

# The role of puberty in students' academic motivation and achievement<sup>☆</sup>



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## ABSTRACT

This study investigates the relationship between baseline puberty hormones, self-reported physical pubertal status, academic motivation, and academic achievement. Using structural equation modeling among a sample of 342 young people (10–15 years of age), we examined a longitudinal model in which puberty hormones impact one's physical pubertal status, pubertal status predicts subsequent academic motivation (self-efficacy and valuing of school), and both pubertal status and motivation predict academic achievement. We found that beyond the effects of covariates (age, school stage, gender), puberty hormones predicted pubertal status, more advanced pubertal status (but not puberty hormones) was associated with lower self-efficacy and valuing, and lower self-efficacy and valuing were associated with lower achievement. Achievement was not significantly predicted by hormones or pubertal status; rather, motivation explained the bulk of its variance. These findings show that more advanced physical pubertal status is associated with lower academic motivation that in turn is associated with lower achievement. Numerous indirect effects were found between hormones and motivation and achievement via pubertal status and between pubertal status and achievement via motivation. With regards to covariates, findings identified puberty as a potentially more salient factor in motivation than participants' age, whether they are a boy or girl, or in elementary or high school.

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## 1. Introduction

Adolescence is characterized by substantial biological, cognitive, social-cognitive, and social-organizational changes that mark the beginning of the transition to emerging adulthood and which have significant educational implications (Grumbach, 2002; Martin, Way, Bobis, & Anderson, 2015). Puberty is a hallmark of this developmental period (Blakemore, Burnett, & Dahl, 2010). Alongside the physiological (e.g., hormonal), physical, social, and emotional shifts occurring during adolescence, the onset of these changes are also associated with substantial changes in drives and motivations that continue throughout adolescence and into early adulthood (Blakemore et al., 2010). There is also evidence that puberty hormones play a role in brain and cognitive development (Blakemore et al., 2010). Thus, there are links between the endocrine system, the brain, and behavior that are relevant to understanding adolescent development during puberty (Peper & Dahl, 2013; Smith, Chein, & Steinberg, 2013).

However, with regards to young people's academic development, these links are not well understood (Steinbeck et al., 2012), the

sensitivity of older hormone testing methods is questionable (Rosner, Hankinson, Sluss, Vesper, & Wierman, 2013; Wartofsky & Handelsman, 2010), and the effects of puberty are often confounded with the effects of other developmental indicators (e.g., age). Moreover, in educational psychology, very little research has included hormones and puberty in analytic designs; hence, their place and role in the educational process is an area in need of investigation. Accordingly, the present study contributes to the area in seeking to identify the associations between more up-to-date serum gonadal hormone levels (testosterone and estradiol), pubertal status,<sup>1</sup> academic motivation (self-efficacy and valuing), and academic achievement (see Fig. 1). The study also seeks to extend prior research by modeling hormones and pubertal status alongside age, school stage (elementary vs. high school), and gender with a view to disentangling the effects of puberty from the effects of these other developmental indicators.

### 1.1. Pubertal mechanisms and a proposed academic process model

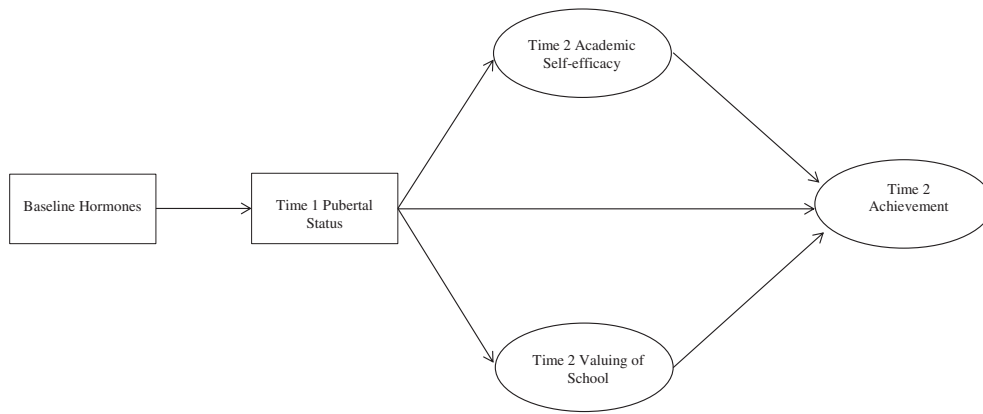
There are a number of ways that puberty might impact behavioral and cognitive outcomes in education, with two particularly influential processes: hormonal changes and physical maturation. In terms of

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<sup>1</sup> Pubertal status refers to one's level of physical maturation and stage of physical development in puberty. This is distinct from pubertal timing which refers to whether one's physical maturation is on time, early or late; and, pubertal tempo which refers to the speed with which one moves through the pubertal stages (Dubas et al., 1991).



**Fig. 1.** Hypothesized model of hormones, pubertal status, motivation, and achievement. *Notes.* All substantive parameters represented in figure; Model controls for covariates (age, stage of school, gender) and also the correlation between Time 2 pubertal status and Time 2 motivation.

hormones, it is possible that changes in hormone concentration may increase an adolescent's arousal or emotional lability. In turn, their responses to adults (e.g., teachers, parents) may be more variable and unpredictable (Buchanan, Eccles, & Becker, 1992; Paikoff & Brooks-Gunn, 1991). It has also been suggested that rising gonadal hormones may sensitize the brain's reward system, making adolescents more receptive and reactive to rewards that may impact motivation and behavior (Peper & Dahl, 2013).

In terms of physical changes and maturation, it may also be the case that pubertal changes impact outcomes through shifts in secondary sex characteristics that are salient to others and which carry particular meaning and assumptions (e.g., about pubertal adolescents). In turn, these assumptions may impact interactions that others (e.g., teachers, parents) have with adolescents that may be relevant to their motivation and academic development. Thus, there may be changes in self and others' expectations, including self-efficacy and valuing of school, that in turn impact achievement (Martin, 2007, 2009). According to Nottelmann, Susman, Blue, et al. (1987a), Nottelmann, Susman, Inoff-Germain, et al. (1987b), hormones may influence adolescent psychological adjustment directly, and also indirectly via effects on physical maturation and, in turn, the response of adolescents and others to these maturational changes.

In explaining the processes by which puberty impacts outcomes, some have suggested the stage termination hypothesis (e.g., see Petersen & Taylor, 1980) that describes the termination of physical childhood that is then associated with problematic psychosocial outcomes. Thus, (early) maturation places adolescents at risk of developmental problems because they engage in activities and roles for which they have not yet developed the appropriate adaptive skills (Williams & Currie, 2000). Related to this, with puberty comes a normative change in self-concept that has a more adult-oriented perspective that in some cases may have adolescents seeing themselves as "all grown up" and rejecting academic conventions and teacher authority. Indeed, this is in line with psychosocial acceleration theory that has shown physical maturation associated with increased risk behaviors by way of smoking and drinking at an earlier age (Arim, Tramonte, Shapka, Dahinten, & Willms, 2011). Thus, for some students in this period, puberty significantly impacts high school trajectories (Cavanagh, Riegle-Crumb, & Crosnoe, 2007).

Taken together, puberty creates a "neurobehavioral nudge" toward exploring these social complexities that in turn can promote adaptive learning across adolescence. At the same time, however, puberty also has potential to create vulnerability to negative developmental trajectories (Peper & Dahl, 2013). The present study explores this by way of the role of puberty on young people's academic motivation and achievement. We hypothesize a model in which hormones give rise to young people's pubertal status (one's physical and therefore visible stage of pubertal development), pubertal status predicts academic motivation

(self-efficacy and valuing), and motivation predicts academic achievement (see Fig. 1). Each of these proposed links is now discussed.

### 1.2. Hormones and puberty

In terms of causal ordering, hormonal changes precede physical maturation changes (i.e., pubertal status). Adrenarche generally precedes gonadarche by a few years, with a rise in weak androgens in both sexes. The physical changes of puberty are driven primarily by the estradiol and testosterone rises of gonadarche marking the activation of the hypothalamic-pituitary-gonadal axis, ending with reproductive competence (see Dorn & Biro, 2011; Grumbach, 2002). This process commences in response to gonadotropin-releasing hormones (GnRH) from the hypothalamus. This activates pituitary production of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) in both sexes. In turn, LH and FSH activate maturational changes in the gonads that attain reproductive capacity. Maturing ovaries and testes secrete increasing amounts of gonadal steroids, with estradiol and testosterone the primary hormones respectively. Increases in gonadal steroids prompt change in the reproductive organs, and the development and appearance of secondary sex characteristics (Blakemore et al., 2010; Peper & Dahl, 2013; Susman & Rogol, 2004).

Importantly, hormonal changes occur quite early in the pubertal process (Buchanan et al., 1992) and longitudinal measures of serum hormones in community samples are difficult to collect with adequate frequency to determine patterns of puberty change. Thus, alternate measures to describe the physical changes of puberty are generally used to capture individual variance through puberty which may take 2–5 years to complete. Many puberty studies have relied on physical staging of puberty alone using Tanner staging (Tanner & Whitehouse, 1976; see also Petersen's development scale as a modification of Tanner staging; Petersen, Crockett, Richards, & Boxer, 1988). Accordingly, hormone measurement and staging assessment (e.g., using Tanner stages, such as in this study—see Method section) may be used in the one research design, with hormones being the proximal influence on pubertal status (Blakemore et al., 2010) and both being considered in terms of their association with motivation. According to Nottelmann et al. (1987a), Nottelmann et al. (1987b), hormones can operate independently of physical pubertal status. For example, there is a time lag (of months to years) between the rise of hormone levels and the appearance of secondary sex characteristics. Thus, different psychosocial adjustment may occur for hormone levels than for physical pubertal status.

It is also the case that there are many biochemical and neurotransmitter processes relevant to puberty, not simply hormones such as testosterone and estradiol levels (the two hormones in our study) (Peper & Dahl, 2013). Additionally, while there is good correlation between

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