively related to status (Gladue 1991). Clearly further research is needed to reach conclusions regarding gender differences in the links between testosterone and dominance and risk behavior. For example, higher levels of testosterone are positively related to interest in masculine activities in pre-pubertal females (McHale et al. 2004) and to resistance to parental socialization efforts encouraging feminine behavior (Udry 2000).

In addition, we must continue to explore developmental and cultural factors. For example, Taylor and colleagues suggested that "fight or flight" is not an appropriate model to use in explaining behavior during a crisis. They proposed "tend and befriend" as a more appropriate model for females and that oxytocin is one of the key hormones involved. Drawing on conflict theory, Campbell (1995) argued that because of the greater value of mothers' health relative to fathers in providing sufficient resources to offspring, women are less likely to involve themselves in potentially dangerous conflicts over status. While women are less likely to engage in dangerous conflicts, women do engage in aggression to compete for scarce resources. Campbell argued that female non-aggressiveness is a myth created by men to sanction female aggression.

Conclusion

The advent of non-invasive means of measuring hormones and new paradigms has opened windows of opportunity to integrate testosterone into sociology. The new paradigms have shifted thinking away from biodeterminism and focused it on the integral role of the environment for understanding the links between biology and behavior. This realization has enabled research attention to focus on identifying new sources of individual differences, modeling intra-individual change, and exploring interactive and reciprocal effects.

Social status is a fundamental building block of human groups. The way in which status is gained, maintained and lost is fundamental to understanding the structure of individual social networks, corporations and governments. Status governs the way in which resources are obtained and distributed. It also defines the way in which order is maintained. It is apparent that testosterone has a role in organizing status hierarchies. Next steps in the research should incorporate females to a significant extent and move beyond the sports venue.

To date much of the testosterone research on problem behavior has focused on aggression and antisocial behavior. Missing from this research is the understanding that the behavior of concern is dominance, risk taking and initiative, and that only a small portion of these acts involves aggression, defined as the intent to physically harm others. One of the reasons high levels of testosterone are so seldom associated with aggression is because of the protective influence of the social environment and the resilience individuals develop by living in such an environment. While much research has focused on externalizing behavior (aggression, deviance, crime), it is now apparent that testosterone has a role in our understanding of depression as well. The topic most in need of research is the process by which the environment moderates the link between testosterone and problem behavior.

Largely ignored for many years is the positive role testosterone may play in family and friendship relationships. There are now enough studies to assert that this is rich area for research. As in other relationship domains, the social environment plays a important role in defining whether testosterone has a positive or negative influence on the quality of intimate relationships. Research is needed to explore a wide range of environmental factors that have the potential for affecting the quality of intimate relationships.

From the research to date it is clear that there are important gender differences that need explanation. Why should female testosterone count in some areas (e.g., parenting) but not others (e.g., adolescent peer relations and marriage)? Yet there is symmetry in the way in which low testosterone in both males and females enhances parenting. Research is needed to understand gender differences and similarities in testosterone's link to behavior.

The field is still in the early stages of carefully describing the nature of testosterone-behavior links in everyday social life, but the establishment of these associations is only the beginning. The next generation of biosocial research needs to go beyond describing the associations and uncover the fundamental mechanisms and processes underlying them (Raine 2002). The appropriate measurement tools and statistical strategies necessary to move this endeavor toward understanding the nature of biosocial phenomenon are now available. In our opinion, the critical need is for sociologists to increase our understanding of how social, behavioral, cognitive and biological variables shape individual and group processes.

References

Aleman, A., E. Bronk, R. Kessels, H. Koppeschaar and J. van Honk. 2004. "Time course of effects of testosterone administration on sexual arousal in women." *Archives of General Psychiatry* 59:403-4.

Banks, T., and J. Dabbs Jr. 1996. "Salivary testosterone and cortisol in a delinquent and violent urban subculture." *The Journal of Social Psychology* 136:49-56.

Bateup, Helen S., Alan Booth, Elizabeth A. Shirtcliff and Douglas A. Granger. 2002. "Testosterone, Cortisol, and Women's Competition." *Evolution and Human Behavior* 23:181-92.

Baucom, Donald H., Paige K. Besch and Steven Callaan. 1985. "Relation Between Testosterone Concentration, Sex Role Identity and Personality Among Females." *Journal of Personality and Social Psychology* 48:1218-26.

Bauman, Karl E., Vangie A. Foshee and Nancy J. Haley. 1992. "The Interaction of Sociological and Biological Factors in Adolescent Cigarette Smoking." *Addictive Behaviors* 17:459-67.

Booth, Alan, and James M. Dabbs. 1993. "Testosterone and Men's Marriages." *Social Forces* 72:463-77.

Booth, Alan, David R. Johnson and Douglas A. Granger. 1999a. "Testosterone and Men's Health." *Journal of Behavioral Medicine* 22:1-19.

_____. 1999b. "Testosterone and Men's Depression: The Role of Social Behavior." *Journal of Health and Social Behavior* 40:130-40.

_____. 2005. "Testosterone and Marital Quality." *Journal of Marriage and Family.* 67:483-98.

Booth, Alan, David R. Johnson, Douglas A. Granger, Ann C. Crouter and Susan McHale. 2003. "Testosterone and Child and Adolescent Adjustment: The Moderating Role of Parent-Child Relationships." *Developmental Psychology* 39:85-98.

Booth, Alan, Greg Shelley, Allan Mazur, Gerry Tharp and Roger Kittok. 1989. "Testosterone, and Winning and Losing in Human Competition." *Hormones and Behavior* 23:556-71.

Bowlby, J. 1958. "The Nature of the Child's Tie to His Mother." *International Journal of Psychoanalysis* 39:350-73.

Breedlove, S. 1992. "Sexual Differentiation of the Brain and Behavior." Pp. 39-68. *Behavioral Endocrinology*. J. Becker, S. Breedlove and D. Crews, editors. MIT Press.

Brennan, Patricia A., and Adrian Raine. 1997. "Biosocial Bases of Antisocial Behavior: Psychophysiological, Neurological, and Cognitive Factors." *Clinical Psychology Review* 17:589-604.

Cacioppo, John T., and Gary G. Bernston. 1992. "Social Psychological Contributions to the Decade of the Brain." *American Psychologist* 47:1019-28.

Campbell, Anne. 1999. "Staying Alive: Evolution, Culture, and Women's Intrasexual Aggression." *Behavioral and Brain Sciences* 22:203-52.

Campbell, Anne. 1995. "A Few Good Men: Evolutionary Psychology and Female Adolescent Aggression." *Ethology and Social Biology* (now *Evolutionary Psychology*) 16:99-123.

Cashdan, Elizabeth. 1995. "Hormones, Sex, and Status in Women." *Hormones and Behavior* 29:354-66.

_____. 1998. "Are Men More Competitive Than Women?" *British Journal of Social Psychology* 37:213-29.

Cicchetti, Dante, and Geraldine Dawson. 2002. "Multiple Levels of Analysis." *Development and Psychopathology* 14(3):417-20.

Cohan, Catherine L., Alan Booth and Douglas A. Granger. 2003. "Gender Moderates the Relationship between Testosterone and Marital Interaction." *Journal of Family Psychology* 17(1):29-40.

Dabbs, J. 1993. "Salivary Testosterone Measurements in Behavioral Studies." *Annals of the New York Academy of Sciences* 694:177-83.

Dabbs, J., Jr. and M. Hargrove. 1996. "Age, Testosterone, and Behavior among Female Prison Inmates." Department of Psychology. Georgia State University.

Dabbs, J., Jr., R. Ruback, R. Frady, C. Hopper and D. Sgoutas. 1988. "Saliva Testosterone And Criminal Violence among Women." *Personality and Individual Differences* 9:269-75.

Dabbs, James M., Frank J. Bernieri, Rebecca K. Strong, Rebecca Campo and Rhonda Milun. (2001). "Going on Stage: Testosterone in Greetings and Meetings." *Journal of Research in Personality* 35:27-40.

Dabbs. James M., and R. Barry Ruback. 1988. "Saliva Testosterone and Personality of Male College Students." *Bulletin of the Psychonomic Society* 26:244-47.

Daitzman, Reid, and Marvin Zuckerman. 1980. "Disinhibitory Sensation Seeking, Personality and Gonadal Hormones." *Personality and Individual Differences* 1:103-10.

Drigotas, Stephen M., and J. Richard Udry. 1993. "Biosocial Models of Adolescent Problem Behavior: Extension to a Panel Design." *Social Biology* 40:1-7.

Ehrenkranz, J., E. Bliss and M. Sheard. 1974. "Plasma Testosterone: Correlation with Aggressive Behavior and Social Dominance in Men." *Psychosomatic Medicine* 36:469-75.

Elias, Michael. 1981. "Serum Cortisol, Testosterone, and Testosterone-Binding Globulin Response to Competitive Fighting in Human Males." *Aggressive Behavior* 7:215-24.

Eysenck, Hans J. 1964. *Crime and Personality*. 1st edition. Methuen.

Filaire, E., and G. Lac. 2000. "Dehydroepiandrosterone (DHEA) Rather than Testosterone Shows Saliva Androgen Response to Exercise in Elite Female Handball Players." *International Journal of Sports Medicine* 21:17-20.

Fleming, Alison S., Carl Corter, Joy Stallings, and Meir Steiner. 2002. "Testosterone and Prolactin are Associated with Emotional Responses to Infant Cries in New Fathers." *Hormones and Behavior* 42:399-413.

Ford, Donald H. 1987. *Humans as Self-Constructing Living Systems.* Lawrence Erlbaum Associates, Inc.

Foshee, V.A., S.B. Ennett, K.E. Bauman, D.A. Granger, A. Hussong, R. DuRant, T. Benefield and C. Suchindran. Forthcoming. "A Test of Biosocial Models of Adolescent Cigarette and Alcohol Use."

Geary, David C., and Mark V. Flinn. 2002. "Sex Differences in Behavioral and Hormonal Response to Social Threat: Commentary on Taylor et al. (2000)." *Psychology Review* 109(4):745-50.

Gimble, C., and A. Booth. 1996. "Who Fought in Vietnam?" *Social Forces* 74:1137-57.

Gladue, B. 1991. "Aggressive Behavior Characteristics, Hormones, and Sexual Orientation in Men and Women." *Aggressive Behavior* 17:313-26.

Gonzalez-Bono, E., A. Salvador, M.A. Serrano and J. Ricarte. 1999. "Testosterone, Cortisol, and Mood in a Sports Team Competition." *Hormones and Behavior* 35:55-62.

Gottlieb, Gilbert. 1992. *Individual Development and Evolution: The Genesis of Novel Behavior.* Oxford University Press.

Granger, Douglas A., and Katie T. Kivlighan. 2003. "Integrating Biological, Behavioral, and Social Levels of Analysis in Early Child Development: Progress, Problems, and Prospects." *Child Development* 74:1058-63.

Granger, Douglas A., Eve B. Schwartz, Alan Booth and Matthew Arentz. 1999. "Salivary Testosterone Determination in Studies of Child Health and Development." *Hormones and Behavior* 35:18-27.

Granger, Douglas A., Elizabeth Shirtcliff, Alan Booth, and Katie T. Kivlighan. 2005. "The Trouble with Salivary Testosterone." *Psychoneuroendocrinology* 30:58-71.

Granger, Douglas A., Elizabeth A. Shirtcliff, Carolyn Zahn-Waxler, Barbara Usher, Bonnie Klimes-Dougan and Paul Hastings. 2003. "Salivary Testosterone Diurnal Variation and Psychopathology in Adolescent Males and Females: Individual Differences and Developmental Effects." *Development and Psychopathology* 15:431-39.

Gray, Peter B., Sonya M. Kahlenberg, Emily S. Barrett, Susan F. Lipson and Peter T. Ellison. 2002. "Marriage and Fatherhood are Associated with Lower Testosterone in Males." *Evolution and Human Behavior* 23:193-201.

Halpern, Carolyn Tucker, Richard Udry, and Chirayath Suchindran. 1997. "Testosterone Predicts Initiation of Coitus in Adolescent Females." *Psychosomatic Medicine* 59:161-71.

_____. 1998. "Monthly Measures of Salivary Testosterone Predict Sexual Activity in Adolescent Males." *Archives of Sexual Behavior* 27:445-65.

Harris, Dale B. (1957). *The Concept of Development.* University of Minnesota Press.

Harris, J., P. Veron and D. Boomsma. 1998. The Heritability of Testosterone: A Study of Dutch Adolescent Twins and Their Parents." *Behavioral Genetics* 28:165-71.

Herrmann, W.M., and R.C. Beach. 1976. "Psychotropic Effects of Androgens: A Review of Clinical Observations and New Human Experimental Findings." *Pharmakopsych* 9:205-19.

Herrmann, W., R. McDonald and M. Bozak. 1976. "A Psycho Experimental Model of the Investigation of Hormones and Psychotropic Agents." *In The Psychotropic Actions of Hormones: Proceedings of the First World Congress of Biological Psychiatry, Buenos Aires, Argentina, September 1974.* Turan M. Itil, Gerhard Laudahn and Werner M. Herrmann, editors. Spectrum Publications.

Hong, Y, J. Gagnon, T. Rice, L. Perusse, J. Leon, J. Skinner, C. Wilmore, C. Bourchar, and D. Rao. 2001. "Familial Resemblance for Free Androgens and Androgen Glucuronides in Sedentary Black and While Individuals: The HERITAGE Family Study. Health, Risk Factors, Exercise Training and Genetics." *Journal of Endocrinology* 170:485-92.

Inoff-Germain, Gale, Gina Snyder-Arnold, Editha D.Nottelmann, Elizabeth J. Susman, Gordon B. Cutler, Jr. and George P. Chrousos. 1988. "Relations Between Hormone Levels and Observational Measures of Aggressive Behavior of Young Adolecents in Family Interactions." *Developmental Psychology* 24:129-39.

Kivilighan, Katie T., Douglas A. Granger and Alan Booth. Forthcoming. "Gender Differences in Testosterone and Cortisol Response to Competition." *Psychoneuroendocrinology*.

Klaiber, E.L., D.M. Broverman, W. Gogel, G.E. Abraham and F.L. Cone. 1971. "Effects of Infused Testosterone on Mental Performances and Serum LH." *Journal of Clinical Endocrinology and Metabolism* 32:342-49.

Kouri, E., S. Lukas, H. Pope and P. Oliva. 1995. "Increased Aggressive Responding in Male Volunteers Following the Administration of Gradually Increasing Doses of Testosterone Cypionate." *Drug and Alcohol Dependence* 40:73-9.

Kreuz, L., R. Rose and J. Jennings. 1972. "Suppression of Plasma Testosterone Levels and Psychological Stress." *Archives of General Psychiatry* 26:479-82.

Lerner, Richard M. 1986. *Concepts and Theories of Human Development.* 2nd edition. Random House.

Luthar, S., D. Chicchetti and B. Becker. 2000. The Construct of Resilience: A Critical Evaluation and Guidelines for Future Work. *Child Development* 71:543-62.

Magnusson, David, and Robert B. Cairns. 1996. "Developmental Science: Toward a Unified Framework." Pp. 7-30. *Developmental Science.* Robert B. Cairns, Glen H. Elder, Jr. and E. Jane Costello, editors. Cambridge University Press.

Masten, A., K. Best and N. Garmezy. 1990. "Resilience and Development: Contributions from the Study of Children who Overcome Adversity." *Development and Psychopathology* 2:425-44.

Mattsson, A., D. Schalling, D. Olweus, H. Low and J. Svensson. 1980. "Plasma T, Aggressive Behavior, and Personality Dimensions in Young Male Delinquents." *Journal of the American Academy of Child Psychiatry* 19:476-90.

Mazur, Allan. 1985. "A Biosocial Model of Status in Face-to-Face Primate Groups." *Social Forces* 64:377-402.

_____. 2005. Biosociology of Dominance and Deference. Rowman & Littlefield.

Mazur, Allan, and Alan Booth. 1998. "Testosterone and Dominance in Men." *Behavioral and Brain Sciences* 21:353-63.

Mazur, Allan, Alan Booth and James M. Dabbs. 1992. "Testosterone and Chess Competition." *Social Psychology Quarterly* 55(1):70-7.

Mazur, Allan, and Theodore A. Lamb. 1980. "Testosterone, Status, and Mood in Human Males." *Hormones and Behavior* 14:236-46.

Mazur, Allan, and Joel Michalek. 1998. "Marriage, Divorce, and Male Testosterone." *Social Forces* 77:315-30.

Mazur, Allan, Elizabeth J. Susman and Sandy Edelbrock. 1997. "Sex Difference in Testosterone Response to a Video Game Contest." *Evolution and Human Behavior* 18:317-26.

McCaul, Kevin D., Brian A. Gladue and Margaret Joppa. 1992. "Winning, Losing, Mood, and Testosterone." *Hormones and Behavior* 26:486-504.

McHale, Susan, L. Shanahan, K. Updegraff, Ann C. Crouter and Alan Booth. 2004. "Developmental and Individual Differences in Girls Sex Typed Activities in Middle Childhood and Adolescence." *Child Development* 75:1575-93.

Monaghan, E., and S. Glickman. 1992. "Hormones and Aggressive Behavior." Pp. 261-85. *Behavioral Endocrinology*. J. Becker, S. Breedlove and D. Crews, editors. MIT Press.

Neave, Nick, and Sandy Wolfson. 2003. "Testosterone, Territoriality and the 'Home Advantage'." *Physiology and Behavior* 78:269-75.

Nelson, Randy J. (2000). *An Introduction to Behavioral Endocrinology*. 2nd edition. Sinauer.

Olweus, Dand, Ake Mattsson, Daisy Schalling and Hans Loew. 1980. "Testosterone, Aggression, Physical and Personality Dimensions in Normal Adolescent Males." *Psychosomatic Medicine* 42:253-69.

_____. 1988. "Circulating Testosterone Levels and Aggression in Adolescent Males: A Causal Analysis." *Psychosomatic Medicine* 50:261-72.

Plomin, Robert, and Michael Rutter. 1998. "Child Development, Molecular Genetics, and What to do with Genes Once They are Found." *Child Development* 69:1223-42.

Pope, H., E. Kouri and J. Hudson. 2000. "Effects of Supraphysiologic Doses of Testosterone on Mood and Aggression in Normal Men: A Randomized Control Trial." *Archives of General Psychiatry* 57:133-40.

Rahe, R., S. Karson, N. Howard, R. Rubin and R. Poland. 1990. "Psychological and Physiological Assessments on American Hostages Freed from Captivity in Iran." *Psychosomatic Medicine* 52:1-16.

Raine, Adrian. 2002. "Biosocial Studies of Antisocial and Violent Behavior in Children and Adults: A Review." *Journal of Abnormal Child Psychology* 30:311-26.

Rose, R, I. Bernstein and T. Gordon. 1975. "Consequences of Social Conflict on Plazma Testosterone Levels in Rhesus Monkeys." *Psychosomatic Medicine* 37:50-61.

Rowe, Richard, Barbara Maughn, Carol M. Worthman, E. Jane Costello and Adrian Angold. 2004. "Testosterone, Antisocial Behavior and Social Dominance in Boys: Pubertal Development and Biosocial Interactions." *Biological Psychiatry* 55:546-52.

Rutter, Michael, Judy Dunn, Robert Plomin, Emily Simonoff, Andrew Pickles, Barbara Maughan, Johan Ormel, Joanne Meyer and Lindon Eaves. 1997. "Integrating Nature and Nurture: Implications of Person-Environment Correlations and Interactions for Developmental Psychopathology." *Development and Psychopathology* 9:335-64.

Rutter, M., H. Giller and A. Hagell. 1998. *Antisocial Behavior by Young People.* Cambridge University Press.

Salvador, Alicia, Vicente Simon, Fernando Suay and Luis Llorens. 1987. "Testosterone and Cortisol Responses to Competitive Finding in Human Males." *Aggressive Behavior* 13:9-13.

Salvador, Alicia, Ferran Suay, Sonia Martinez-Sanchis, Vicente M. Simon and Paul F. Brain. 1999. "Correlating Testosterone and Fighting in Male Participants in Judo Contests." *Physiology & Behavior* 68:205-9.

Sapolsky, R. 1997. *The Trouble with Testosterone: And Other Essays on the Biology of the Human Predicament*. Scribner.

Shang, L., W. Ma, J. Barker and D. Rubinow. 1999. "Sex Differences in Expression of Serotonin Receptors (Subtypes, 1A and 2A) in Rats Brain: A Possible Role of Testosterone." *Neuroscience* 94:251-59.

Steinberg, L., and J. Silk. 2002. "Parenting Adolescents." Pp. 103-133. *Handbook of Parenting: Vol. 1. Children's Parenting*. 2nd edition. M. Bornstein, editor. Lawrence Erlbaum.

Storey, Anne E., Carolyn J. Walsh, Roma L. Quinton and Katherine E. Wynne-Edwards. 2000. "Hormonal Correlates of Paternal Responsiveness in New and Expectant Fathers." *Evolution and Human Behavior* 21:79-95.

Suay, F., A. Salvador, E. González-Bono, C. Sanchís, M. Martínez, S. Martínez-Sanchis, V.M. Simón and J.B. Montoro. 1999. "Effects of Competition and its Outcome on Serum Testosterone, Cortisol and Prolactin." *Psychneuroendocrinology* 24: 551-66.

Susman, Elizabeth J., Gale Inoff-Germain, Editha D. Nottelmann, D. Lynn Loriaux, G.B. Cutler and G.P. Chrousos. 1987. "Hormones, Emotional Dispositions, and Aggressive Attributes in Young Adolescents." *Child Development* 58:1114-34.

Taylor, Shelley E., Laura Cousino Klein, Brian P. Lewis, Tara L. Gruenewald, Regan A.R. Gurung and John A. Updegraff. 2000. "Biobehavioral Responses to Stress in Females: Tend-and-Befriend, Not Fight-or-Flight." *Psychological Review* 107(3): 411-29.

Thompson, W., J. Dabbs, Jr. and R. Frady. 1990. "Changes in Saliva Testosterone Levels during a 90-day Shock Incarceration Program." *Criminal Justice and Behavior* 17:246-52.

Tremblay, R. 2000. "The Development of Aggressive Behaviour During Childhood: What Have We Learned in the Past Century?" *International Journal of Behavior and Development* 24:129-41.

Tremblay, R., B. Schaal, B. Boulerice, L. Arseneault, R. Soussignan and D. Perusse. 1997. "Male Physical Aggression, Social Dominance and Testosterone Levels at Puberty: A Developmental Perspective." Pp. 271–91. *Biosocial Bases of Violence*. A. Raine, P. Brennan, D. Farrington and S. Mednick, editors. Plenam.

Tremblay, Richard E., Benoist Schaal, Bernard Boulerice, Louise Arseneault, Robert G. Soussignan, Daniel Paquette and Denis Laurent. 1998. "Testosterone, Physical Aggression, Dominance and Physical Development in Early Adolescence." *International Journal of Behavioral Development* 22:753-77.

Tuiten, A., J. van Honk, H. Koppeschaar, C. Bernaards, F. Thijssen and R. Verbaten. 2002. "Time Course of Effects of Testosterone Administration on Sexual Arousal in Women." *Archives of General Psychiatry* 58:403-4.

Udry, J. Richard. 1988. "Biological Predispositions and Social Control in Adolescent Sexual Behavior." *American Sociological Review* 53:709-22.

_____. 1990. "Biosocial Models of Adolescent Problem Behaviors." *Social Biology* 37:1-10.

_____. 2000. "Biological Limits of Gender Construction." *American Sociological Review* 65:443-57.

Udry, J. Richard, Naomi M. Morris and Judith Kovenock. 1995. "Androgen Effects on Women's Gendered Behavior." J*ournal of Biosocial Science* 27:359-69.

Updegraff, K., Alan Booth and S. Shawna. (2006). "Hormones and Adolescents' Peer Experiences: The Moderating Roles of the Parent-Adolescent Relationship." *Family Psychology* 20:151-471.

Van Honk, J., A. Tuiten, E. Hermans, P. Putman, H. Koppeschaar, J. Thijssen, R. Verbaten and L. Doornen. 2001. "A Single Administration of Testosterone Induces Cardiac Accelerative Responses to Angry Faces in Healthy Young Women." *Behavioral Neuoscience* 200:238-42.

Wang, Christina, Gerianne Alexander, Nancy Berman, Behrouz Salehia, Tina Davidson, Veronica McDonald, Barbara Steiner, Laura Hull, Carlos Callegari and Ronald S. Swerdloff. 1996. "Testosterone Replacement Therapy Improves Mood in Hypogonadal Men: A Clinical Research Center Study." *Journal of Clinical Endocrinology and Metabolism* 81:3578-83.

Windle, Michael. 1994. ":Temperamental Inhibition and Activation: Hormonal and Psychosocial Correlates and Associated Psychiatric Disorders." *Personality and Individual Differences* 17:67-70.