Psychoneuroendocrinology 68 (2016) 111–116

Contents lists available at ScienceDirect

Psychoneuroendocrinology

journal homepage: www.elsevier.com/locate/psyneuen

Early postnatal testosterone predicts sex-related differences in early expressive vocabulary

Karson T.F. Kung*, Wendy V. Browne, Mihaela Constantinescu, Rebecca M. Noorderhaven, Melissa Hines

Department of Psychology, University of Cambridge, Free School Lane, Cambridge CB2 3RQ, UK

ARTICLE INFO

Article history:
Received 20 October 2015
Received in revised form 29 February 2016
Accepted 2 March 2016

Keywords:
Testosterone
Postnatal development
Sex
Gender
Vocabulary
Language development

ABSTRACT

During the first few years of life, girls typically have a larger expressive vocabulary than boys. This sex difference is important since a small vocabulary may predict subsequent language difficulties, which are more prevalent in boys than girls. The masculinizing effects of early androgen exposure on neurobehavioral development are well-documented in nonhuman mammals. The present study conducted the first test of whether early postnatal testosterone concentrations influence sex differences in expressive vocabulary in toddlers. It was found that testosterone measured in saliva samples collected at 1–3 months of age, i.e., during the period called mini-puberty, negatively predicted parent-report expressive vocabulary size at 18–30 months of age in boys and in girls. Testosterone concentrations during mini-puberty also accounted for additional variance in expressive vocabulary after other predictors such as sex, child's age at vocabulary assessment, and paternal education, were taken into account. Furthermore, testosterone concentrations during mini-puberty mediated the sex difference in expressive vocabulary. These results suggest that testosterone during the early postnatal period contributes to early language development and neurobehavioral sexual differentiation in humans.

1. Introduction

Certain aspects of language development differ between the sexes. Females are typically better at speech production than males (Hyde and Linn, 1988). In particular, during the first few years of life, girls on average speak more words and thus have a larger expressive vocabulary than boys (Berglund et al., 2005; Feldman et al., 2000; Fenson et al., 1994; Zubrick et al., 2007). Early expressive vocabulary development is particularly important, since a small vocabulary may indicate language delay and predict subsequent language difficulties, which are more prevalent in boys than girls (Hawa and Spanoudis, 2014; Rescorla, 2011).

Early androgen exposure may contribute to the sex difference in early expressive vocabulary development. Androgens, particularly the testicular hormone, testosterone, are elevated in male fetuses between about 8 and 24 weeks of gestation (Reyes et al., 1974). There is also an early postnatal surge of testosterone in male infants, called "mini-puberty", with testosterone peaking at about 1–3 months of age, and declining to baseline by about 6 months of age (Winter et al., 1976). During these periods, the adrenal glands produce some androgens in both sexes, but in males the gonads produce larger amounts of testosterone. In studies of non-human mammals, manipulations of testosterone prenatally or neonatally exert enduring influences on behavioral characteristics that differ for the two sexes (Arnold, 2009). Higher concentrations of testosterone produce more male-typical behavior whereas lower concentrations of testosterone produce more female-typical behavior (Arnold, 2009).

Two studies have investigated whether early testosterone exposure contributes to expressive vocabulary size in humans. The first study included 40 boys and 47 girls aged 18–24 months and used amniotic fluid testosterone to estimate prenatal testosterone exposure (Lutchmaya et al., 2001). The second study included 197 boys and 176 girls aged 2 years and used umbilical cord blood testosterone to estimate late prenatal testosterone exposure (Hollier et al., 2013). Both studies employed parent-report questionnaires and found the expected differences between boys and girls in testosterone and in vocabulary. The first study found no correlation between testosterone and vocabulary in either boys or girls, whereas the second study found the expected negative correlation in boys, but not in girls. Similarly, studies relating amniotic or umbilical cord blood testosterone to other aspects of language

* Corresponding author.
E-mail address: tk418@cam.ac.uk (K.T.F. Kung).

http://dx.doi.org/10.1016/j.psyneuen.2016.03.001

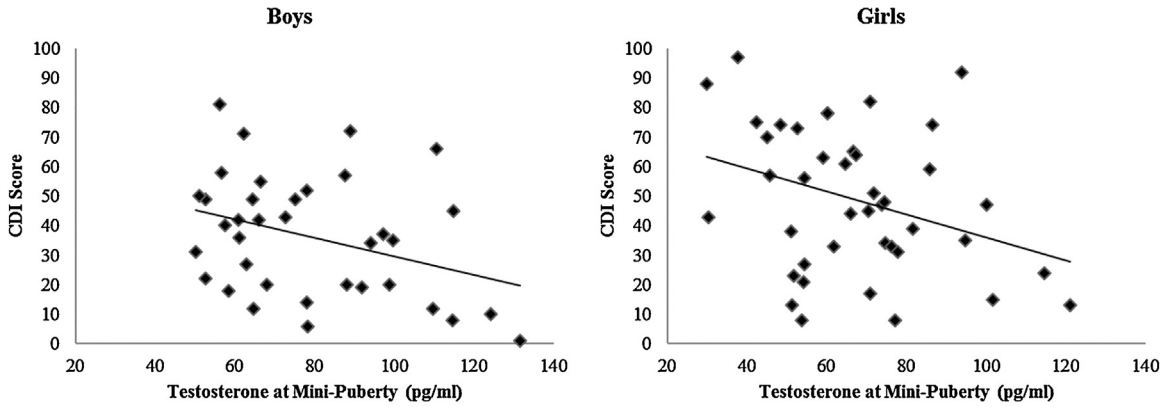

Fig. 1. Scatter plot showing the relationship between scores on the toddler short form for vocabulary production from the MacArthur Communicative Development Inventory (CDI) and concentrations of testosterone at mini-puberty in boys (left) and girls (right).

Table 1
Descriptive and Inferential Statistics for Differences Between Boys and Girls.

	Boys (B)			Girls (G)			All			B vs. G		
	n	M	SD	n	M	SD	n	M	SD	t	p	d[a]
Testosterone at mini-puberty (pg/ml)	36	79.09	22.75	42	67.37	20.79	78	72.78	22.36	2.38	0.020	0.55
CDI scores	37	36.97	20.83	42	48.62	24.54	79	43.18	23.48	−2.26	0.027	−0.51
Birth weight (kg)	37	3.42	0.53	42	3.46	0.42	79	3.44	0.47	−0.37	>0.250	−0.08
Child's age at saliva sampling (weeks)	37	7.64	1.72	42	8.14	2.27	79	7.90	2.03	−1.09	>0.250	−0.24
Child's age at CDI assessment (months)	37	22.59	3.54	42	22.19	3.23	79	22.38	3.64	0.53	>0.250	0.12
Maternal age (years)	37	34.48	3.28	41	34.05	4.58	78	34.25	3.99	0.47	>0.250	0.11
Paternal age (years)	36	36.03	3.79	41	36.78	6.10	77	36.43	5.13	−0.64	>0.250	−0.15
Maternal education	37	4.68	0.47	42	4.62	0.54	79	4.65	0.51	0.49	>0.250	0.12
Paternal education	37	4.46	0.65	42	4.69	0.52	79	4.58	0.59	−1.76	0.083	−0.39
Number of siblings	37	0.59	0.90	42	0.57	0.77	79	0.58	0.83	0.12	>0.250	0.02

Note. CDI = the toddler short form for vocabulary production from the MacArthur Communicative Development Inventory; Maternal and paternal education were rated on a 5-point scale from 1 (*primary education only*) to 5 (*postgraduate degree*).

[a] Positive *d*s indicate higher values in boys than girls.

development have produced mixed findings (e.g., Finegan et al., 1992; Grimshaw et al., 1995; Lust et al., 2010; Whitehouse et al., 2012, 2014). These largely negative findings could reflect insufficiently sensitive measures of testosterone exposure (Hines et al., 2015; Hollier et al., 2014). The negative findings in some studies could also reflect the use of language outcome measures that showed no sex differences (e.g., Finegan et al., 1992; Grimshaw et al., 1995; Lust et al., 2010).

No studies have yet related the early postnatal testosterone surge, mini-puberty, to later expressive vocabulary. However, testosterone exposure during mini-puberty appears to be important for normal development of the male genitalia and reproductive function (Boas et al., 2006; Kuiri-Hänninen et al., 2011; Main et al., 2005). Testosterone during mini-puberty also has been found to predict subsequent sex-typical play behavior (Lamminmaki et al., 2012; Pasterski et al., 2015). In addition, brain plasticity remains high and the brain continues to develop rapidly throughout the early postnatal period (de Graaf-Peters and Hadders-Algra, 2006). Language-related neural development can be expected to involve both prenatal and early postnatal influences. Thus, testosterone during mini-puberty, as well as prenatally, may relate to later expressive vocabulary.

Although no research has related testosterone during mini-puberty to expressive vocabulary, three studies have examined other language outcomes in relation to early postnatal testosterone concentrations. The first study related testosterone in infant blood samples collected at age 1 month to lateralization of language function measured by electroencephalography (EEG) at the same age in 18 boys and 18 girls (Friederici et al., 2008). It was found that EEG responses differed by sex and that testosterone related to EEG responses in boys and in girls. Nevertheless, because the study was contemporaneous, findings could reflect transient influences of androgen, instead of the enduring influences that testosterone can exert on behavior. The second study related testosterone in infant saliva samples collected at age 3–4 months to durations of vocalizations and to the number of words expressed during laboratory play sessions at age 18–24 months in 47 boys and 37 girls (Saenz and Alexander, 2013). The third study related testosterone in infant blood samples collected at age 5 months to scores on measures of language comprehension completed at age 3–5 years in 9 girls and 11 boys (Schaadt et al., 2015). Correlational findings from both of these longitudinal studies were mostly non-significant, perhaps partly due to the use of outcome measures that showed no sex differences. Also, one of the longitudinal studies reported no sex difference in testosterone, which could reflect the collection of saliva samples at 3–4 months postnatal, after the peak of the postnatal surge (Saenz and Alexander, 2013). In addition to limitations in measures of testosterone and sex-related language development, these prior studies did not test whether testosterone may mediate sex differences in early language development.

The present study investigated whether salivary testosterone at 1–3 months of age predicts expressive vocabulary size at 18–30 months of age. Saliva sampling was employed since it affords a non-invasive approach for assessing testosterone concentrations. Expressive vocabulary during toddlerhood was assessed, because it shows a reliable sex difference and because low expressive vocabulary during toddlerhood may predict subsequent language difficulties. It was expected that boys would have higher salivary testosterone concentrations, and a smaller expressive vocabulary, than girls. We also tested the hypotheses that testosterone would: