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Detrimental psychological outcomes associated with pubertal timing in adolescent boys

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ABSTRACT

Though often discussed as a discrete event, puberty comprises one segment of a larger developmental continuum and is notable for rapid transformation across a multitude of domains. While an earlier timing of puberty relative to peers stands as one of the most well-replicated antecedents of adolescent difficulties for girls, findings have been less consistent for boys' development. The current review synthesizes the research on pubertal timing and psychosocial development in adolescent boys. Results are evaluated in the context of three theoretical perspectives by which precocious development is believed to affect the emergence of adverse outcomes: biological, psychosocial and selection.

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Introduction

Puberty represents a time of dramatic transformation. The striking physiological changes of this period are paralleled by an equally striking cascade of personal, social, and emotional adjustment, as individuals transition into the new roles and expectations which accompany biological maturation. Psychologists have long been intrigued by individual differences in puberty, and how these might predict later health and emotional well-being. A wide body of research has established that an earlier timing of puberty, relative to peers, presages a number of deleterious outcomes in girls. Mendle, Turkheimer, and Emery (2007) provided a comprehensive synthesis of the literature on psychosocial correlates of early pubertal timing in girls. The present review seeks to supplement this work by addressing the relations of pubertal timing with adverse psychological outcomes in boys.

At the outset, it is worth mentioning that the developmental salience of pubertal timing in boys is less frequently studied and less clearly understood than in girls; indeed, Huddleston and Ge lamented

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nearly a decade ago that “the study of boys at puberty lags far behind the girls” (2003, p. 129). Whereas early pubertal timing is reliably associated with a wide gamut of negative sequelae in girls, the literature lacks a similar consistency and breadth of results for boys (Ge, Conger, & Elder, 2001a). Such inconsistency is often attributed to measurement difficulties in capturing pubertal development in boys: The gold standard for assessing puberty is a physical exam, but such exams can be expensive and perceived as invasive, especially since testicular volume seems to be the most valid indicator of male pubertal status (Dorn, Dahl, Woodward, & Biro, 2006). Many studies of girls’ pubertal timing circumvent physical exam by using age at menarche (e.g., Stice, Presnell, & Bearman, 2001), but there is no analogous milestone in males. (Spermarche has been occasionally utilized as an alternative, but there is greater Tanner stage variability when boys reach spermarche than menarche and boys also note reluctance disclosing spermarche to others; Dorn et al., 2006; Downs & Fuller, 1991; Gaddis & Brooks-Gunn, 1985). While self or parent reports of maturation are frequently used, they can vary widely in accuracy (e.g., Dubas, Graber, & Petersen, 1991a) and their validity remains a source of debate (Dorn & Biro, 2011; Dorn et al., 2006).

In addition to measurement challenges, there is the possibility that the social meaning of puberty has changed over time for boys (Ge et al., 2001a). Historically, there has been a prevailing view that early maturation confers benefits for boys, in large part due to the athletic advantages which come with acquiring physical growth before peers. Indeed, early maturing boys have reported higher levels of body satisfaction and self-esteem and late maturers have tended to report lower levels (Benjet & Hernández-Guzmán, 2002; Blyth et al., 1981; Crockett & Petersen, 1987; Simmons, Blyth, Van Cleave, & Bush, 1979). Jones and colleagues (Jones & Bayley, 1950; Mussen & Jones, 1957, 1958) and Clausen (1975) additionally noted that early maturing boys tended to be more confident, popular, relaxed and independent, whereas later maturing boys displayed greater feelings of inadequacy, inferiority, and social rejection. Such differences between early and late developers persisted into early adulthood, when early maturers were described as being more poised, responsible, and sociable than peers, as well as potentially more accepting of and conforming to traditional social roles (Jones 1957, 1965).

More recent perspectives suggest the relations of pubertal timing with psychological well-being may be more complex than initial findings indicated. In particular, early maturation is no longer viewed as uniformly advantageous (Ge et al., 2001a; Huddleston & Ge, 2003); multiple studies have suggested higher risk for both internalizing and externalizing disorders among early maturing boys (e.g., Flannery, Rowe, & Gulley, 1993; Graber, Lewinsohn, Seeley, & Brooks-Gunn, 1997; Susman, Dorn, & Chrousos, 1991), while other studies implicate both early and late development as problematic for adjustment (Alsaker, 1992; Williams & Dunlop, 1999).

Several theoretical perspectives have been proposed to explain the mechanisms by which timing of maturation is associated with adverse outcomes. None of these perspectives are specific to male development; rather, the same mechanisms offered for pubertal timing effects in females are believed to apply also to males. As in Mendle et al. (2007), we classify these perspectives into three broad categories: psychosocial, biological, and selection. It is worth noting, however, that others have applied slightly different labels to the same theories (e.g., Ge & Natsuaki, 2009). Empirical evidence for each perspective with regard to specific outcomes will be reviewed separately.

Advocates of a *psychosocial process* emphasize the importance of environmental experiences in individual coming of age. As physical appearance matures, children are forced to confront new social roles and expectations. Because early maturation inadvertently curtails the pre-adolescent period, early maturers will be forced to grapple with these new stressors before they may be emotionally or cognitively ready to do so, with fewer resources than peers who reach the same developmental milestones at a later chronological age. This situation is commonly referred to as “maturational disparity,” referencing the mismatch between physical and emotional or cognitive development in early maturers (Ge & Natsuaki, 2009); historically, it has also been termed the “stage termination hypothesis” or “developmental readiness hypothesis” (e.g., Petersen & Taylor, 1980).

A variation of this perspective suggests that either early or late maturation will be psychologically distressing, as both place children in a visibly aberrant position at a critical point in development. *Maturational deviance* is believed to elicit damaging social comparisons that diminish self-esteem and trigger problematic outcomes. While the deviance hypothesis has been shown to be insufficient for explaining girls’ pubertal timing effects, since late maturing girls do not seem to encounter

comparable difficulties as early maturers, it remains of interest for understanding pathways of risk in boys' development, as some studies show similar effects of timing for any boys who mature "off-time."

Biological theories of maturational difficulties posit that steep rises in adrenal and gonadal hormones at puberty play a critical role in increasing risk for psychological difficulties (Susman, 1997). Such a perspective seems logical, given that many of the hormones which rise steadily over the course of puberty have also been implicated in depression, social dominance, aggressive behavior, and frustration tolerance (Mazur & Booth, 1998; Olweus, Mattson, Schalling, & Low, 1988; Rowe, Maugham, Worthman, Costello, & Angold, 2004). Yet hormones rise globally for all children over the course of puberty, and there is presently no clear evidence that boys who mature either earlier or later than peers differ in their overall level or pattern of hormonal secretion. This makes it difficult to discern whether it is the timing of puberty – rather than puberty itself – which constitutes risk for emotional and behavioral change. One possibility is that the brain's sensitivity to hormones wanes with age; therefore, the earlier children experience hormonal rises, the greater the impact (Schultz, Molenda-Figueira, & Sisk, 2009). Although this research has primarily been conducted within animals, the perspective is congruent with findings from developmental neuroscience, which note that self-regulatory skills are among the last neural capacities to develop (Casey, Getz, & Galvan, 2008; Dahl, 2004); thus, the earlier children experience hormone-related surges, the less likely they may be to have the skills to manage the resulting emotionality.

Rather than a strict biological model of pubertal timing effects, it is also possible that the social environment intersects with normative hormonal increases in a way that is especially challenging for early or late maturers (e.g., a psychobiological model). Hormonal surges during puberty may intensify a child's sensitivity to social and emotional circumstances, resulting in disproportionate increases in sadness, irritability, anger, or frustration following negative events or interactions with others. Because off-time maturers must navigate hormonal changes at a time when the majority of peers are less labile, this may additionally provoke feelings of being different or misunderstood; conversely, hormone-related emotionality may be interpreted by others in a way that results in increases in peer conflict and declines in friendship quality.

Lastly, the correlates of pubertal timing, particularly early pubertal timing, may evolve from *selection effects*. Puberty serves as a vital juncture in people's lives, bridging childhood experiences with later development, and serving as a harbinger of adjustment or maladjustment in adolescence. Caspi and Moffitt (1991, 1993) have proposed that life transitions – such as early puberty – which inherently provoke high levels of doubt and insecurity are likely to amplify or accentuate any previous behavioral or emotional difficulties. Such transitions may also perhaps activate pre-existing vulnerabilities for psychological problems.

In addition, early pubertal timing does not occur at random; rather, like all constructs, it derives from a complex interplay of genetic and environmental influences. For example, children who experience an earlier timing of maturation are more likely to grow up in childhood environments characterized by chronic stress, parental conflict, harsh parenting, socioeconomic adversity, and father absence (e.g., Belsky et al., 2007; Kim & Smith, 1998). Advocates of a *contextual approach* note that the associations of early puberty with detrimental outcomes may be magnified within children who are already experiencing a high degree of environmental stress. It is therefore difficult to differentiate pathways of risk attributable to pubertal timing from the overall "complex web of effects" (Ge & Natsuaki, 2009); thus, effects that may seem related to pubertal timing might in fact be due to socioenvironmental confounds.

In addition both the onset of puberty and many of the outcomes correlated with it are heritable (Ge, Natsuaki, Neiderhiser, & Reiss, 2007; Mustanski, Viken, Kaprio, Pulkkinen, & Rose, 2004), meaning that genes may function as additional confounding variables. This could occur in three ways. First, the same genes which influence timing of maturation might also influence propensity for a particular outcome (a situation known as *pleiotropy*, in which a single gene affects multiple traits). Second, timing of puberty may represent an example of gene-environment correlation (*rGE*). For example, peers, parents, or teachers may behave differently towards children who appear visibly older or younger than their chronological age (aka, evocative *rGE*). Pubertal timing might also represent active *rGE*, which occurs when individuals select or construct environmental experiences that are correlated with their

genetic propensities. In the case of pubertal timing, early developers, for example, may choose to socialize with an older peer group, who might be engaging in the sorts of delinquent behaviors which tend to be more common later in adolescence. Lastly, the extent to which genes for a particular disorder are expressed may depend on the timing of puberty (aka, gene x environment interaction).

Sequae of pubertal timing

In the following section, we present findings on psychological sequelae associated with pubertal timing in boys. For each correlate, we also evaluate theoretical perspectives and how well each explains the finding. It is worth noting that a broad range of measures were used to operationalize pubertal development in these studies, including children's perceptions of their own maturation relative to peers, hormonal assays, physical exam, and self- or parent-reported Tanner stages. Although these metrics are not equally accurate in assessing development (see Dorn and Biro, 2011; Dorn et al., 2006, for a review), we note differences across measurement modality when these might be particularly relevant to the results obtained.

Internalizing symptoms

Findings in the literature on pubertal timing and internalizing symptoms in boys are equivocal. The majority of studies confirm early maturation as a primary risk: boys who mature earlier than peers also display higher levels of both depression and anxiety during adolescence (Ge, Brody, Conger, & Simons, 2006; Natsuaki, Klimes-Dougan, et al., 2009; Negri, Fung, & Trickett, 2008; Rudolph & Troop-Gordon, 2010) and into early adulthood (Zehr, Culbert, Sisk, & Klump, 2007). This effect notably holds across a variety of measurement modalities for both pubertal timing and internalizing, and across samples with differing levels of ethnic and socioeconomic diversity.

Despite the common historical view of early puberty as advantageous for boys, the relation of early puberty with higher depressive symptoms is not a new one, but was rather first documented approximately 40 years ago (Peskin, 1967, 1973). Among the clearest support for detrimental effects of early maturation comes from Ge, Conger, and Elder (2001b), who reported that advanced pubertal status early in adolescence was a more powerful predictor of depression and anxiety 4 years later than either initial symptom levels or stressful life events. A smaller body of work suggests that either early and/or late maturation places children at risk for depression (Conley & Rudolph, 2009; Graber, et al., 1997; Kaltiala-Heino, Kosunen, & Rimpela, 2003) and that symptoms may persist over the course of adolescence and into early adulthood for both early and late developers (Graber, Seeley, Brooks-Gunn, & Lewinsohn, 2004).

Typically, the association of pubertal timing and internalizing is interpreted in terms of a psychosocial mechanism, considering how early (and, less commonly, late) maturers may struggle to adapt to the changing social environment precipitated by physical maturation. Such perspectives are buoyed by research which incorporate direct socioenvironmental measures into studies of puberty and internalizing. Conley and Rudolph (2009), for example, found that late pubertal timing correlated with high levels of depressive symptoms when peer relationships were problematic, but not when relationships with peers were more harmonious.

Familial factors may additionally mediate or moderate the role of pubertal development in subsequent adjustment, suggesting the possibility of selection effects. The association of early pubertal timing with depression seems to be exacerbated in boys whose mothers report high and moderate levels of depression and whose familial environments are characterized by high levels of stress and adversity (Rudolph & Troop-Gordon, 2010). Such findings highlight the importance of considering pubertal timing within a child's particular context. This is not inconsistent with psychosocial theories, but rather suggests that certain pre-existing circumstances render some children more susceptible to the psychological distress associated with early development. One possibility is pleiotropy – the same genes which influence pubertal timing also influence internalizing symptoms. Alternatively, it may be that early maturation actually provokes problematic environmental circumstances, by placing early maturers in situations for which they are unprepared both cognitively and emotionally. Such situations play

a key role in shaping the course of future development and are consistent with theories that risk for adolescent depression may be, at least in part, explained by genetic predisposition to experiencing stressful events (Silberg et al., 1999).

With regard to a biological mechanism, Susman et al. (1985) found higher levels of negative affect in boys whose hormonal profiles were marked by larger amounts of adrenal androgens, which are among the first hormones to increase at puberty. In a similar vein, boys who experience extremely premature adrenarche (and therefore possess greater levels of adrenal androgens than later-maturing children of the same age) report greater levels of depression and withdrawal symptoms (Dorn, Hitt, & Rosenstein, 1999). Conversely, lower levels of testosterone have been implicated in depression and anxiety in adult men (Almeida, Yeap, Hankey, Jamrozik, & Flicker, 2008; Pope, Cohane, Kanayama, Siegel, & Hudson, 2003) and gender-specific rises in gonadal hormones have been suggested as one possible explanation for the dramatic disparity in depression rates between males and females which first emerges at puberty (reviewed in Cyranowski, Frank, Young, & Shear, 2000).

Lastly, it is important to note that a number of investigations of puberty and internalizing in boys have yielded disparate results. Angold, Costello, and Worthman (1998) failed to find any significant relationships between pubertal timing and depression. A handful of studies additionally report associations of solely late maturation with depressive symptomatology and poor self-image, but no effects of early maturation (Dorn, Susman, & Ponirakis, 2003; Kim & Smith, 1999; Siegel, Yancey, Aneshensel, & Schuler, 1998).

Externalizing symptoms

Externalizing behaviors globally increase following the onset of puberty (Hayward & Solomon, 2002), but timing of maturation seems to play a pivotal role in both severity and frequency of symptoms. The vast majority of research confirms that early maturing boys tend to display greater levels of a range of externalizing problems throughout puberty and early adolescence, including attention deficit disorder, oppositional defiant disorder, conduct disorder, hostility, aggression, and risk-taking behaviors (e.g., Ge, Brody, Conger, & Simons, 2006; Halpern, Kaestle, & Halfors, 2007). Perhaps because of the high salience of delinquency during adolescence (Moffitt, 1993), it is worth noting that the association of early maturation with adolescent delinquent activity is particularly robust, with early maturers displaying greater levels of vandalism, property damage, trespassing, shoplifting, speeding, rule-breaking, lying to parents, and truancy (Cota-Robles, Neiss, & Rowe, 2002; Duncan, Ritter, & Carlsmith, 1985; Felson & Haynie, 2002; Flannery et al., 1993; Halpern, Udry, Campbell, & Suchindran, 1993a; Kaltiala-Heino, Marttunen, Rantanen, & Rimpela, 2003; Najman et al., 2009; Negri & Trickett, 2009; Negri et al., 2008).

This association can be explained by psychosocial, biological, and selection mechanisms. In terms of a psychosocial mechanism, early maturers may have difficulty maintaining friendships with peers who have not developed at a similar pace and may be more likely to affiliate with an older social group engaging in the sorts of acting out and externalizing behaviors which tend to be more common later in adolescence (Ge, Brody, Conger, Simons, & Murry, 2002). These acting out behaviors are believed to be rooted in the imbalance between physical maturity and immature social status; children contend with this “maturity gap” by engaging in rebellious activities designed to demonstrate independence or flaunt adult-enforced rules (Moffitt, 1993; Moffitt & Caspi, 2001; Moffitt, Caspi, Dickson, Silva, & Stanton, 1996). While the discrepancy between biological and social maturity is commonly distressing during this critical developmental window, such a contrast may be particularly pronounced for children who reach full physical maturation at a younger chronological age. In support of this, within a sample of early maturing boys, those who perceived their mothers as more controlling and less tolerant of autonomy also exhibited greater levels of externalizing symptoms (Arim & Shapka, 2008).

In addition, puberty seems to challenge coping resources at a time when daily stressors are continually escalating (Dahl & Gunnar, 2009). Psychosocial theories of early maturation are buoyed by the fact that environmental context seems to be a critical protective factor for children during this pivotal transition. For example, supportive parenting can serve as a buffer for early maturing children whereas harsh and unpredictable parenting practices increase the association between early maturation and externalizing (Ge et al., 2002). In addition, although early maturers at all socioeconomic levels

are more likely to affiliate with deviant peers than later maturers, children who come of age within impoverished neighborhoods are most at risk for forming these friendships, which subsequently facilitate externalizing (Ge et al., 2002).

Deviant peers are among the most well-established risk factors for externalizing behavior in general (e.g., Dishion, Spracklen, Andrews, & Patterson, 1996), and may also mediate associations of pubertal timing with aggressive and delinquent behavior (e.g., Lynne, Graber, Nichols, Brooks-Gunn, & Boitvin, 2009). It is worth considering the interplay between genes and social context in this relationship, and specifically the possibility of selection effects. Children do not select into peer groups at random, but rather are most likely to become friends with children who are similar to them (Guo, 2005; Jaccard, Blanton, & Dodge, 2005). Those children who are most drawn to affiliating with deviant peers and most susceptible to the influence of such friends – regardless of socioeconomic context – might be individuals who are initially predisposed to externalizing. In support of this, peer group affiliations – including affiliation with deviant peers – have been shown to be genetically influenced (Manke, McGuire, Reiss, Hetherington, & Plomin, 1995), with heritability increasing over the course of puberty and adolescence (Kendler et al., 2007).

In terms of a neuroendocrine pathway, boys who experience an aberrantly early onset of adrenarche not only have higher levels of adrenal androgens such as DHEA, but also correspondingly higher levels of aggression, acting out, and difficulty getting along with other children (Dorn et al., 1999). There is, moreover, a well-established correlation between testosterone and aggressive behaviors in a variety of different species of animals (e.g., Archer, 1988; Herting & Belthoff, 1997). Within humans, the relationship seems more complex. Many studies show a correlation between testosterone levels and aggressive behaviors at different ages across the lifespan in both men and women (Archer, 2006; Dabbs, Carr, Frady, & Riad, 1995; Dabbs & Hargrove, 1997; Dabbs & Morris, 1990; Hermans, Ramsey, & van Honk, 2008), but effects are inconsistent (Archer, Birring, & Wu, 1998) and often do not take into account the type of aggressive behavior (Popma et al., 2007).

Of additional interest is research which suggests that the associations between testosterone and aggression may be moderated by cortisol levels. Specifically, testosterone seems associated with aggressive behaviors among individuals with lower levels of cortisol in adolescence, but not necessarily among individuals with higher levels of cortisol (Dabbs, Jurkovic, & Frady, 1991; Popma et al., 2007). This is congruent with recent findings that the relations of cortisol and salivary alpha amylase (another marker of stress reactivity) with externalizing behaviors vary according to timing of development (Susman et al., 2010). Both early maturers with low cortisol and SAA reactivity and late maturers with high cortisol and SAA reactivity exhibit more rule-breaking. This effect is, moreover, stronger for boys than for girls (Susman et al., 2010). Such findings reinforce that varied aspects of the pubertal transition may be differentially challenging based on individual patterns of maturation and individual characteristics. For example, although cortisol is typically thought of in conjunction with stress, it also correlates with characteristics such as inhibition and social withdrawal (Goldsmith & Lemery, 2000; Klimes-Dougan, Hastings, Granger, Usher, & Zahn-Waxler, 2001), which may help explain some of the interaction.

Substance abuse

Like externalizing symptoms and delinquency, substance use and abuse tend to increase over the course of adolescence (Harrell, Bangdiwala, Deng, Webb, & Bradley, 1998; Kirillova et al., 2001; Patton et al., 2004). A number of studies suggest this general trend is particularly true for boys who experience an earlier onset of puberty (e.g., Tschann et al., 1994; Wiesner & Ittel, 2002). Early maturing boys tend to consume greater amounts of alcohol and report more frequent intoxication during adolescence (Biehl, Natsuaki, & Ge, 2007; Costello, Sung, Worthman, & Angold, 2007; Udry, 1991; Wichstrom, 2001). They are also more likely to smoke cigarettes and to use marijuana and other illicit drugs (Felson & Haynie, 2002; Graber et al., 1997; Kaltiala-Heino, Marttunen, Rantanen, & Rimpela, 2003; Van Jaarsveld, Fidler, Simon, & Wardle, 2007).

Psychosocial, biological, and selection pathways all explain these associations. Early maturing boys seem to have easier access to and utilize a greater number of social and commercial sources to acquire alcohol (Storvoll, Pape, & Rossow, 2008), perhaps due to their older-seeming physical appearance. In

addition, Bratberg, Nilsen, Holmen, and Vatten (2007) found that frequent drunkenness and daily smoking was more common among those who perceived themselves as early-matures, consistent with the idea that imitating adult behaviors may be a normative response to the gap between social and biological maturation. This association was intensified among those boys who were part of a peer group where smoking, drinking, and acting out behaviors were more common (Costello et al., 2007; Drapela, Gebelt, & McRee, 2006; Wichstrom, 2001) and parental monitoring less common (Westling, Andrews, Hampson, & Peterson, 2008).

Yet several variables that mediate or moderate this relationship suggest a biological as well as psychosocial mechanism. High sensation-seeking mediates the relationship between early puberty and alcohol, tobacco, and marijuana use, whereas reduced sensation seeking is associated with a comparatively later pubertal timing and decreased alcohol use (Martin et al., 2001, 2002). Sensation seeking is a complicated trait, but one which has generally been correlated with dopaminergic transmission in the mesocortical pathway (e.g., Zuckerman, 1994) and multiple genetic polymorphisms related to the dopamine system (Derringer et al., 2010). For this reason, it is hard to consider early puberty simply in terms of a psychosocial effect; rather it seems that early puberty may activate or exacerbate pre-existing biological propensities for substance use and abuse.

Lastly, a subset of studies have conversely found that *late* maturation is a significant risk factor for substance use. Andersson and Magnusson (1990) found that boys with both early and late timing of skeletal growth reported more frequent and severe drinking at age 14.5 (although these results did not replicate at follow-up 17 months later). Graber et al. (2004) reported that boys who perceived themselves as late maturers reported greater levels of substance abuse in young adulthood compared to those who perceived themselves as maturing early or on-time. As early onset of substance use is a strong predictor of later substance abuse, longitudinal associations of pubertal timing and substance use may require additional research to clarify whether the effects of late maturation match or exceed those of earlier development for the majority of cases.

Victimization

Early pubertal timing not only constitutes risk for delinquency, aggression, and substance use, but also increases the likelihood that boys will be placed in physically perilous situations. Specifically, boys who report earlier perceived maturation are at substantially greater risk for being victims of violent assault or threatened with weapons such as knives or guns (Craig, Pepler, & Connolly, 2001; Haynie & Piquero, 2006; Schreck, Burek, Stewart, & Mitchell Miller, 2007). It has been suggested that this association can be explained primarily by the social and environmental changes precipitated by puberty. One possibility is that parents, teachers, or authorities view early maturing boys as looking mature and self-sufficient, and are therefore less likely to supervise, monitor, or consider them in need of help or protection (Haynie & Piquero, 2006). Another is that by engaging in delinquent and aggressive behavior themselves, early maturing boys come into frequent contact with the sorts of individuals who are likely to commit acts of physical violence. Lastly, it may be that early puberty triggers such a high level of emotional distress and instability that it leads boys to act out in ways that violate social expectations and which may be perceived by others as offensive, provocative, or belligerent (Schreck et al., 2007). This latter perspective is congruent with *social interactionist* theories from the criminology literature, which explore how the processes that make some individuals likely to be perpetrators also make the same individuals likely to be victims (e.g., Felson, 1992). To discriminate between these potential pathways would require a level of data that is not currently available: knowledge about the perpetrators and the context in which such violence occurs. Specifically, it is unclear whether the perpetrators of such assaults are schoolmates, adults, known acquaintances, etc.; the extent to which substances were used by one or both parties at the time; and whether or not other people were present during the assault. Regardless, we believe this finding echoes the higher prevalence rates of rape and domestic violence among early maturing girls (Foster, Hagan, & Brooks-Gunn, 2004; Vicary, Klingaman, & Harkness, 1995) and reinforces the idea that early puberty does not occur in biological isolation, but rather may initiate a cascade of environmental sequelae which shape the course of future development.

Eating disorders

There is a paucity of research on eating disorders in adolescent boys due to the greater prevalence of disordered eating observed in females (American Psychiatric Association, 2000). However, two studies have examined pubertal timing and disordered eating in samples of adolescent boys. Kaltiala-Heino, Rimpela, Rissanen, and Rantanen (2001) found that extremely early onset of puberty was a predictor of bulimia nervosa. A subsequent study by Zehr et al. (2007) similarly reported that retrospective reports of early maturation were associated with significantly higher levels of dietary restraint, shape concerns, weight concerns, and binge eating relative to on-time and late maturers.

A biological pathway might most clearly explain these effects. Levels of estradiol and progesterone correlate with disordered eating, including bingeing, body dissatisfaction, and compensatory behaviors (Edler, Lipson, & Keel, 2007; Klump, Culbert, Edler, & Keel, 2008; Klump et al., 2006, though a caveat is that these studies have only been conducted in females). Adolescents with more advanced pubertal status have higher levels of estradiol and progesterone relative to later-developing peers (see Dorn & Biro, 2011; Sisk & Zehr, 2005 for a review), which is posited to contribute to increased risk for disordered eating during puberty and at subsequent points longitudinally (Zehr et al., 2007). While estrogen and progesterone are obviously higher in females than males (explaining, in part, the higher rates of eating disorders among females), these hormones surge in both genders during puberty; in addition, testosterone – the primary gonadal hormone which rises for boys over the course of puberty – metabolizes to estrogen. Because the developing brain is plastic, and sensitive to the organizational effects of hormones, it has been hypothesized that this results not only in concurrent disordered eating, but neural changes which maintain eating disorder symptoms longitudinally (Zehr et al., 2007).

Sexual activity

A myriad of research suggests that boys who mature early also begin to date, engage in kissing, petting and other romantic behaviors, and report earlier sexual arousal and earlier ages of first intercourse than peers (Crockett, Bingham, Chopak, & Vicary, 1996; Flannery et al., 1993; Halpern, Udry, Campbell, & Suchindran, 1993b; Kim & Smith, 1998, 1999; Silbereisen, Kracke, & Nowak, 1992; Smith, Udry, & Morris 1985). They are additionally significantly more likely than later-developing peers to download and view Internet pornography during middle school (Skooog, Stattin, & Kerr, 2009). This association seems to be primarily a biological one, related to the precocious secretions of testosterone, DHEAS, and estradiol that accompany earlier development and are believed to increase sexual desire and attraction (Halpern, Udry, & Suchindran, 1998; Halpern et al., 1993b; McClintock & Herdt, 1996). In support of a biological mechanism is the fact that this association has been replicated cross-culturally, including samples from Zimbabwe (Campbell, Prossinger, & Mbzivo, 2005), Sweden (Edgardh, 2002); Great Britain (Downing & Bellis, 2009); Hong Kong (Lam et al., 2002); and the Republic of Transkei, which is now part of South Africa (Buga, Amoko, & Ncayiyana, 1996).

There is considerable debate over the “meaning” of early sexual intercourse for adolescents, and the extent to which such activity should be considered a problem outcome (e.g., Meier, 2007). Earlier ages of first intercourse are typically considered disadvantageous because they increase risk for sexually transmitted infections and unwanted teenage pregnancy, resulting in broad public health concerns (Downing & Bellis, 2009). In addition, adolescents who are sexually active also report an array of negative psychosocial outcomes, including poor academic achievement, depression, delinquency, and low self-esteem (Armour & Haynie, 2007; Hallfors, Waller, Bauer, Ford, & Halpern, 2005; Meier, 2007; Spriggs & Halpern, 2008). Boys who experience early pubertal timing are certainly less likely to use contraception than later developing peers (Downing & Bellis, 2009), which may be a by-product of the younger age at which they transition to sexual maturity, and difficulties inherent in acquiring both contraception and accurate and informed knowledge about contraceptive use. Yet an emerging body of research suggests that adolescent sexuality is a heterogeneous outcome, and may predict outcomes differently according to genetic propensities (Harden, Mendle, Hill, Turkheimer, & Emery, 2008); relationship context (Donald, Lucke, Dunne, & Raphael, 1995; McCarthy & Casey, 2008); school environment (Guo, Tong, & Cai, 2008), and likely other mediators yet to be identified.

Academic achievement, intelligence and cognitive ability

There is less research on the relationship between pubertal timing, academic achievement and school performance relative to the previous outcomes addressed in this review. Three studies failed to find a significant relationship between pubertal timing and school performance (Graber et al., 1997, 2004; Simmons & Blyth, 1987). However, three other studies actually suggest an academic advantage for early maturing boys. Petersen and Crockett (1985) reported that early maturing boys received higher grades than late maturers; Dubas, Graber, and Petersen (1991b) observed a similar effect in adolescent boys in sixth, seventh, and eighth grade, and Duke et al. (1992) reported that earlier maturers received more positive reports from teachers, reported higher levels of educational expectations and earned higher achievement scores.

Associations of pubertal timing with IQ and other cognitive tests are also mixed (Mussen & Bouterline-Young, 1968; Orr, Brack, & Ingersoll, 1988; Petersen, 1976; Sanders & Soares, 1986). A handful of largely historical studies report that earlier maturers have elevated scores on IQ and spatial reasoning tests (Abernathy, 1936; Shuttleworth, 1939; Douglas and Ross, 1964; Kohen-Raz, 1974). Contradictorily, other studies note late maturing boys perform better on measures of spatial, listening, and vocabulary abilities (Hassler, 1991; Waber, 1977; Waber, Bauermeister, Cohen, Ferber, & Wolff, 1981; Waber, Mann, Merola, & Moylan, 1985), and one study found that on-time maturers reported the highest IQ scores (Freeman & Flory, 1937). While it may superficially appear that understanding of the relationship between pubertal timing and measures of academic achievement and cognitive ability is nebulous, such inconsistent results in fact support psychosocial theories of development. Specifically, it has long been assumed that cognitive and emotional skills do not necessarily mature in concordance with physical development. This mismatch, coupled with a deceptively adult appearance, results in early maturers being placed in situations they may lack the developmental skills to manage. The limited support for associations between pubertal timing and cognition implicitly reinforces this perspective, since there is no evidence that children's cognitive skills match their level of physical maturation.

Declining age of puberty

There has been considerable recent attention within both academic research and the popular media regarding the potential lowering of pubertal onset in Westernized countries (e.g., Biro et al., 2010; Grady, 2010). The majority of this work has been devoted to female development, particularly secular declines in age at menarche (e.g., Wyshak & Frisch, 1982). Far fewer data are available on boys (Euling et al., 2008) and some of the earliest studies comprise small samples lacking in diversity (Nicolson & Hanley, 1953) or assess participants at ages which are too far along in the process to gain a true sense of timing of pubertal onset (Harlan, Grillo, Cornoni-Huntley, & Leaverton, 1979). Based on the sparse nature of the data, an expert panel convened by the American Academy of Pediatrics concluded that it was impossible to establish or even to suggest a trend towards earlier puberty in American boys over the latter half of the twentieth century (Euling et al., 2008).

Far more speculative than the American Academy of Pediatrics report is an intriguing series of data collected by boys' choirs, recording changes in voice that limit children's singing. Although voice breaking has been included on assessments of puberty such as the Pubertal Development Scale (Petersen, Crockett, Richards, & Boxer, 1988) it is not often utilized singly as an indicator of maturation. Voice changing is a comparatively late occurrence in boys' puberty, resulting from growth in the larynx, and occurs gradually over a period of roughly 1–2 years. Deepening of the voice correlates with Tanner stage (Harries, Walker, Williams, Hawkins, & Hughes, 1997) and with height and assays of testosterone (Pedersen, Moller, Krabbe, & Bennett, 1986). According to records kept by the Leipzig choir, the most common period of voice breaking for male singers in the mid-18th century was between 17.5 and 18.5 years of age (Daw, 1970); in contrast, children enrolled in the Copenhagen Municipal Choir School from 1994–2003 had a median age of voice breaking of 10.4 years (Juul, Magnusdottir, Scheike, Prytz, & Skakkebaek, 2007), which is consistent with the choir's subjective reports of difficulty retaining children as singers past the age of 12 or 13 years.

The primary disadvantage for a secular trend towards earlier maturation is that children's social and emotional development lags behind their physical development; an entire population of children who experience puberty at an increasingly younger chronological age can generate a number of public health and educational challenges, particularly if efforts are not made to encourage social maturity (Bellis, Downing, & Ashton, 2006). There is additionally persistent anxiety and frequent media attention about the causes driving such a trend. Although much of the overall change seems attributable to improved nutrition and prenatal care, as well as reduced childhood infection (Parent et al., 2003), more recent questions have emerged about the role of endocrine-disrupting chemicals, such as those found in plastics, flame retardants, and pesticides (e.g., Schoeters, Den Hond, Dhooge, Van Larebeke, and Leijts (2008). While there is no conclusive evidence that a secular change in pubertal timing can be linked to such chemicals, high plasma levels of endocrine disruptors have been linked with specific pubertal abnormalities including pubertal breast growth (or gynecomastia) in boys (Durmaz et al., 2010). The extent to which such chemicals, in conjunction with other environmental stressors and genetic predispositions, actually shape pubertal trajectories remains unclear (Jacobson-Dickman & Lee, 2009).

Discussion

Although puberty is a universal transition, there are substantial individual differences in children's biological experiences, and these individual differences have been shown to be vital predictors of adolescent health and well-being. In girls, an earlier timing of development relative to peers has repeatedly been implicated as a risk factor for a broad range of psychosocial difficulties (i.e., depression, suicidality, anxiety, disordered eating, delinquency, poor academic performance; Graber et al., 1997; Stice et al., 2001; Stattin & Magnusson, 1990). In contrast to the robust findings for girls, associations of pubertal timing with outcomes for boys have been more equivocal and represented a long-standing area of opportunity.

Critically, the present review suggests one clear and notable finding: similar to the well-documented findings for girls, an earlier timing of puberty for boys robustly predicted negative sequelae. The consistency of this effect occurred across different measurement modalities, domains of outcomes, and despite the fact that early puberty has been traditionally and widely been viewed as advantageous for boys. The contrast between this effect and the historical perspective of early puberty could perhaps be attributable to earlier studies focusing less on psychopathology and more on general attitudes and feelings (e.g., Jones & Bayley, 1950; Mussen & Jones, 1957, 1958). But it may also be the case that the meaning and consequences of puberty have changed since the foundational studies on boys' pubertal timing were conducted. Certainly, one enduring challenge of modern puberty is the disparity between biological and social maturity. If potential secular declines in puberty are indeed occurring, children would be faced with an expanded duration of this "disparity period" as well as a need to contend with the resulting role confusion at a chronologically more precocious age.

Effects regarding late pubertal timing were far less consistent than those of early timing, and seemed limited to internalizing and substance use. Of particular interest is the fact that many of the studies which obtained effects for late development utilized perceived developmental timing (e.g., Graber et al., 2004; Siegel et al., 1998). While self-reports of development are not strictly representative of actual maturation (Dorn & Biro, 2011), such findings underscore that the experience of being a "late bloomer" may be potentially distressing for some children. In general, there has been a laudable trend over the past decade to emphasize the accuracy and validity of measure of pubertal development, and to distinguish between subjective and objective experiences of maturation. Yet even though children's self-reports of maturation may not be biologically accurate, they may nevertheless be tremendously psychologically informative, especially since self-perceptions – and particularly inaccurate self-perceptions – have long been implicated as a key factor in the onset and maintenance of multiple forms of psychopathology in both adults and children.

Explanations of the mechanisms by which pubertal timing predicts developmental outcomes generally fall into three broad categories: psychosocial, biological, and selection. These perspectives have been developed in accordance with the well-established literature on girls' pubertal timing

(Ge & Natsuaki, 2009). There are presently no gender specific theories for considering the importance of pubertal timing in subsequent adjustment – despite the obvious differences in biological processes, interpersonal changes, and social challenges for boys and girls. In the case of early pubertal timing, some of the socioenvironmental stressors associated with precocious timing in girls would certainly be expected to apply to boys as well, most particularly the experience of being viewed and treated as more mature than one is either emotionally or cognitively. Yet the way this occurrence would be manifest and understood by boys and girls would naturally be different, as puberty is believed to intensify adherence to traditional gender roles (e.g., Galambos, Almeida, & Petersen, 1990; Hill & Lynch, 1983). Thus, while traditionally masculine expectations of self-reliance, emotional restraint, and social dominance might seem daunting for a child to adopt at any age, they may be particularly difficult to adopt for early maturers, who may already be experiencing a vulnerable and tumultuous transition.

Future directions

The boys' puberty literature is a small one, rich with opportunities for inquiry and expansion. Yet given the difficulty measuring male physical development – and the extent to which such difficulty has constrained research findings – it seems that a basic direction for future research would be to re-visit noninvasive but valid techniques for capturing male maturation. Updates in scientific technology have enabled salivary assays of hormones to be collected more easily. At a simpler level, after considering the records kept by boys' choirs, a different possibility might be to assess the reliability and validity of retrospective, self-reported age of voice changes. Although voice change is not a discrete event, like menarche, it is certainly one which is socially noticeable and may therefore be personally memorable. Because it occurs over a range of years, questions would have to inquire about both the initial age of voice breaking and the year at which change in voice seemed complete. The advantage of such a technique would be its ease and affordability, coupled with its suitability for administration in schools or other settings in which inquiring about other pubertal indicators might be perceived as too intimate.

A second focus for future research would be to move beyond the construct of development timing, as timing is not the only source of individual variability in puberty (Marshall & Tanner, 1969, 1970; Tanner, 1962). In their seminal work on puberty, Marshall and Tanner actually identified three sources of variation in pubertal development: (1) *timing*, which they described as “variation in the chronological age at which adolescence begins and different stages of physical maturity are reached”; (2) *tempo*, which they described as “variation in the time taken to pass through the various stages of development of the breasts/genitalia and of pubic hair”; and (3) *coordination*, or “variation in the temporal relationships between the development of the breast, of the pubic hair, the adolescent growth spurt, and menarche” in girls and “variation in the temporal relation between the adolescent growth spurt and the development of the genitalia and the pubic hair” in boys (Marshall & Tanner, 1969, p. 291, 1970, p. 14).

There is minimal understanding of how these other individual differences in maturation relate to outcomes. Some of this scarcity may relate to methodological and logistical complexities: to gain a solid measure of pubertal tempo and pubertal coordination would require detailed longitudinal data, collected during a precise and compact period of time, analyzed using intricate quantitative methods. As statistical software have reached increasingly sophisticated levels, however, complex longitudinal modeling of puberty has become more viable, allowing for a more nuanced understanding of both inter- and intra-individual developmental change. In particular, recent efforts to understand the salience of pubertal tempo have yielded surprising results for boys. In a recent investigation of pubertal timing, pubertal tempo, and depression, both early timing and rapid tempo of development were significant predictors of depressive symptoms in boys; notably, however, the effects of pubertal tempo were substantially stronger than those of timing (Mendle, Harden, Brooks-Gunn, & Graber, 2010). Marceau and colleagues likewise found that rapid developmental tempo predicted significant externalizing problems in boys (Marceau, Ram, Houts, Grimm, & Susman, *in press*).

Pubertal coordination, like pubertal tempo, has yet to be systematically investigated by psychosocial researchers. Certainly, there are multiple different bodily changes that occur during puberty:

breast development and menarche in girls; genital development and spermatarche in boys; pubic hair and ancillary body hair growth; increase in height, weight, and muscle mass; deepening of the voice in boys; and sebaceous skin changes. Both an individual's own subjective experience of puberty, as well as social responses to puberty, might differ to the extent that these various bodily changes occur in synchrony (e.g., rather like experiencing an "alpha coefficient" for puberty). More specifically, greater pubertal coordination might contribute to a sense of being fully immersed in the pubertal transition whereas comparatively less coordinated maturation might contribute to a sense that puberty is a sporadic, confusing, and unpredictable process.

Lastly, recent research has made considerable strides investigating mediators and moderators for associations of pubertal timing with psychosocial sequelae. Such investigations are of particular benefit for articulating precisely which aspects of the pubertal transition are challenging for children, and therefore play an active role in testing and confirming psychosocial perspectives, and for understanding processes which may be differentially salient for boys and girls. Such inquiry is vital, given that Ge and Natsuaki (2009) have powerfully referred to psychosocial hypotheses as "the most widely accepted but, paradoxically, least tested" (page 328). The most commonly targeted mediators involve social or familial relationships, such as peer characteristics and relationships (e.g., Lynne et al., 2009; Westling, Andrews, Hampson, & Peterson, 2008), parental monitoring and control (e.g., Arim & Shapka, 2008; Westling et al., 2008), or romantic partnerships (e.g., Natsuaki, Biehl, & Ge, 2009). Advances in the girls' puberty literature point to two additional areas for future investigations in both genders. First, the moderating effects of ethnicity, culture, and socioeconomic status have yet to be fully elucidated. Of especial interest is whether different cultural conceptions of maturation and puberty might play a role in the associations between pubertal development and psychological outcomes. Second, in girls, the extent to which genetic influences for particular disorders are expressed (aka, gene \times environment interaction) seems to differ according to the timing of pubertal onset (Burt, McGue, Demarte, Krueger, & Iacono, 2006; Harden & Mendle, 2011), but it is not yet clear if similar processes operate in boys. Given that quantitative genetic models can help resolve questions of causality and reduce confounding variables (Johnson, Turkheimer, Gottesman, & Bouchard, 2009), such models may be of additional benefit both for testing and contrasting psychosocial and selection perspectives.

Conclusion

Puberty is distinctive in the scale and breadth of its transformation. Despite being a universal stage, it seems to hold more resonance and presents more of a stumbling block for some children than others. While individual variability in maturation seems to be one critical determinant of risk versus resiliency, it is our belief that timing of physical development is best viewed as one facet in a larger continuum of experiences that contribute to individual adjustment and well-being. Understanding the multiple systems which comprise the pubertal transition, and how these may intersect with each other, holds not only theoretical interest, but applications for prevention and intervention in the outcomes associated with earlier development.

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