



Within-person changes in salivary testosterone and physical characteristics of puberty predict boys' daily affect



Kathrin Klipker^{a,*}, Cornelia Wrzus^{a,2}, Antje Rauters^{a,3}, Steven M. Boker^b, Michaela Riediger^{a,3}

^a Max Planck Research Group "Affect Across the Lifespan", Max Planck Institute (MPI) for Human Development, Berlin, Germany

^b Department of Psychology, University of Virginia, United States

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ABSTRACT

Recent investigations highlighted the role of within-person pubertal changes for adolescents' behavior. Yet, little is known about effects on adolescents' daily affect, particularly regarding the hormonal changes underlying physical changes during puberty. In a study with 148 boys aged 10 to 20 years, we tested whether within-person physical and hormonal changes over eight months predicted everyday affect fluctuations, measured with experience sampling. As expected, greater within-person changes in testosterone (but not in dehydroepiandrosterone) were associated with higher affect fluctuations in daily life. Additionally, greater physical changes predicted higher affect fluctuations for individuals in the beginning of puberty. The findings demonstrate the relevance of physical and hormonal changes in boys' affective (in)stability.

Adolescents are widely assumed to experience rapid mood swings. Empirical findings indeed demonstrate a tendency for amplified affect in adolescence as compared to late childhood and adulthood (e.g., Larson et al., 2002; Sallquist et al., 2009; Weinstein et al., 2007; for an overview see Zimmermann and Iwanski, 2014). Pubertal, as compared to prepubertal, adolescents showed more intense, more varying, and more negative affective experiences (e.g., Berenbaum et al., 2015; Buchanan et al., 1992; Steiner et al., 2003). Findings are less clear when it comes to whether different stages of pubertal development (beginning, middle, or advanced puberty) are particularly prone to elevated affective responding (e.g., Gunnar et al., 2009; Hunt, 1999; Sumter et al., 2010). We propose that findings remain inconclusive because most prior studies on adolescents' affective experiences have taken a cross-sectional approach, that is, compared different physical characteristics or hormonal levels, and thus were unable to capture within-person changes during puberty.

Employing a within-person approach, investigations on behavior problems and psychopathology highlighted the potential importance of the amount of pubertal changes adolescents experience during a particular time. This perspective has been subsumed by using the term pubertal tempo (e.g., Dorn and Biro, 2011; Mendle, 2014). With regard to everyday affective experiences, however, investigations on the role of within-person pubertal changes are lacking. It has been argued that

quicker pubertal maturation may demand quicker adaption to biological and social transitions (Dorn and Biro, 2011; Mendle and Ferrero, 2012) and reflect more pronounced hormonal changes (e.g., Dorn and Biro, 2011; Shirtcliff et al., 2009; Spielberg et al., 2014). Particularly hormonal changes in puberty are widely assumed to have implications for affect and behavior (e.g., Amin, 2006; Balzer et al., 2015; Buchanan et al., 1992; Mendle, 2014; Walker et al., 2004). The vast majority of these studies, however, stem from adolescent girls and adult women (Balzer et al., 2015; Steiner et al., 2003). Very little is known about associations between sex-steroids and affect in boys (for reviews, see Duke et al., 2014; Mendle and Ferrero, 2012).

In the present paper, we attempt to contribute to a better understanding of the role of puberty in boys' affect since the evidence is still inconclusive. We propose that it is the amount of pubertal and especially hormonal changes that influence the stability of individuals' affective experiences, with greater amount of changes in a given time resulting in more intense and more quickly fluctuating daily affective experiences. Using a multi-method investigation, we studied boys' within-person changes in self-reported physical development as well as their within-person changes in sex-steroid hormone levels. We focused on within-person affect fluctuations (i.e., how quickly and intensely an individual's affect occurs and diminishes, thus fluctuates, throughout the course of the day), as affect fluctuations constitute a central

* Corresponding author at: Robert Koch Institute, Unit Mental Health, General-Pape-Str. 66, 12101 Berlin, Germany.

E-mail address: kathrin.klipker@rub.de (K. Klipker).

¹ Kathrin Klipker is now at Robert Koch Institute, Berlin, Germany.

² Cornelia Wrzus is now at Johannes-Gutenberg University Mainz, Germany.

³ Antje Rauters and Michaela Riediger are now at the University of Jena, Germany.

characteristic of affective experiences (e.g., Eid and Diener, 1999; Wang et al., 2012) and psychological health (e.g., Bowen et al., 2006; Gruber et al., 2013; Klinkman, 2007). We use the terms adolescence or puberty when prior evidence refers to both boys and girls, and otherwise identify findings as solely referring to boys or girls.

1. The role of pubertal changes in affective experiences

Different hypotheses have been discussed in the literature on how puberty impacts adolescents' affective experiences (for review, see Ge and Natsuaki, 2009). First, hormonal changes in puberty have long been assumed to be relevant for affective experiences (e.g., Buchanan et al., 1992; Duke et al., 2014; Steiner et al., 2003). Second, physical changes in puberty might elicit feelings of distress or insecurity because of others' reactions or own perceptions of the changes (e.g., for a review, see Mendle and Ferrero, 2012), especially when physical changes occur rapidly (e.g., Mendle et al., 2010).

Physical development in puberty (e.g., genital or pubic hair growth) results from hormonal changes, primarily androgens, such as testosterone in boys and estrogens in girls (Ellison et al., 2012). Androgens exert stimulating effects on the central nervous system and result in structural changes (e.g., Brouwer et al., 2015; Schulz et al., 2009; Smith et al., 2002; Van Wingen et al., 2011). Specifically, sex steroids activate androgen and estrogen receptors that are particularly prevalent in regions involved in the processing of affective information, such as the hypothalamus, amygdala, septal nucleus, and hippocampus (e.g., Brouwer et al., 2015; Van Wingen et al., 2011). Through receptor activity, large changes in sex steroids can stimulate affect-related brain structures (for further readings on mechanisms stemming from human and animal studies, see Celec et al., 2015). This likely results in unstable affective experiences in both boys and girls (e.g., Amin, 2006; Schulz et al., 2009; Walker et al., 2004).

Hormonal changes during puberty, and especially in beginning⁴ stages of puberty (e.g., Ankarberg-Lindgren and Norjavaara, 2004; Khairullah et al., 2014), exceed most hormonal changes that occur later in life (e.g., testosterone decline in older men or menopause in women; Schulz et al., 2009; Walker et al., 2004). Hence, it seems plausible to assume that hormonal changes in puberty contribute to elevated affective experiences in pubertal adolescents. Importantly, greater amount of hormonal changes in boys (Ankarberg-Lindgren and Norjavaara, 2004; Khairullah et al., 2014) and girls (Alonso and Rosenfield, 2002) were observed in beginning as compared to more advanced stages of physical puberty. In addition, changes in beginning stages of physical puberty might be particularly stressful to individuals because they experience these changes for the first time (e.g., Ge and Natsuaki, 2009). We therefore predicted that (a) greater amount of hormonal changes and (b) physical changes especially during beginning stages of physical puberty are related to higher affect fluctuations.

Next, we discuss the available empirical evidence on the association between puberty and affective experiences with regard to the role of within-person changes in puberty. Because the majority of studies focused on physical development in puberty, we first review studies that investigated physical development in puberty in relation to affective experiences. Next, we review the few studies that directly investigated underlying hormonal changes in puberty in relation to affective experiences.

⁴ Throughout the manuscript, we chose the terminology “beginning” and “advanced” stages of puberty as opposed to the terminology “early” and “late” status of puberty to avoid confusion with the concept of early and late pubertal timing. Pubertal timing denotes the age at which changes in primary and secondary sex characteristics appear relative to peers, that is, earlier, concurrently, or later than same-aged peers.

1.1. Empirical evidence on associations between physical development and affect in puberty

Longitudinal studies on associations between physical changes in puberty and affective experiences are rare. Most prior studies on adolescents' affective experiences used a cross-sectional approach. In some of these studies, adolescents in beginning and middle puberty, as compared to those in advanced puberty, were prone to amplified affective experiences (e.g., Hunt, 1999; Steiner et al., 2003). Other studies found lower affect reactivity in middle as compared to advanced puberty (Sumter et al., 2010) or no differences in affective experiences between levels of physical development in puberty (Gunnar et al., 2009; Yim et al., 2010). Differences in sample selectivity (Shirtcliff et al., 2009), in the assessment of physical development in puberty (e.g., Gunnar et al., 2009; Sumter et al., 2010), or in the investigated facet of affective experiences (e.g., Oldehinkel et al., 2011; Silk et al., 2009) impede comparisons across studies. However, inconclusive findings may also be due to one-time cross-sectional assessments that did not capture the temporal characteristics of the pubertal process.

We argue that the omission of temporal characteristics of puberty may be crucial, as adolescents with comparable levels of pubertal maturation may well differ in how fast pubertal changes occurred. Thus, pubertal changes may be more important for affective experiences than current maturation levels. In support of this notion, Hunt (1999) found more varying and more intense affective experiences when adolescents experienced physical changes in puberty over six and twelve months, as compared to when they did not experience physical changes. Further support for the potential importance of investigating within-person pubertal changes stems from studies on adolescents' psychopathology and behavior problems (for a review, see Mendle, 2014). These studies showed that individuals experiencing more physical changes in puberty during a fixed time period displayed higher depressive and other internalizing symptoms, substance abuse, and social difficulties (e.g., Beltz et al., 2014; Marceau et al., 2011). By relying on physical changes in self-reported puberty rather than directly measuring hormonal changes, these studies only provide indirect evidence on the importance of hormonal changes for individual differences in affect fluctuations.

1.2. Empirical evidence on associations between hormonal development and affect in puberty

There is only limited direct evidence for associations between sex-steroids and affective experiences in adolescence, which almost entirely stems from cross-sectional studies on girls. A recent systematic literature review found nine studies on the effects of girls' estradiol concentrations on affect, of which seven studies were older than 20 years. The authors concluded that estrogen showed consistent associations with depression and affect variability (Balzer et al., 2015). In one study, the effect of estrogen was stronger than the effect of self-reported physical puberty characteristics, emphasizing the role of hormonal characteristics of puberty in affect (Angold et al., 1999). Boys' primary sex-steroids, such as testosterone, have not been studied in relation to affective experiences in adolescence (Duke et al., 2014). In their systematic review, Duke et al. (2014) concluded that, to date, testosterone levels can only be associated with aggressive behavior. With respect to aggressive behavior, these studies provide further support for the hypothesis that changes in hormone levels in adolescence might be more important than the current level of hormones. This is the case because aggressive behavior often decreases across adolescence despite testosterone levels remaining high (Duke et al., 2014).

One study directly investigated longitudinal change in testosterone concentration across a two-year study period in young adolescents in relation to affective processing. Results showed that higher changes in testosterone were related to greater brain activity in emotion-relevant brain regions in response to emotional stimuli in a mixed-sex sample as well as in a boys-only sample (Spielberg et al., 2014). To date,

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