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Review

Neither antecedent nor consequence: Developmental integration of chronic stress, pubertal timing, and conditionally adapted stress response☆

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ABSTRACT

Puberty is often implicated in the onset or exacerbation of psychopathology during adolescence, and pubertal timing and tempo have emerged as important predictors of wellbeing. In the psychosocial literature there is a tendency to view individual differences in the nature (timing and tempo) of pubertal development as either determined by stress experienced in childhood or as a determinant of the development of psychopathology; few studies, however, have examined puberty as both. We propose that pubertal timing and tempo are neither simply antecedents nor consequences with respect to onset or exacerbation of psychopathology, but rather as markers of accumulating risk such as that conceptualized as allostatic load. Further, we propose that integrating coping and self-regulation into models of off-time pubertal maturation presents an opportunity to forge linkages among the processes that precede and follow pubertal development, which may provide malleable intervention targets to offset the costs of early life stress and off-time maturation. The present narrative review synthesizes research from the following literatures: (1) the role of stress in determining the timing and tempo of pubertal development; (2) the role of stress in influencing how pubertal development affects socioemotional and behavioral outcomes during adolescence, and (3) the role of coping and self-regulation in understanding conditional adaptations to stress. Given the conclusions of this synthesis, critical recommendations are made for research and intervention work with adolescents.

Introduction and goals

Exposure to stressors early in life is associated with the development of psychopathology in some individuals. Even in the absence of psychopathology, chronic stress is known to take a physical toll on the body, leading in adulthood to higher risk of health complications and shorter life spans (Evans & Kim, 2007). Childhood adversity and its associated chronic stress (hereafter referred to as early life stress (ELS), with "early" defined as "during childhood") and the development of psychopathology are both also associated with pubertal timing, such that ELS predicts progression through puberty earlier than one's peers (experiencing "off-time" pubertal development), and those adolescents who experience early pubertal development are at increased risk of developing psychopathology (Graber, 2013; Mendle, Turkheimer, & Emery, 2007). In fact, for all but the most extreme stressors which result in

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nutritional deprivation (e.g., famine), chronic stress in childhood serves to accelerate reproductive maturity, resulting in earlier puberty, premature cellular aging, and a general physical weathering of the body (Allsworth, Weitzen, & Boardman, 2005; Ellis, 2004; Geronimus, 1994; Mendle, Ryan, & McKone, 2015). Unfortunately, early life and chronic stress also affect biological (neuroendocrine) and psychosocial (coping) self-regulatory capacities negatively, leaving the organism especially vulnerable to ill effects of off-time maturation, for example. Traditionally, these pathways (from ELS to pubertal timing, and from pubertal timing to psychopathology) have been researched separately and thus the literatures on the antecedents and consequences of off-time pubertal development have progressed somewhat independent of each other. However, it is evident that stress and an individual's responses to said stress play critical roles in conferring risk for both off-time pubertal development and negative outcomes stemming from such off-timing.

Most models involving off-time pubertal development do not fully integrate the prominent role of stress in conferring risk before, during, and after puberty nor clearly delineate the role of self-regulation. This may be a missed opportunity to identify a common psychobiological pathway that serves as a mechanism of both risk and resilience that could have powerful translational implications. The purpose of this narrative review in part is to unite the research literature on variability in pubertal timing and adolescent psychological outcomes. We provide this synthesis in light of compelling evidence supporting the role of stress and stress system calibrations in setting a child's development on an accelerated or delayed life course with numerous physical and psychological sequelae. Through the course of this review, we argue that there is a compelling need for future work to integrate chronic stress into research on the developmental causes and sequelae of individual differences in pubertal timing across biological, social, and psychological contexts.

Adolescence is increasingly recognized as a(nother) particularly plastic period during which the brain and related systems are responsive to and shaped by environmental inputs—a phenomenon with obvious survival benefits. However, adaptation (and survival) generally comes with tradeoffs. Adolescence has therefore been identified as a vulnerable period for the development of psychopathology in some individuals (Costello, Copeland, & Angold, 2011; Dorn & Chrousos, 1997; Mendle, 2014), and this is especially true for those who experience puberty earlier or later than their peers (Graber, 2013; Mendle et al., 2007). Hence, psychopathology may be an unintended consequence of an *adapted* reproductive system, which has been calibrated to meet the needs of an inhospitable rearing environment (e.g., Del Giudice, Ellis, & Shirtcliff, 2011). Taking this idea a step further, we propose that the psychobiological stress response systems (hypothalamic pituitary adrenal (HPA) axis and associated self-regulatory systems) may represent a common pathway (e.g., Thayer & Brosschot, 2005) linking chronic environmental stress, pubertal development, and psychopathology.

In this article, we aim to advance a functionalist perspective of the antecedents and consequences of off-time puberty by incorporating chronic stress and pubertal processes into developmental context. We will: (1) offer a brief discussion of key considerations related to puberty and stress; (2) detail extant explanatory models with and without chronic stress as a mechanism within pubertal development research; (3) review the largely separate literatures on "antecedents" and "consequences" of off-time pubertal maturation; (4) extend existing explanatory models to highlight calibration of HPA axis and associated coping and self-regulation as potentially critical common pathways of conditional adaptation to stress; and (5) provide our conclusions and recommendations, particularly implications for future research and interventions that could minimize both the antecedents and consequences of off-time maturation.

Preliminary considerations

Before embarking on an examination of the developmental integration of stress with what we know of off-time pubertal development, we first clarify key issues in how puberty is measured, define terminology used in puberty research, describe the normative course of puberty for boys and girls, and provide a brief discussion of how we conceptualize stress exposure, stressors, and stress responsivity.

Measurement of puberty

A persistent problem in the research literatures on the psychosocial causes and ramifications of off-time pubertal development is the lack of consistency in measurement of puberty (e.g., Berenbaum, Beltz, & Corley, 2015; Dorn & Biro, 2011; Dorn, Dahl, Woodward, & Biro, 2006). This is problematic because the different measures each provide different information about pubertal development—age at menarche, for example, approximates the near completion of gonadarche for girls, whereas the initial development of breast tissue and enlargement of testicles signal the beginning of puberty for girls and boys, respectively. The gold standard for measuring pubertal status is physical examination by a trained clinician (Dorn et al., 2006). However, perhaps because of the believed intrusiveness and expense of physically examining a child's developing body and concerns of attrition, few researchers use this procedure, and instead rely on parent and self-reports (Dorn & Biro, 2011). The most popular of these is the Petersen Pubertal Development Scale (PDS; Petersen, Crockett, Richards, & Boxer, 1988), a questionnaire about the physical changes of puberty. Other frequently used self-report measures include the presentation of either pictures (Dorn, Susman, Nottelmann, Inoff-Germain, & Chrousos, 1990) or line drawings (Morris & Udry, 1980) of each pubertal stage, with reporters indicating which picture or line drawing best represents the child's physical development. As reviewed by Dorn and Biro (2011), studies of interrater consistency with physical assessments have consistently found self-reports to have only moderate agreement with the gold standard and are often determined to be as reliable or less so than physical examinations (Brooks-Gunn, Warren, Rosso, & Gargiulo, 1987; Desmangles, Lappe, Lipaczewski, & Haynatzki, 2006; Dorn et al., 1990). In addition, self-reported age of menarche is used frequently as a measure