ARTICLE

Testosterone and male behaviours

Nick Neave and **Daryl B. O'Connor** describe their research into the complex effects of this hormone

The steroid hormone testosterone has long been associated with various male-typical behaviours. This review first highlights key issues in behavioural endocrinology, and then provides a brief summary of the authors' research into various associations between testosterone and male behaviours. Some evidence in support of the assumption is found, but some critical issues regarding testosterone-behaviour relationships are also raised.

questions

To what extent does testosterone influence aspects of male-typical behaviours?

How useful is the 2D:4D ratio in determining links between prenatal steroid exposure and subsequent physical/behavioural characteristics?

What role do social/environmental factors play in hormone–behaviour interactions?

Is testosterone related to variations in aspects of cognition?

resource

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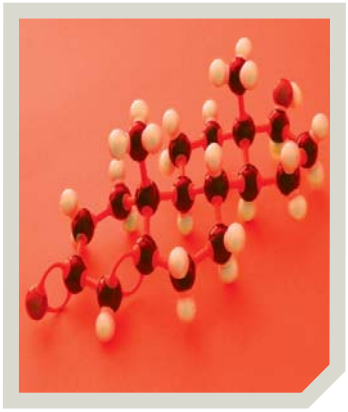
Think of testosterone and you probably think of lust, violence and machismo. Indeed, testosterone is often labelled 'the aggression hormone' due to its presumed relationships with such negative, antisocial and principally male qualities.

Over the past decade or so our principal research activities have investigated the extent to which levels of testosterone can be associated with certain male-typical behaviours. As you might expect, the answer is by no means straightforward. For one thing, hormones do not directly change behaviour; they influence the expression of a behaviour within appropriate environmental/social contexts. When studying human behaviours, identifying which environmental/social contexts might be important remains a significant challenge to researchers trying to identify hormone–behaviour relationships.



Testosterone influences the expression of many behaviours

In behavioural endocrinology animal models are routinely used to address such questions. The effects of any hormones on behaviour are normally described in terms of 'organisational' versus 'activational' effects. In the former, it is known that during early fetal development, levels of the sex steroids (principally testosterone) play a pivotal role in sexual differentiation. The sexes begin life in an undifferentiated state; the presence of the TDF protein (Testis Determining Factor) on the Y chromosome in male offspring triggers the developing testes to secrete massive doses of testosterone. This then sculpts the body and the brain in a male-typical direction, and at the same time suppresses female-typical development. In the absence of this protein in the female fetus, development of the body and the central nervous system proceeds along nature's default setting (female). Later on, during puberty and beyond, the second 'activational' effect becomes apparent: those cells and structures in the body that have been initially 'organised' along male or female lines, are then 'activated' by the sex steroids (Nelson, 2000).

Animal models can be used to compare organisational versus activational effects, for example by castrating a male before or after fetal sexual differentiation has taken place, or castrating him before or after pubertal differentiation has taken place. Such males can be compared physically and behaviourally with other males who have been left gonadally intact; in addition these castrated males can then of course have their testosterone levels returned to normal (or even higher than normal) via replacement therapy, and once again alterations in their physiology/behaviour noted. Such studies have provided significant information concerning the role of sex steroids in certain animal behaviours.

In terms of organisational effects,

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assessing the hormonal environment associated with fetal development and then comparing that environment to subsequent behaviour in humans is rather more difficult. Castration and replacement studies are of course ethically impossible, but some clinical conditions in which the fetus has been exposed to abnormal levels of certain hormones can shed some light on this issue. In a condition called congenital adrenal hyperplasia (CAH), the female fetus is exposed to very high levels of testosterone, which acts to physically masculinise her external genitalia. More interestingly to psychologists, girls with CAH are reported to show more male-typical behaviours, such as increases in rough-and-tumble play and aggression, and more male-typical toy preferences (e.g. Berenbaum & Hines, 1992).

2D: 4D ratio

Determining the organising effects of sex steroids in non-clinical groups appeared to be beyond the reach of psychologists. However, some anatomical observations made on the hand over a century ago have provided a possible window into prenatal steroid exposure.

Several researchers noted that the differences between the second (index) and fourth (ring) fingers are sexually dimorphic; in males it is often the case that the fourth finger is longer than the second, while in females the second and fourth fingers are typically around the same length. At the time, this difference could not be readily explained, and so remained an interesting scientific footnote until the publication of John Manning's 2002 book *Digit Ratio*. Here, Manning proposed that prenatal testosterone and estrogen differentially influence the growth of the fingers. The second and fourth fingers appear to be particularly sensitive to the early hormonal environment (we still don't know why) and as the male fetus is normally exposed to higher levels of testosterone, their fourth finger grows relative to their second finger. This difference between second (2D) and fourth (4D) fingers can easily be measured using calipers, and the resulting 2D:4D ratio (lower in males, higher in females) correlated with various physical/behavioural traits.

Along with various collaborators we have explored such relationships and have found intriguing associations between the 2D:4D ratio and numerical processing (Brookes et al., 2007), certain aspects of personality (Fink et al., 2004a; 2006); body morphology (Fink et al., 2003; Manning et al., 2006); hand skill (Fink et al., 2004b), and perceptions of dominance and masculinity (Neave et al., 2003). Other researchers have reported significant associations between 2D:4D and measures of aggression (Bailey & Hurd, 2005), sex role identity in males (Rammsayer & Troche, 2007), sexual orientation (Rahman, 2005); sporting achievement (Tester & Campbell, 2007); and performance in SAT tests (Brosnan, 2008).

Of course, any observed relationships remain circumstantial; evidence is based upon associations between characteristics that are themselves dependent upon sex steroids; and correlations of course do not guarantee causality. Nevertheless, measuring a couple of fingers might form our best available estimate of prenatal steroid exposure (McIntyre, 2006), even though it may only shed light upon a fairly narrow window of early prenatal development (Putz et al., 2004). Many researchers are now using this simple technique, and many papers reporting associations between 2D:4D and various behaviours/characteristics have now been published; large-scale meta-analytic studies will hopefully inform us as to the reliability and validity of these many reported associations.

Activational effects

Research questions concerning the activational effects of testosterone can now be more easily addressed because it is simple and relatively cheap to measure levels of circulating testosterone, and compare levels with observed behaviours. Bioavailable (or 'free') testosterone can be measured in saliva (as well as in blood), and such testing can be conducted outside of a laboratory setting in various groups (e.g. children, athletes, etc.) with basic training and equipment.

Several research paradigms can be adopted. The most commonly used is correlational – associating the level of testosterone with a certain behavioural characteristic. More experimental designs can also be adopted, whereby testosterone levels can be (a) compared between different groups, (b) compared within the same individuals in different situations, or (c) directly manipulated via hormone therapy. Our research has used all of these methods; some examples follow.

The home advantage in sport

A robust phenomenon is found in numerous sports: teams win more games, and score more goals/points when playing at their home venue. Traditional explanations for home advantage have considered referee bias, home crowd support, greater venue familiarity by the home team, and travel/fatigue /disruption experienced by the away team (Neave & Wolfson, 2004).

An additional factor might be physiological, and related to perceptions of territoriality. In animals, territorial behaviours are common, and it has been established that the acquisition and defence of territories (especially by males) is at least partly mediated by surges in testosterone (Wingfield et al., 1990). As humans also display territoriality, could home advantage be partly explained by a surge in testosterone before defending one's home territory? Two studies (Neave & Wolfson, 2003) found that footballers do indeed demonstrate a testosterone surge before a home game compared with before a training session or an away game; this home surge being particularly apparent when playing a team perceived as being a 'bitter' rival. As yet, we can only guess at how testosterone is able to improve home player performance, but likely explanations relate to increases in

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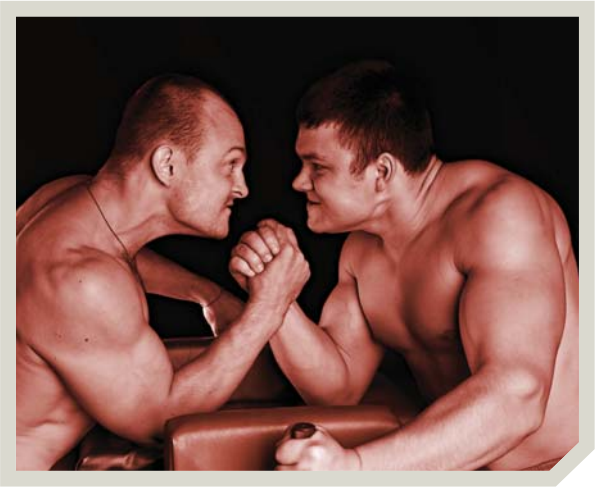
motivation, confidence, reaction times, information processing, and physiological potential. In addition, we need to determine how individual differences in testosterone might relate to performance during a game; and whether it is possible to (legally) manipulate testosterone to improve team performance when playing away. Our research into such questions continues.

Aggression and mood

The association between testosterone, aggression and mood has been the focus of considerable research attention for some time now (e.g. Archer, 1991; O'Connor et al., 2004; Pagonis et al., 2006). This has been prompted by several developments. Firstly, the high-profile media coverage of incidents of 'roid rage' seemingly associated with the abuse by strength athletes of androgenic-anabolic steroids (AAS). Secondly, the use of exogenous testosterone clinically as part of the development of a reversible, hormonal contraceptive for men, its use for replacement therapy in HIV illness and for treating the psychological and physiological effects of ageing in men.

Anecdotal and early correlational evidence suggests that higher levels of circulating testosterone in men are associated with increases in male-typical behaviours, such as physical aggression and anger. However, much of this research has been observational, retrospective and/or cross-sectional in nature, making it difficult to render conclusions about the causal relations between testosterone and male behaviour (Archer, 1991; O'Connor et al., 2002).

More recently, researchers have turned their attention to conducting experimental studies where testosterone levels can be manipulated. However, of the existing studies, different doses of testosterone have been administered for different purposes. For example, in order to mimic levels used by AAS users, some studies have administered high, supraphysiological doses of testosterone. Others, as part of hormonal male contraceptive studies or testosterone replacement therapy, use a lower therapeutic dose (see below). These methodological differences further complicate conclusions about the extent to which testosterone influences important aspects of male behaviour.



To this end, a recent review compared the effects of administering supraphysiological doses with therapeutic doses of testosterone on aggression, anger and mood outcomes in men (O'Connor, 2007). The results showed that there was some evidence that supraphysiological doses were associated with increases in measures of direct aggression, anger and mood. In particular, studies that administered the very highest doses reported a small, but significant number of participants experiencing psychiatric episodes such as mania following treatment (Su et al., 1993). In contrast, the therapeutic dose studies using a wide range of self- and partner-reported measures provided little or no evidence of changes in aggression or mood outcomes (e.g. O'Connor et al., 2004).

Taken together, the evidence suggests that the relatively modest doses of testosterone required for clinical purposes are not associated with changes in aggressive or angry behaviour. Moreover, reports of AAS abusers exhibiting high levels of aggressiveness and experiencing episodes of mania or hypomania after taking huge doses of AAS should not be compared with or extrapolated to the effects of therapeutic doses of testosterone.

In terms of helping us understand the relationship between testosterone and aggressive behaviour, the current evidence suggests that the relationship is nonlinear. Instead, there seems to be a threshold level after which exogenous administration of very high doses of testosterone may lead to negative behavioural changes in particular people under certain circumstances. Individual differences in personality traits such as impulsivity are also likely to play an important role in moderating these effects (see O'Connor et al., 2002). Therefore, further studies using more sophisticated designs and employing more sensitive measures and partner reports are required to uncover important vulnerability factors (O'Connor et al., 2001b). Moreover, there is a need to establish whether the relatively modest incidence of psychiatric symptoms observed in illicit AAS abusers is a true estimate or whether the findings from a relatively small number of studies represent the tip of the iceberg.

Sexual behaviour

It is well established that testosterone plays a vital role in governing sexual behaviour in humans. Early behavioural evidence comes from studies of hypogonadal men who, due to abnormal gonadal function have low or no circulating testosterone, and as a result exhibit impaired sexual functioning. Once these men receive testosterone replacement therapy, their sexual function is restored to normal (Wang et al., 2000).

So, can increases in circulating

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testosterone activate changes in aspects of sexual functioning, such as frequency of sexual behaviour and libido? This is a pertinent question in light of the likelihood in the future of a substantial uptake of hormonal male contraceptive methods in sexually active men. A number of previous studies have failed to find any 'negative' effects of exogenous testosterone on sexual behaviour, although it has been suggested that suitably sensitive or detailed measures were not employed (e.g. Bagatell et al., 1994). In a comprehensive, double-blind, placebo-controlled, cross-over study (O'Connor et al., 2004), increasing testosterone levels in healthy young men did not significantly increase either the interactional (i.e. the frequency of sexual intercourse) or non-interactional (i.e. libido) components of sexual behaviour.

Part of the explanation for these findings may be that relationship and other social factors have an overriding influence on sexual activity. There are some data that show therapeutic doses of testosterone can enhance sexual arousal when measured under carefully monitored laboratory conditions using a dichotic listening task (Alexander et al., 1997). Nevertheless, the weight of evidence suggests that testosterone administration reliably restores sexual functioning in young and middle-aged men with lower than normal testosterone levels, but has no influence on interactional or non-interactional components of sexual behaviour when hormone levels are raised above normal. We have now turned our attention to exploring the role of declining hormone levels in relation to a myriad of behavioural outcomes in ageing men as part of the European Male Ageing Study (see O'Connor et al., 2008).

Cognition

Hormone administration studies have also provided useful insights into the factors associated with variations in cognitive performance, particularly in relation to the established gender differences that exist in cognitive functioning. It is well known that on average, men generally outperform women on visuospatial tasks and women outperform men on verbal fluency and perceptual speed tasks (Halpern, 2000). Of course, it is important to note that the overlap in performance between men and women on each of these tasks is much greater than the mean differences between the sexes. Nonetheless, several biologically plausible mechanisms have been proposed to account for these differences. Evidence suggests that endogenous sex hormones affect cognitive functioning through their pre- and perinatal effects on sexually dimorphic brain structures (Collaer & Hines, 1995). For example, in a seminal study Hier and Crowley (1982) showed that androgen deficient (hypogonadal) men exhibited a marked deficit in visuospatial ability compared with matched controls and hypogonadal men who acquired the condition post-pubertally. These findings indicate that testosterone has an organisational effect on the normal expression of spatial ability. More recently, we found testosterone to also have activational effects on cognitive functioning in healthy men: improvements in verbal ability were found to accompany a reduction in spatial ability following testosterone treatment (O'Connor et al., 2001a). These findings suggest that the relationship between testosterone and cognitive functioning is not straightforward, and that an optimum level of hormone is required for the normal expression of spatial ability.

Age-related reductions in testosterone have been found to be associated with a progressive decline in cognitive abilities. In fact, several studies have examined whether testosterone supplementation in older men can benefit cognition. Exciting recent developments in this area have shown that hormone replacement therapy in men can have beneficial effects on aspects of cognitive functioning. Cherrier and colleagues (2007) found that moderate-to-high increases in testosterone were associated with significant improvements in verbal and spatial memory. This could be a promising avenue for future research, with implications for treating older men with existing cognitive difficulties such as mild cognitive impairment or Alzheimer's disease.

Entering an exciting period

It is clear that an enormous amount of work remains to completely understand the relationships between testosterone and human behaviour. Traditional research questions have focused on the role of testosterone in male behaviours, but we are becoming increasingly aware that this is not a simple linear relationship; the social context and individual behaviours might also play a significant role in determining hormone levels (van Anders & Watson, 2006). This 'chicken and egg' problem remains a key issue, and there are many questions that remain to be addressed and many variables that need to be considered. We are currently in an exciting period where hormone analyses are becoming cheaper and easier to conduct, so that more psychologists can begin to get involved in attempting to address these important questions.

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